



REPUBLIC OF SLOVENIA  
MINISTRY OF THE ENVIRONMENT AND SPATIAL PLANNING  
SLOVENIAN ENVIRONMENT AGENCY

# Slovenia's National Inventory Report 2022

GHG emissions inventories 1986 - 2020

Submitted under the United Nations  
Framework Convention on Climate Change

Ljubljana, April 2022



Republic of Slovenia  
Ministry of the Environment and Spatial Planning  
Slovenian Environment Agency

Phone: +386 (0)1 478 40 00, Fax: +386 (0)1 478 40 52  
E-Mail: [gp.arso@gov.si](mailto:gp.arso@gov.si)  
Adresse: Agencija RS za okolje, Vojkova 1b, SI-1000 Ljubljana  
Internet: [www.arso.gov.si](http://www.arso.gov.si)

Contact person:

Tajda Mekinda Majaron  
Phone: +386 (0)1 478 44 27, Fax: +386 (0)1 478 40 51  
E-Mail: [tajda.mekinda-majaron@gov.si](mailto:tajda.mekinda-majaron@gov.si)





## **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 report (NIR), 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. Before this submission GHG inventory should be reported to the EU on 15 March.

The submission includes the main part of the NIR and additional information in five Annexes to the NIR:

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: Additional information – Registry (SEF, Annex A, Annex B)

The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the common reporting format (CRF) tables for the period 1986-2020 and accompanied XML file.

Specific responsibilities for the 2022 inventory report have been as follows:

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

PART 1: NATIONAL INVENTORY 1986-2020

Cross-cutting issues Tajda Mekinda Majaron

Energy Tajda Mekinda Majaron,  
Road Traffic Martina Logar D.Sc.

IPPU Martina Logar D.Sc.  
F-gases Tajda Mekinda Majaron

Agriculture Jože Verbič D.Sc., Žan Pečnik

LULUCF Boštjan Mali D.Sc., Gal Kušar, D.Sc.

Waste Tajda Mekinda Majaron,  
Waste Waters Martina Logar D.Sc.,

Annexes Tajda Mekinda Majaron, Martina Logar D.Sc.

PART 2 : SUPPLEMENTARY INFORMATION UNDER ARTICLE 7, PARAGRAPH 1 OF THE KYOTO PROTOCOL

KP- LULUCF Boštjan Mali D.Sc.,

Information on accounting of Kyoto Units: Veronika Tolar Šmid

Information on changes in the national registry: Veronika Tolar Šmid

Information on minimization of adverse impacts: Barbara Simonič M.Sc.

CFR Tables Tajda Mekinda Majaron,  
Martina Logar D.Sc.  
Boštjan Mali D.Sc.

## TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY</b>	<b>13</b>
<b>1 INTRODUCTION</b>	<b>15</b>
<b>1.1 Background Information on Greenhouse Gas Inventories and Climate Change</b>	<b>15</b>
<b>1.2 A description of the national inventory arrangements</b>	<b>17</b>
1.2.1 Institutional, legal and procedural arrangements	17
1.2.2 Overview of inventory planning, preparation and management	19
1.2.3 Quality assurance, quality control and verification plan	21
1.2.4 Changes in the national inventory arrangements since previous annual GHG inventory submission	24
<b>1.3 Inventory preparation, and data collection, processing and storage</b>	<b>25</b>
<b>1.4 Brief General Description of Methodologies and Data Sources</b>	<b>26</b>
<b>1.5 Brief Description of Key Categories</b>	<b>28</b>
<b>1.6 General Uncertainty Evaluation, Including Data on Overall Uncertainty for Inventory Totals</b>	<b>32</b>
<b>1.7 General Assessment of Completeness</b>	<b>33</b>
<b>2 TRENDS IN GREENHOUSE GAS EMISSIONS</b>	<b>35</b>
<b>2.1 Description and Interpretation of Emission Trends for Aggregated GHG emissions</b>	<b>35</b>
<b>2.1 Description and Interpretation of Emission Trends for by Gas</b>	<b>35</b>
<b>2.2 Description and Interpretation of Emission Trends by Sector</b>	<b>36</b>
<b>2.3 Description and Interpretation of Emission Trends for Indirect GHGs and SO<sub>2</sub></b>	<b>41</b>
<b>3 ENERGY (CRF SECTOR 1)</b>	<b>42</b>
<b>3.1 Overview over the Sector</b>	<b>42</b>
<b>3.2 Fuel Combustion (CRF 1A)</b>	<b>44</b>
3.2.1 Comparison of the Sectoral Approach with the Reference Approach	48
3.2.2 International Bunker Fuels	49
3.2.3 Feedstock and Non-Energy Use of Fuels	51
3.2.4 Energy industries (CRF 1A1)	55
3.2.5 Manufacturing Industries and Construction (CRF 1A2)	65
3.2.6 Transport (CRF 1.A.3)	78
3.2.7 Other Sectors (CRF 1A4)	96
3.2.8 Other (CRF 1A5)	105
<b>3.3 Fugitive emissions from solid fuels, oil, natural gas and other emissions from energy production, (CRF 1.B)</b>	<b>107</b>
3.3.1 Solid Fuels (CRF 1.B.1)	109

3.3.2	Oil and natural gas (CRF 1.B.2)	115
<b>3.4</b>	<b>CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage</b>	<b>121</b>
<b>4</b>	<b>INDUSTRIAL PROCESSES AND PRODUCT USE (CRF SECTOR 2)</b>	<b>122</b>
<b>4.1</b>	<b>Overview of Sector</b>	<b>122</b>
<b>4.2</b>	<b>MINERAL INDUSTRY (CRF 2.A)</b>	<b>125</b>
4.2.1	Cement Production (CRF 2.A.1)	125
4.2.2	Lime Production (CRF 2.A.2)	129
4.2.3	Glass Production (CRF 2.A.3)	134
4.2.4	Other Process Uses of Carbonates	136
<b>4.3</b>	<b>CHEMICAL INDUSTRY (CRF 2.B)</b>	<b>139</b>
4.3.1	Nitric Acid Production (CRF 2.B.2)	139
4.3.2	Carbide Production (CRF 2.B.5)	140
4.3.3	Titanium dioxide production (CRF 2.B.6)	141
4.3.4	Petrochemical and carbon black production (CRF 2.B.8)	143
4.3.5	Other - Hydrogen production (CRF 2.B.10)	144
<b>4.4</b>	<b>METAL PRODUCTION (CRF 2.C)</b>	<b>145</b>
4.4.1	Iron and Steel Production (CRF 2.C.1)	145
4.4.2	Ferroalloys Production (CRF 2.C.2)	148
4.4.3	Aluminium Production (CRF 2.C.3)	150
4.4.4	Lead Production (CRF 2.C.5)	155
4.4.5	Zinc Production (CRF 2.C.6)	156
<b>4.5</b>	<b>NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE (CRF 2.D)</b>	<b>157</b>
4.5.1	Lubricant use (CRF 2.D.1)	157
4.5.2	Paraffin wax use (CRF 2.D.2)	158
4.5.3	Other (CRF 2.D.3)	159
<b>4.6</b>	<b>Product uses as substitutes for ODS (CRF 2.F)</b>	<b>162</b>
4.6.1	Category description	162
4.6.2	Methodological issues	164
4.6.3	Uncertainties and time-series consistency	170
4.6.4	Source-specific QA/QC and verification	171
4.6.5	Category-specific recalculations	171
4.6.6	Source-specific planned improvements	171
<b>4.7</b>	<b>Other Product Manufacture and Use (CRF 2.G)</b>	<b>172</b>
4.7.1	Electrical equipment (CRF 2.G.1)	172
4.7.2	SF <sub>6</sub> and PFCs from other product use (CRF 2.G.2)	174
4.7.3	N <sub>2</sub> O from Product Uses (CRF 2.G.3)	175
<b>5</b>	<b>AGRICULTURE (CRF SECTOR 3)</b>	<b>177</b>
<b>5.1</b>	<b>Overview of sector</b>	<b>177</b>
<b>5.2</b>	<b>Enteric Fermentation (CRF 3.A)</b>	<b>179</b>
5.2.1	Category description	179
5.2.2	Methodological issues	179
5.2.3	Uncertainties and time-series consistency	190
5.2.4	Category-specific QA/QC and verification	190
5.2.5	Category-specific recalculations	191
5.2.6	Category-specific planned improvements	191

<b>5.3</b>	<b>CH<sub>4</sub> Emissions from Manure Management (3.B)</b>	<b>192</b>
5.3.1	Source category description	192
5.3.2	Methodological issues	193
5.3.3	Uncertainties and time-series consistency	201
5.3.4	Category-specific QA/QC and verification	201
5.3.5	Category-specific recalculations	202
5.3.6	Category-specific planned improvements	202
<b>5.4</b>	<b>N<sub>2</sub>O Emissions from Manure Management (CRF 3.B)</b>	<b>202</b>
5.4.1	Source category description	202
5.4.2	Methodological issues	203
5.4.3	Uncertainties and time-series consistency	211
5.4.4	Category-specific QA/QC	211
5.4.5	Category-specific recalculations	212
5.4.6	Category-specific planned improvements	212
<b>5.5</b>	<b>N<sub>2</sub>O Emissions from Agricultural Soils (CRF 3.D)</b>	<b>213</b>
5.5.1	Overview of category	213
5.5.2	Direct N <sub>2</sub> O Emissions from Managed Soils (CRF 3.D.a)	213
5.5.3	Indirect N <sub>2</sub> O Emissions from Managed Soils (CRF 3.D.b)	219
<b>5.6</b>	<b>Liming (CRF 3.G)</b>	<b>224</b>
5.6.1	Category description	224
5.6.1	Methodological issues	224
5.6.2	Uncertainties and time-series consistency	225
5.6.3	Category-specific QA/QC	225
5.6.1	Category-specific recalculations	226
5.6.2	Category-specific planned improvements	226
<b>5.7</b>	<b>Urea application (CRF 3.H)</b>	<b>227</b>
5.7.1	Category description	227
5.7.2	Methodological issues	227
5.7.3	Uncertainties and time-series consistency	227
5.7.4	Category-specific QA/QC and verification	227
5.7.5	Category-specific recalculations	227
5.7.6	Category-specific planned improvements	227
<b>5.8</b>	<b>Other carbon containing fertilizers (CRF 3.I)</b>	<b>228</b>
5.8.1	Category description	228
5.8.2	Methodological issues	228
5.8.3	Uncertainties and time-series consistency	228
5.8.4	Category-specific QA/QC and verification	228
5.8.5	Category-specific recalculations	228
5.8.6	Category-specific planned improvements	228
<b>6</b>	<b>LULUCF (CRF SECTOR 4)</b>	<b>229</b>
<b>6.1</b>	<b>Overview of sector</b>	<b>229</b>
<b>6.2</b>	<b>Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories</b>	<b>233</b>
6.2.1	Land use and land-use change	233
6.2.2	Forest land	234
6.2.3	Cropland	234
6.2.4	Grassland	234

6.2.5	Wetlands	234
6.2.6	Settlements	234
6.2.7	Other land	235
<b>6.3</b>	<b>Information on approaches used for representing land areas and on land-use databases used for the inventory preparation</b>	<b>236</b>
6.3.1	Development of land-use change matrices	236
<b>6.4</b>	<b>Forest Land (4A)</b>	<b>243</b>
6.4.1	Source category description	243
6.4.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	246
6.4.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	246
6.4.4	Methodological issues	247
6.4.5	Uncertainties and time-series consistency	258
6.4.6	Source specific QA/QC and verification	259
6.4.7	Source specific recalculations	259
6.4.8	Source specific planned improvements	260
<b>6.5</b>	<b>Cropland (4B)</b>	<b>261</b>
6.5.1	Source category description	261
6.5.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	264
6.5.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	264
6.5.4	Methodological issues	264
6.5.5	Uncertainties and time-series consistency	273
6.5.6	Category-specific QA/QC and verification	273
6.5.7	Category-specific recalculations	273
6.5.8	Source-specific planned improvements	273
<b>6.6</b>	<b>Grassland (4C)</b>	<b>274</b>
6.6.1	Source category description	274
6.6.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	277
6.6.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	277
6.6.4	Methodological issues	277
6.6.5	Uncertainties and time-series consistency	282
6.6.6	Category-specific QA/QC and verification	282
6.6.7	Category-specific recalculations	282
6.6.8	Source-specific planned improvements	282
<b>6.7</b>	<b>Wetlands (4D)</b>	<b>283</b>
6.7.1	Source category description	283
6.7.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	286
6.7.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	286
6.7.4	Methodological issues	286
6.7.5	Uncertainties and time-series consistency	288
6.7.6	Category-specific QA/QC and verification	288
6.7.7	Category-specific recalculations	288

6.7.8	Source-specific planned improvements	288
<b>6.8</b>	<b>Settlements (4E)</b>	<b>289</b>
6.8.1	Source category description	289
6.8.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	292
6.8.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	292
6.8.4	Methodological issues	292
6.8.5	Uncertainties and time-series consistency	294
6.8.6	Category-specific QA/QC and verification	294
6.8.7	Category-specific recalculations	294
6.8.8	Category-specific planned improvements	294
<b>6.9</b>	<b>Other land (4F)</b>	<b>295</b>
6.9.1	Source category description	295
6.9.2	Information on approaches used for representing land areas and on land-use databases used for the inventory preparation	298
6.9.3	Land-use definitions and the classification systems used and their correspondence to the LULUCF categories	298
6.9.4	Methodological issues	298
6.9.5	Uncertainties and time-series consistency	299
6.9.6	Category-specific QA/QC and verification	299
6.9.7	Category-specific recalculations	299
6.9.8	Category-specific planned improvements	299
<b>6.10</b>	<b>Harvested wood products (4G)</b>	<b>300</b>
6.10.1	Source category description	300
6.10.2	Methodological issues	300
6.10.3	Uncertainties and time-series consistency	305
6.10.4	Category-specific QA/QC and verification	305
6.10.5	Category-specific recalculations	305
6.10.6	Category-specific improvements	305
<b>7</b>	<b>WASTE (CRF SECTOR 5)</b>	<b>306</b>
<b>7.1</b>	<b>Overview of sector</b>	<b>306</b>
<b>7.2</b>	<b>Solid Waste Disposal Sites (CRF 5.A)</b>	<b>311</b>
7.2.1	Category description	311
7.2.2	Methodological issues	311
7.2.3	Uncertainty and time series consistency	324
7.2.4	Category-specific QA/QC and verification	324
7.2.5	Category-specific recalculations	325
7.2.6	Category-specific planned improvements	325
<b>7.3</b>	<b>Biological Treatment of Solid Waste (CRF 5.B)</b>	<b>326</b>
7.3.1	Category description	326
7.3.2	Methodological issues	326
7.3.3	Uncertainty and time series consistency	327
7.3.4	Category-specific QA/QC and verification	327
7.3.5	Category-specific recalculations	327
7.3.6	Category-specific planned improvements	327
<b>7.4</b>	<b>Waste incineration (CRF 5.C)</b>	<b>328</b>

7.4.1	Category description	328
7.4.2	Methodological issues	328
7.4.3	Uncertainty and time series consistency	330
7.4.4	Category-specific QA/QC and verification	331
7.4.5	Category-specific recalculations	331
7.4.6	Category-specific planned improvements	331
<b>7.5</b>	<b>Emissions from Wastewater Treatment and Discharge (CRF 5.D)</b>	<b>332</b>
7.5.1	Category description	332
7.5.2	Methodological issues	334
7.5.3	Category-specific QA/QC and verification	347
7.5.4	Uncertainty and time-series consistency	347
7.5.5	Source-specific recalculations	348
7.5.6	Future improvements	348
<b>8</b>	<b>OTHER</b>	<b>349</b>
<b>9</b>	<b>INDIRECT CO<sub>2</sub> AND N<sub>2</sub>O EMISSIONS</b>	<b>349</b>
<b>10</b>	<b>RECALCULATIONS AND IMPROVEMENTS</b>	<b>350</b>
<b>10.1</b>	<b>Explanations and justification for recalculations, and implication for emission level</b>	<b>350</b>
10.1.1	Energy	350
10.1.2	Industrial processes and product use	351
10.1.3	Agriculture	352
10.1.4	LULUCF	354
10.1.5	Waste	355
<b>10.2</b>	<b>Response to the Review Process</b>	<b>356</b>
<b>PART II:</b>	<b>SUPPLEMENTARI INFORMATION UNDER ARTICLE 7, PARAGRAPH 1</b>	<b>374</b>
<b>11</b>	<b>KP-LULUCF</b>	<b>374</b>
<b>11.1</b>	<b>General information</b>	<b>374</b>
11.1.1	Definition of forest and any other criteria	374
11.1.1	Elected activities under Article 3, paragraph 4, of the Kyoto Protocol	375
11.1.2	Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time	375
11.1.3	Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified	375
<b>11.2</b>	<b>Land-related information</b>	<b>376</b>
11.2.1	Spatial assessment unit used for determining the area of the units of land under Article 3.3	376
11.2.2	Methodology used to develop the land transition matrix	376
11.2.3	Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations	376
<b>11.3</b>	<b>Activity-specific information</b>	<b>377</b>
11.3.1	Methods for carbon stock change and GHG emission and removal estimates	377
<b>11.4</b>	<b>Article 3.3</b>	<b>381</b>



11.4.1	Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced	381
11.4.1	Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	382
11.4.2	Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested	382
11.4.3	Emissions and removals from Deforestation	382
<b>11.5</b>	<b>Article 3.4</b>	<b>383</b>
11.5.1	Information that demonstrates that activities under Article 3.4 have occurred since January 1990 and are human-induced	383
11.5.2	Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year	383
11.5.3	Information relating to Forest Management	383
11.5.4	Emissions and removals from Forest Management	383
11.5.5	Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for	384
11.5.6	Information that demonstrates methodological consistency between the reference level and reporting for forest management during the second commitment period	384
11.5.7	Technical corrections	384
<b>11.6</b>	<b>Other information</b>	<b>386</b>
11.6.1	Key category analysis for Article 3.3 activities and any elected activities under Article 3.4	386
<b>11.7</b>	<b>Information relating to Article 6</b>	<b>386</b>
<b>11.8</b>	<b>Legal entities authorized to participate in mechanisms under Article 6, 12 and 17 of the Kyoto Protocol</b>	<b>387</b>
<b>12</b>	<b>INFORMATION ON ACCOUNTING OF KYOTO UNITS</b>	<b>388</b>
<b>12.1</b>	<b>Background information</b>	<b>388</b>
<b>12.2</b>	<b>Summary of information reported in the SEF tables, discrepancies and notifications</b>	<b>388</b>
<b>12.1</b>	<b>Publicly Accessible Information</b>	<b>389</b>
<b>12.2</b>	<b>Calculation of the Commitment Period Reserve</b>	<b>389</b>
<b>12.3</b>	<b>KP-LULUCF Accounting</b>	<b>390</b>
<b>13</b>	<b>CHANGES TO NATIONAL SYSTEM</b>	<b>390</b>
<b>14</b>	<b>INFORMATION ON CHANGES IN THE NATIONAL REGISTRY</b>	<b>391</b>
<b>15</b>	<b>INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14</b>	<b>393</b>
	<b>ABBREVIATIONS</b>	<b>396</b>
	<b>SOURCES AND LITERATURE</b>	<b>398</b>



## 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 report as an opportunity to fulfil these commitments.

This report summarizes the latest information on Slovenian anthropogenic greenhouse gas emission trends from 1986 through 2020. 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 report 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.

As Annex I Party and the Party to the Kyoto Protocol Slovenia is required to report supplementary information under Article 7, paragraph 1, of the Kyoto Protocol, with the inventory submission due under the Convention, in accordance with paragraph 3(a) of [decision 15/CMP.1](#).



# 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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), nitrogen oxides (NO<sub>x</sub>), 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<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>, PFCs, HFCs and SF<sub>6</sub>). 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 all emission and removals estimates for the period 1986-2012 have been recalculated accordingly.

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 report presents estimates for the following greenhouse gases included in Annex A to the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>), as well as estimates for indirect GHGs, including carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur

oxides (SO<sub>x</sub>) and ammonia (NH<sub>3</sub>). Nitrogen trifluoride (NF<sub>3</sub>) emissions do not occur in Slovenia and, therefore, they are not included in this report.

### Global warming potential

The global warming 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<sub>2</sub> and therefore GWP-weighted emissions are measured in Gg of CO<sub>2</sub> equivalents (Gg CO<sub>2</sub> eq.).

The following table 1.1.1 lists the direct (except for CH<sub>4</sub>) 100-year time horizon GWPs relative to CO<sub>2</sub> 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](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<sub>2</sub> equivalents while according to the COP Decision 24/CP.19 the GWPs from 4AR shall be used for all submissions started with 2015. For this reason the both sets of GWPs are presented in the table 1.1.1.

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

Gas – common name	Chemical formula	GWP from SAR - old	GWP from 4AR - new
Carbon dioxide	CO <sub>2</sub>	1	1
Methane*	CH <sub>4</sub>	21	25
Nitrous oxide	N <sub>2</sub> O	310	298
HFC-32	CH <sub>2</sub> F <sub>2</sub>	650	675
HFC-125	CHF <sub>2</sub> CF <sub>3</sub>	2,800	3,500
HFC-134a	CH <sub>2</sub> FCF <sub>3</sub>	1,300	1,430
HFC-143a	CH <sub>3</sub> CF <sub>3</sub>	3,800	4,470
HFC-227ea	CF <sub>3</sub> CHFCF <sub>3</sub>	2,900	3,220
CF <sub>4</sub>	CF <sub>4</sub>	6,500	7,390
C <sub>2</sub> F <sub>6</sub>	C <sub>2</sub> F <sub>6</sub>	9,200	12,200
SF <sub>6</sub>	SF <sub>6</sub>	23,900	22,800

\* 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<sub>2</sub> is not included.

Global warming potentials are not provided for CO, NO<sub>x</sub>, NMVOCs, SO<sub>2</sub> 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.

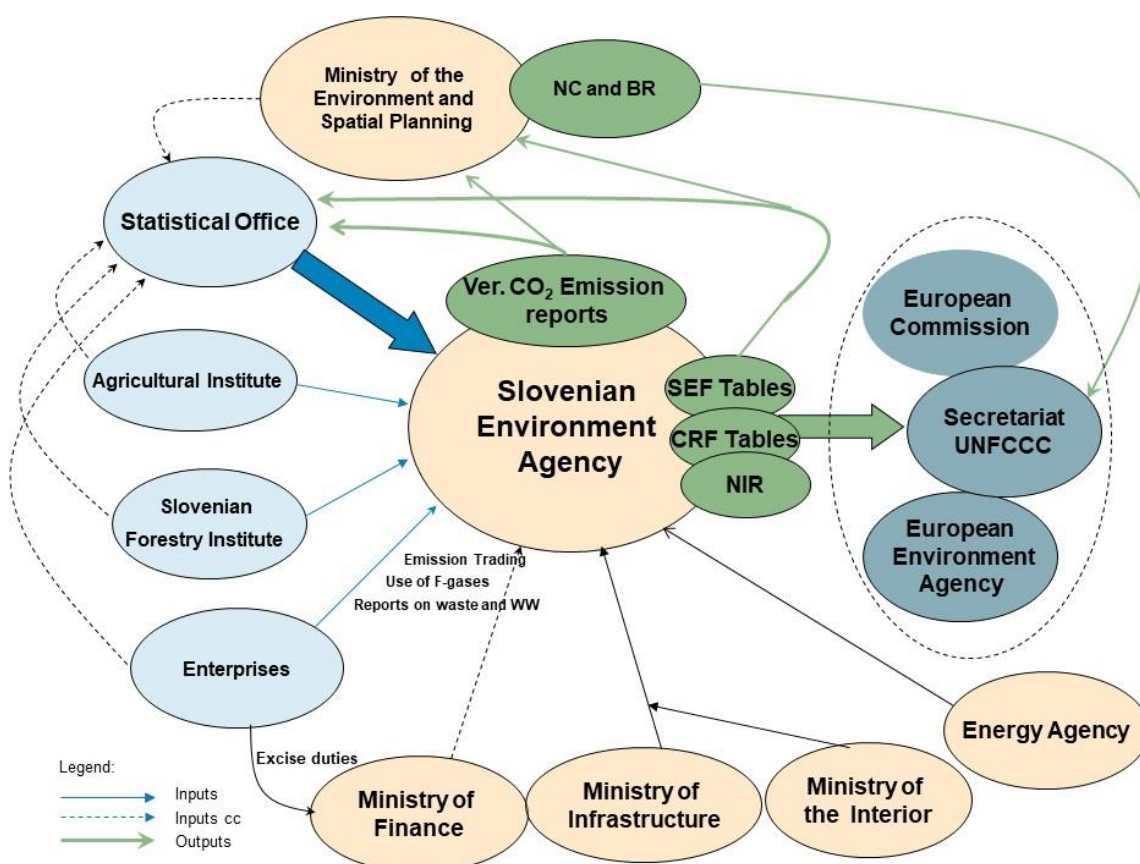


Figure 1.2.1: Data flows in the Slovenian Inventory System

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 NIR have shortened with the entry of Slovenia into the EU, since inventories and part of the NIR for the year before last must be made by 15<sup>th</sup> of January, and with corrections and final submission of the NIR by 15<sup>th</sup> 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	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy Balances, annual energy statistics</li> <li>• Slovenian Environment Agency: ETS data</li> </ul>
	2 Manufacturing Industries and Construction	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy Balances, annual energy statistics</li> <li>• Slovenian Environment Agency: ETS data</li> </ul>
	3 Transport	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia: Joint Questionnaires, Energy balances</li> <li>• Ministry of Infrastructure Directorate for National Roads (DRSC)</li> <li>• Eurocontrol</li> <li>• Plinovodi d.o.o.</li> </ul>
	4 Other Sectors	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> </ul>
	5 Other	<ul style="list-style-type: none"> <li>• Slovenian Army:</li> <li>• Police</li> </ul>
1.B Energy: Fugitive Emissions		<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency: ETS data</li> <li>• Energy Agency</li> </ul>
CRF 2 – Industrial Processes and Product Use	CRF 2A – Mineral Products	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency</li> </ul>
	CRF 2B – Chemical Industry	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> </ul>
	CRF 2C – Metal Production	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency</li> </ul>
	CRF 2D – Non-energy Products	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency</li> </ul>
	CRF 2F – ODS Substitutes	<ul style="list-style-type: none"> <li>• Slovenian Environment Agency</li> <li>• Ministry of Finance</li> <li>• Ministry of Environment and Spatial Planning</li> <li>• Statistical Office of the Republic of Slovenia</li> <li>• Health Insurance Institute of Slovenia</li> </ul>
	CRF 2G – Other product	<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia</li> <li>• Slovenian Environment Agency</li> </ul>
CRF 3 – Agriculture		<ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia</li> <li>• Agricultural Institute of Slovenia</li> </ul>
CRF 4 – Land Use, Land Use Change, and Forestry		<ul style="list-style-type: none"> <li>• Slovenian Forestry Institute</li> <li>• Agricultural Institute of Slovenia</li> </ul>
CRF 5 – Waste	A. Solid waste disposal	<ul style="list-style-type: none"> <li>• Slovenian Environment Agency</li> <li>• Statistical Office of the Republic of Slovenia</li> </ul>
	B. Biological treatment of solid waste	<ul style="list-style-type: none"> <li>• Slovenian Environment Agency</li> <li>• Statistical Office of the Republic of Slovenia</li> </ul>
	C. Incineration and open burning of waste	<ul style="list-style-type: none"> <li>• Slovenian Environment Agency</li> </ul>
	D. Waste water treatment and discharge	<ul style="list-style-type: none"> <li>• Slovenian Environment Agency</li> <li>• Statistical Office of the Republic of Slovenia</li> </ul>



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.

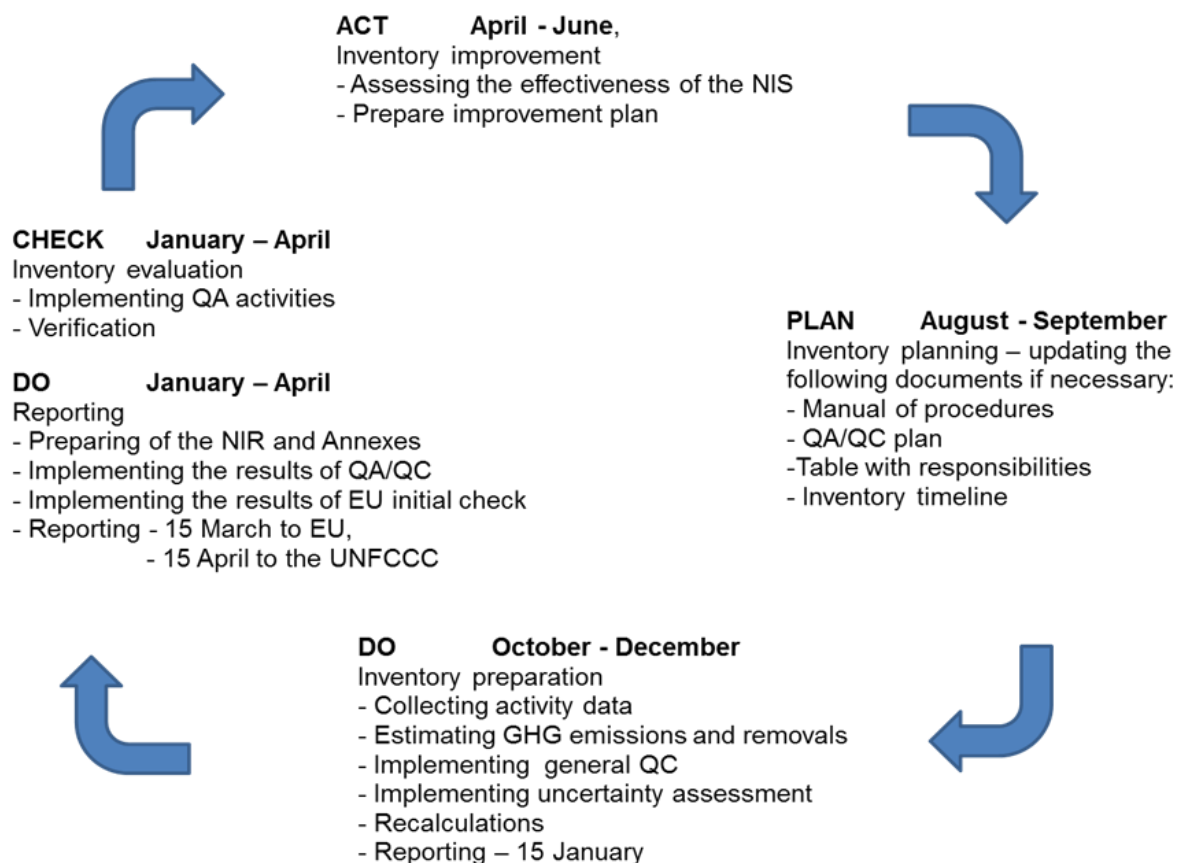


Figure 1.2.2: The inventory cycle.

### 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 CRF tables on January 5-7
- final CRF tables and draft NIR 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 NIR 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-evidence/>

### **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.

**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 reevaluate taking into account data on uncertainties from the 2006 IPCC GL.

### **Check of NIR**

- Check that all chapters from annotated NIR are included in the NIR
- 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 NIR
- Check all EF and other parameters used in the tables in the NIR
- Check all graphs for accuracy and presence in the whole period
- Check all titles for tables and pictures
- Check that all Annexes to the NIR 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 and 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 NIR (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.

### **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 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 CRF tables**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	EF	Method applied	EF	Method applied	EF
<b>1. Energy</b>	<b>M, T1, T2, T3</b>	<b>CS, D, M, PS</b>	<b>M, T1, T2, T3</b>	<b>CS, D, M, PS</b>	<b>M, T1</b>	<b>D, M</b>
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	NA	NA
2. Oil and natural gas	T1	D	T1	D	T1	D
<b>2. Industrial Processes</b>	<b>D, M, T1, T2, T3</b>	<b>CS, D, M, PS</b>	<b>NA</b>	<b>NA</b>	<b>D</b>	<b>D</b>
A. Mineral Products	T2, T3	CS, D	NA	NA	NA	NA
B. Chemical Industry	T2, T3	CS	NA	NA	NA	NA
C. Metal Production	T1, T2	CS, D, PS	NA	NA	NA	NA
D. Non-Energy Product	M, T1	D, M				
F. Substitutes for ODS						
G. Other product man. and use	NA	NA	NA	NA	D	D
<b>3. Agriculture</b>	<b>T1</b>	<b>D</b>	<b>T1, T2</b>	<b>CS, D</b>	<b>T1, T2</b>	<b>CS, D</b>
A. Enteric Fermentation			T1, T2	CS, D		
B. Manure Management			T1, T2	CS, D	T1, T2	CS, D
D. Agricultural Soils			NA	NA	T1, T2	CS, D
G. Liming	T1	D	NA	NA	NA	NA
H. Urea application	T1	D	NA	NA	NA	NA
I. Other C-containing fertilizers	T1	D	NA	NA	NA	NA
<b>4. LULUCF</b>	<b>CS, D, T1, T2, T3</b>	<b>CS, D</b>	<b>D, T1</b>	<b>D</b>	<b>D, T1, T2</b>	<b>D</b>
A. Forest Land	CS, D, T1, T2, T3	CS, D	D, T1	D	D, T1	D
B. Cropland	CS, D, T1, T2	CS, D	NA	NA	D, T1	D
C. Grassland	D, T1, T2	CS, D	NA	NA	D, T1	D
D. Wetlands	D, T1, T2	CS, D	NA	NA	NA	NA
E. Settlements	D, T2	CS, D	NA	NA	D, T1, T2	D
F. Other Land	D, T2	CS, D	NA	NA	D, T2	D
G. HWP	D, T1	D	NA	NA	NA	NA
<b>5. Waste</b>	<b>T1</b>	<b>D</b>	<b>T1, T2</b>	<b>CS, D</b>	<b>T1</b>	<b>D</b>
A. Solid Waste Disposal	NA	NA	T2	CS, D		
B. Biological Treatment			T1	D	T1	D
C. Incineration	T1	D	T1	D	T1	D
D. Waste-water Treatment	NA	NA	T1	CS, D	T1	D



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

In the Energy sector, mainly national/plant specific CO<sub>2</sub> 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<sub>2</sub> and CH<sub>4</sub> 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<sub>2</sub>. The CH<sub>4</sub> emission factor that was determined in this manner was lower than the default IPCC emission factor. CO<sub>2</sub> emissions in post-mining activities were not assessed, as no estimation method is available. Following 2006 IPCC GL CH<sub>4</sub> emissions from abandoned and closed mines have been also included in the inventory using Tier 2 method and default parameters. Under other CO<sub>2</sub> 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<sub>4</sub> 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. For SF<sub>6</sub> emissions, the release of this gas from gas-insulated switchgear for electricity was assessed

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<sub>2</sub>O 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<sub>2</sub>O emissions, CS parameters but default IPCC emission factors were used. A default EF and Tier 1 approach has been used for calculation of CO<sub>2</sub> 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<sub>2</sub>O emissions from N fertilization, N<sub>2</sub>O emissions from drainage of soils, N<sub>2</sub>O emissions from disturbance associated with land-use conversion to cropland, and non-CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O 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 source 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 2020. A level assessment was undertaken for 1986 and 2020, and a trend assessment was performed for 2020. 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, 29 categories were selected as keys in 2020 according to the level assessment, and additional 10 were chosen as key categories according to the trend assessment only. As many as 22 categories are key sources according to level and trend KC analysis.

Table 1.5.1: IPCC Key Source Categories for 2020, Approach 1

IPCC Category	Gas	with LULUCF	w/o LULUCF additional
1.A.1 Energy Industries, Gaseous Fuels	CO <sub>2</sub>	L, T	
1.A.1 Energy Industries, Liquid Fuels	CO <sub>2</sub>	T	
1.A.1 Energy Industries, Solid Fuels	CO <sub>2</sub>	L, T	
1.A.2 Manufacturing Industries and Const., Gaseous Fuels	CO <sub>2</sub>	L, T	
1.A.2 Manufacturing Industries and Const., Liquid Fuels	CO <sub>2</sub>	L, T	
1.A.2 Manufacturing Industries and Const., Other Fuels	CO <sub>2</sub>	L, T	
1.A.2 Manufacturing Industries and Const., Solid Fuels	CO <sub>2</sub>	L, T	
1.A.3.b Road Transportation, Diesel Oil	CO <sub>2</sub>	L, T	
1.A.3.b Road Transportation, Diesel Oil	N <sub>2</sub> O	T	
1.A.3.b Road Transportation, Gasoline	CO <sub>2</sub>	L, T	
1.A.3.c Railways, Liquid Fuels	CO <sub>2</sub>	T	
1.A.4 Other Sectors, Biomass	CH <sub>4</sub>	L	
1.A.4 Other Sectors, Gaseous Fuels	CO <sub>2</sub>	L, T	
1.A.4 Other Sectors, Liquid Fuels	CO <sub>2</sub>	L, T	
1.A.4 Other Sectors, Solid Fuels	CO <sub>2</sub>	T	
1.A.4 Other Sectors, Solid Fuels	CH <sub>4</sub>	T	
1.B.1.a Fugitive Emissions, Coal Mining and Handling	CH <sub>4</sub>	L, T	
1.B.1.c Fugitive Emissions, Other	CO <sub>2</sub>	T	L
2.A.1 Industrial processes, Cement Production	CO <sub>2</sub>	L, T	
2.A.2 Industrial processes, Lime Production	CO <sub>2</sub>	T	
2.B.6 Industrial processes, Titanium dioxide production	CO <sub>2</sub>		T
2.C.3 Industrial processes, Aluminium Production	CO <sub>2</sub>		L
2.C.3 Industrial processes, Aluminium Production	PFC	T	
2.F.1 Industrial processes, Refrigeration and Air Conditioning	HFC	L, T	
2.G.3 Industrial processes, N <sub>2</sub> O from product use	N <sub>2</sub> O		L
3.A Agriculture, Enteric Fermentation	CH <sub>4</sub>	L, T	
3.B Agriculture, Manure Management	CH <sub>4</sub>	L	
3.B Agriculture, Manure Management	N <sub>2</sub> O	L	
3.D.1 Agriculture, Direct N <sub>2</sub> O Emissions from Managed Soils	N <sub>2</sub> O	L, T	
3.D.2 Agriculture, Indirect Emissions from Managed Soils	N <sub>2</sub> O	L	
4.A.1 LULUCF, Forest Land remaining Forest Land	CO <sub>2</sub>	L, T	
4.A.2 LULUCF, Land converted to Forest Land	CO <sub>2</sub>	L, T	
4.B.1 LULUCF, Cropland remaining Cropland	CO <sub>2</sub>	L	
4.B.2 LULUCF, Land converted to Cropland	CO <sub>2</sub>	L, T	
4.C.2 LULUCF, Grassland remaining Grassland	CO <sub>2</sub>	L, T	
4.C.2 LULUCF, Land converted to Grassland	CO <sub>2</sub>	T	
4.E LULUCF, Land converted to Settlements	CO <sub>2</sub>	L, T	
4.E LULUCF, Settlements remaining Settlements	CO <sub>2</sub>	L, T	
4.G LULUCF, Harvested wood products	CO <sub>2</sub>	L, T	
5.A.1 Waste, Managed waste disposal sites	CH <sub>4</sub>	L	
5.D.1 Waste, Domestic and Commercial Waste Water	CH <sub>4</sub>	L	
5.D.2 Waste, Industrial Wastewater	CH <sub>4</sub>	T	

The most of the 39 key categories are from Energy sector (18): 13 categories are CO<sub>2</sub> emissions from fuel combustion, two are CH<sub>4</sub> emissions from biomass and solid fuel combustion in the residential sector, one is N<sub>2</sub>O emissions from diesel oil in Road Transportation, and remaining two are CH<sub>4</sub> fugitive emissions from Coal mining and handling and CO<sub>2</sub> emissions from SO<sub>2</sub> Scrubbing. The second most important sector is LULUCF with 9 key categories, four KCs are in the industrial processes and five in the Agriculture sector, where 2 are related to methane emissions and 3 to N<sub>2</sub>O emissions, and three KC are in the Waste sector. On the basis of the Tier 1 analysis excluding LULUCF two non-KC become KC according to the level and one become KC according to the trend.

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<sub>2</sub>O 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.

**Table 1.5.2: Methodologies used for key categories according to the level in 2020**

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

**Table 1.5.3: Methodologies used for key categories according to the trend only in 2020**

IPCC Category	Gas	Methodology	EF and other parameters
1.A.1 Energy Industries, Liquid Fuels	CO <sub>2</sub>	Tier 1	D
1.A.3.b Road Transportation, Diesel Oil	N <sub>2</sub> O	Model	Model
1.A.3.c Railways, Liquid Fuels	CO <sub>2</sub>	Tier 1	D
1.A.4 Other Sectors, Solid Fuels	CO <sub>2</sub>	Tier 1	D
1.A.4 Other Sectors, Solid Fuels	CH <sub>4</sub>	Tier 1	D
2.A.1 Industrial processes, Lime Production	CO <sub>2</sub>	Tier 3	PS
2.B.6 Industrial processes, Titanium dioxide production	CO <sub>2</sub>	Tier 1	D
2.C.3 Industrial processes, Aluminium Production	PFC	Tier 3	PS
4.C.2 LULUCF, Land converted to Grassland	CO <sub>2</sub>	D, Tier 1 - 2	CS, D
5.D.1 Waste, Industrial Wastewaters	CH <sub>4</sub>	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 2020 by sectors.**

	1986	2020
1A Energy	5.14%	2.02%
1B Fugitive	40.43%	35.00%
2 Industrial Processes/Product use	51.68%	9.01%
3 Agriculture	50.42%	52.47%
4 LULUCF	26.20%	23.95%
5 Waste	57.70%	61.46%
<b>TOTAL COMBINED UNCERTAINTY</b>	<b>12.59%</b>	<b>13.52%</b>
<b>w/o LULUCF</b>	<b>7.49%</b>	<b>6.22%</b>

A total trend uncertainty (2020/1986) is 19.94% and without LULUCF it is 1.93% w/o.

Uncertainty in 2020 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 2020. The similar reason is in waste sector, where CH<sub>4</sub> emissions from WW treatment plants, with very high uncertainty have a bigger share in 2020 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 NIR. 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 relevant chapters in the NIR and in the Annex 2 to the NIR.

## 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

#### NO (not occurring)

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 solve this issue. Until then please consider all blank cells in the CRF Tables as they were filled with "NO".

#### NE (not estimated):

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from 5.B.2 Anaerobic Digestion of solid waste at biogas facilities are not estimated, because they are negligible.

#### IE (included elsewhere):

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<sub>2</sub>O emissions from product use are reported under Medical application
- All GHG emissions from forest fires are reported under Forest land remaining Forest Land.
- CO<sub>2</sub> 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<sub>2</sub>O emissions from Managed soils (CRF table 4(IV)) are reported in the Agriculture sector under Agriculture Soils – Atmospheric Deposition
- Direct N<sub>2</sub>O 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 CRF 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 2020, sinks not considered, amounted to 15,851 kt CO<sub>2</sub> eq, which represents a 22.5% 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.

### 2.1 Description and Interpretation of Emission Trends for by Gas

CO<sub>2</sub> emissions in 2020 represented 81.2% of overall emissions of greenhouse gases. CO<sub>2</sub> 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 23.3% in 2020. CH<sub>4</sub> emissions represented 11.9% of total emissions in 2020 and were by 27.2% lower than in 1986. N<sub>2</sub>O emissions represented 4.9% of total emissions and were by 6.8% lower than N<sub>2</sub>O emissions in 1986. F-gases represented 2.0% of total emissions and some gases (HFCs and SF<sub>6</sub>) 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.

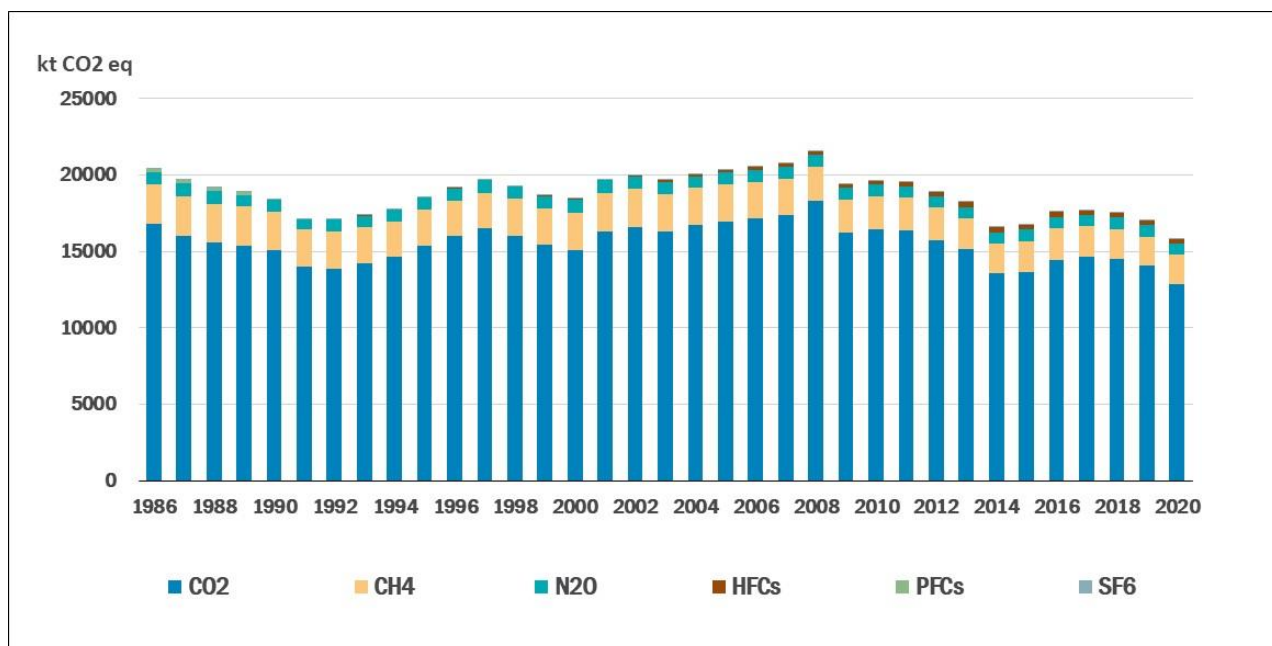


Figure 2.2.1: GHG Emissions in Slovenia by gas.

## 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).

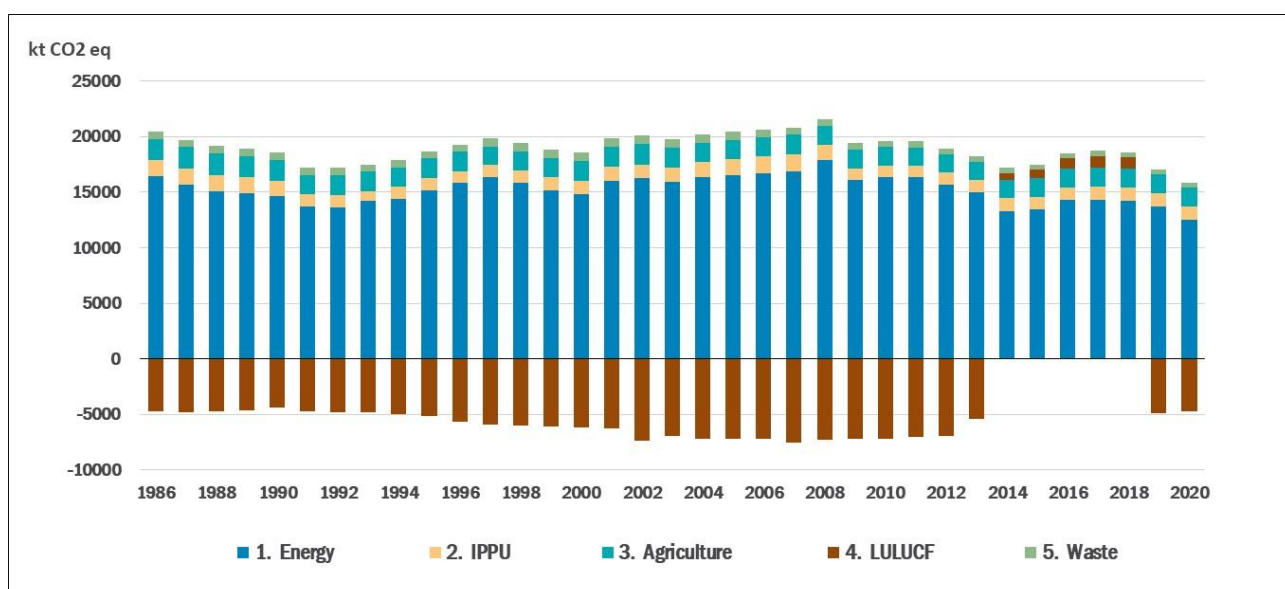


Figure 2.3.1: GHG Emissions in Slovenia by sector

By far the most important sector is Energy, which in 2020 accounted for 79.1% of total GHG emissions. In this sector emissions have decreased by 23.9%, compared to the 1986. Within this sector, in the period 1986–2020, GHG emissions from the Energy Industry, as the biggest sub-sector in the base year, decreased by 34.0%. 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” emissions in the transport sector decreased by 18.7% compared to the previous 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 Const. were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again – however due to the Covid-19 measures emissions in 2020 was by 2.4% lower than in the previous year.

Emissions from the Other sectors fluctuates a lot from year to year and are mostly influenced by air temperature in winter time.

Fugitive emissions from fuel represent only 2.4% of emissions in the sector and have decreased by 35.8% compared to the emissions in 1986.

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 2009 – 2019 slowly increase by 21.3% while in 2020 emissions decreased by 4.3% due to the Covid-19 measures. The most important GHG of this sector was carbon dioxide, with 67.1% of emissions from this category, followed by HFCs with 25.1%, N<sub>2</sub>O with 5.6%, SF<sub>6</sub> with 1.4%, and PFCs with 0.8%. In this sector, no CH<sub>4</sub> emissions have occurred since 2011. The main source of emissions is Mineral industry, of which the production of cement and lime alone contributed 45.5% of the emissions in this sector.

In Agriculture as the second most important sector, emissions in 2020 amounted to 1,724 Gg CO<sub>2</sub> eq, which represents 10.9% of all emissions. Agriculture represents the main source of methane and N<sub>2</sub>O emissions, namely 61.9% of all methane emissions and 67.5% of all N<sub>2</sub>O emissions. In the agricultural sector, CH<sub>4</sub> emissions accounted for 68.0% of emissions and N<sub>2</sub>O emissions accounted for 30.2% of emissions, while CO<sub>2</sub> emissions accounted for 1.8% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2020, emissions were 11.0% below the emissions in the base year. The most important sub-sector represented emissions from enteric fermentation, which contributed 54.6% of all emissions from agriculture, followed by

emissions from agricultural soils, with 25.6%; the rest is contributed by emissions of methane and N<sub>2</sub>O from animal manure (18.0%) while CO<sub>2</sub> emissions due to the liming and application of urea and other C-containing fertilizers represented only 1.8% of emissions in this sector.

The total net removals of CO<sub>2</sub> from the LULUCF sector were -4,736 Gg CO<sub>2</sub> eq and were almost the same as in the base year. The maximum value of net removals was in 2007. Since then, the net removals in the LULUCF sector have been decreasing, which was initially related to change in national forest policy (adoption of the National Forest Programme). However, Slovenian forest have been significantly affected by natural disturbances since 2014. Sanitary cut in damaged forests has increased for around 50% in the period 2014-2018, when the whole sector become a source of GHG emissions. In the last years the situation in the forests has improved but the net GHG sinks in 2020 were still by 12.4% lower than in the year 2013.

Methane emissions from the Waste sector are the second largest source of methane and represents 18.4% of all methane emissions in Slovenia in 2020. The fraction of methane emissions in this sector amounts to 84.1%, while the remaining part represent N<sub>2</sub>O (11.2%) and CO<sub>2</sub> emissions (4.7%). Solid waste handling contributes 49.7% to the total emissions from this sector, wastewater handling 40.9, %, incineration of waste 4.7%, and composting 4.7%. Emissions in 2020 were by 34.5% lower than in 1986. Emissions from solid waste disposal started to decline in 2005 and since then emissions have decreased by 58.9% 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 2020 were lower by 29.6%. Emissions from waste waters were by 49.9% 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<sub>2</sub> eq. by sectors and sub-sectors 1986-2020.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020	Change LY to BY	Change LY to PY
1. Energy	16,472	14,647	15,184	14,831	16,552	16,407	13,435	13,692	12,538	-23.9	-8.4
A. Fuel Combustion	15,879	14,135	14,697	14,359	16,026	15,885	13,065	13,313	12,158	-23.4	-8.7
1. Energy Industries	6,842	6,377	5,727	5,595	6,452	6,349	4,568	4,582	4,517	-34.0	-1.4
2. Man. Industries and Construction	4,349	3,097	2,632	2,296	2,463	1,934	1,614	1,757	1,715	-60.6	-2.4
3. Transport	2,052	2,738	3,996	3,684	4,406	5,303	5,359	5,632	4,581	123.2	-18.7
4. Other Sectors	2,594	1,891	2,341	2,781	2,701	2,295	1,520	1,339	1,342	-48.3	0.2
5. Other	41	32	1	3	3	3	4	4	3	-92.3	-20.8
B. Fugitive Emissions from Fuels	593	512	487	472	526	522	370	378	381	-35.8	0.6
1. Solid Fuels	551	461	442	424	474	474	335	339	341	-38.0	0.7
2. Oil and Natural Gas and other...	42	50	45	48	53	48	36	39	39	-7.4	-0.1
2. Industrial Processes	1,408	1,393	1,073	1,162	1,427	1,015	1,146	1,228	1,175	-16.6	-4.3
A. Mineral Industry	743	694	543	598	636	479	453	566	561	-24.5	-0.9
B. Chemical Industry	98	88	88	113	137	89	60	60	62	-36.6	2.8
C. Metal Industry	471	551	374	334	425	127	208	190	144	-69.4	-24.4
D. Non-energy products	8	8	7	14	25	15	26	33	31	280.9	-5.4
E. Electronics industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Product uses as ODS substitutes	NO	NO	33	46	145	258	343	297	295	100.0	-0.6
G. Other product manufacture and use	89	52	29	56	60	47	55	82	82	-7.3	0.1
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	1,936	1,860	1,774	1,810	1,717	1,678	1,717	1,720	1,724	-11.0	0.2
A. Enteric Fermentation	981	935	904	949	916	903	936	940	942	-3.9	0.3
B. Manure Management	421	416	360	343	329	316	317	315	311	-26.1	-1.3
C. Rice Cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural Soils	477	453	465	484	443	431	439	437	440	-7.7	0.8
E. Prescribed Burning of Savannahs	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field Burning of Agricultural Residues	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming	44	44	29	17	14	13	11	13	14	-67.1	11.5
H. Urea applications	9	9	12	12	12	11	9	10	12	29.8	13.5
I. Other carbon-containing fertilizers	4	4	4	4	4	4	5	5	4	11.0	-9.5

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

	1986	1990	1995	2000	2005	2010	2015	2019	2020	Change LY to BY	Change LY to PY
4. Land Use, Land-Use Change and Forestry	-4,765	-4,364	-5,121	-6,186	-7,209	-7,158	713	-4,888	-4,736	-0.6	-3.1
A. Forest Land	-4,776	-4,796	-5,397	-6,037	-7,258	-7,142	880	-4,589	-4,547	-4.8	-0.9
B. Cropland	270	272	140	138	162	153	188	190	193	-28.4	1.4
C. Grassland	-302	-276	-420	-743	-564	-521	-486	-419	-403	33.6	-3.7
D. Wetlands	2	2	1	0	6	26	3	2	2	18.1	-3.9
E. Settlements	470	471	490	518	601	424	244	169	151	-67.9	-10.9
F. Other Land	14	15	22	9	16	20	4	4	4	-71.2	0.3
G. Harvested wood products	-457	-67	28	-85	-185	-129	-129	-253	-142	-68.9	-43.8
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0	NO
6. Waste	633	699	652	778	766	544	496	435	415	-34.5	-4.7
A. Solid Waste Disposal	292	373	353	475	487	299	256	225	206	-29.6	-8.6
B. Biological treatment of solid waste	NO	NO	NO	NO	3	5	12	19	19	100.0	3.7
C. Incineration and open burning of waste	2	2	1	3	3	7	27	21	20	879.0	-4.7
D. Waste water treatment and discharge	339	324	298	300	273	233	201	171	170	-49.9	-0.5
E. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

## Memo Items.

International Bunkers	59	49	58	69	130	133	283	697	380	548.7	-45.5
Aviation	59	49	58	69	61	73	75	78	78	33.0	-23.8
Navigation	NO,NA	NO,NA	NO,NA	NO,NA	69	60	209	619	354	100.0	-42.9
Multilateral Operations	NO	NO	NO	1	0	0	1	1	0	100.0	28.6
CO <sub>2</sub> Emissions from Biomass	2,763	2,581	2,565	2,581	3,319	3,308	3,207	2,916	2,857	3.4	-2.0
Long term storage of C in waste disposal sites	771	1,084	1,459	2,037	2,587	3,063	3,247	3,249	3,249	321.2	0.0
Total CO <sub>2</sub> Eq. Emissions without LULUCF	20,449	18,599	18,683	18,582	20,462	19,644	16,794	17,074	15,851	-22.,5	-7.2
Total CO <sub>2</sub> Eq. Emissions with LULUCF	15,684	14,235	13,562	12,395	13,254	12,485	17,506	12,186	11,116	-29.3	-8.8

## 2.3 Description and Interpretation of Emission Trends for Indirect GHGs and SO<sub>2</sub>

The largest sources of emissions of NO<sub>x</sub> is transport followed by combustion in energy industries. The road transport sector is the sector contributing the most to the emission of NO<sub>x</sub>, in 2020 38% of the Slovenian emissions of NO<sub>x</sub>. The total emissions have decreased by 66% from 1990 to 2020. 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-NO<sub>x</sub> burners and denitrifying units in power plants and district heating plants.

CO emissions have decreased between 1990 and 2020 by 70%. 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 2020 was industrial processes and product use, followed by small combustion. Emissions of NMVOC have decreased from 1990 to 2020 by 54%. 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<sub>2</sub> emission originates from combustion of fossil fuels, mainly coal and oil in public power plants and district heating plants. From 1990 to 2020, 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 CRF tables because emissions from international aviation are not included in the national total in GHG inventory. In addition for the following CRF categories some pollutants cannot be reported: NO<sub>x</sub> emissions in 2.B.6 TiO<sub>2</sub> production and in 3.B. Manure management; NMVOC emissions in 2.B.10.a Other and SO<sub>2</sub> emissions in 2.C.7 Other (copper production).

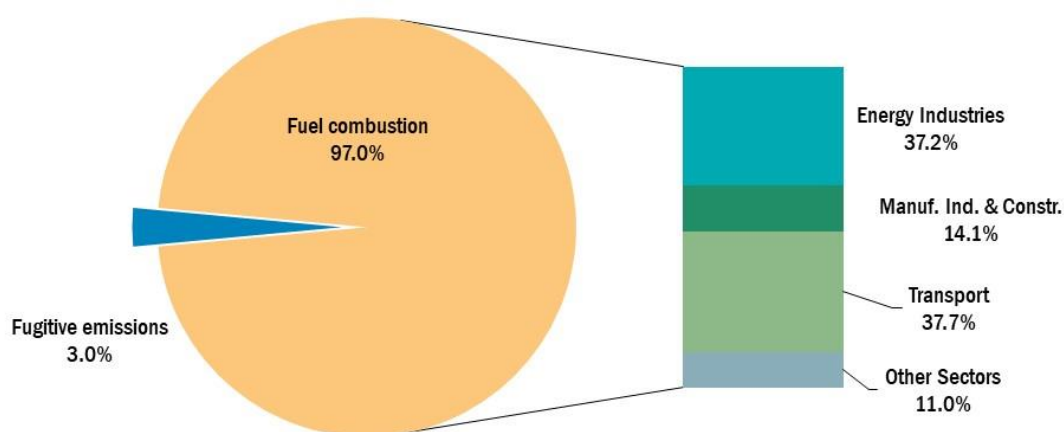
**Table 2.3.1: Emissions of CO, NO<sub>x</sub>, NMVOC and SO<sub>2</sub> (kt) as reported under Directive 2016/2284.**

	1990	1995	2000	2005	2010	2015	2020	Change
NO <sub>x</sub>	75.3	75.6	59.0	55.3	47.9	35.2	25.3	-66.4
CO	291.7	283.6	206.1	183.2	143.3	121.6	87.1	-70.1
NMVOC	65.2	62.8	55.1	48.3	39.7	32.5	30.1	-53.8
SO <sub>2</sub>	202.9	124.7	93.1	39.7	10.3	5.6	4.0	-98.0

### 3 ENERGY (CRF 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 879.1% of overall CO<sub>2</sub> eq. emissions (w/o considering LULUCF) in 2020. Emissions from this sector arise from fuel combustion, accounting for 97.0% emissions from the energy sector, and as fugitive emissions from fuels, accounting for 3.0% of emissions (Figure 3.1.1).



**Figure 3.1.1: Emissions of GHG in Energy Sector by categories in 2020**

Emissions from Energy sector are presented on the Table 3.1.1. Compared to 2019, GHG emissions decreased by 8.4% in 2020 and were by 23.9% 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 2020, 6.0 TWh (i.e. 37.1%) of electrical energy was produced in the Krško Nuclear Power Plant, 5.2 TWh (i.e. 31.7%) in public hydroelectric power plants, 4.7 TWh in thermal power plants (i.e. 28.9%), while the remaining 0.4TWh (i.e. 2.7%) was produced using wind or solar 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 1986–2020, GHG emissions from the Energy Industry, as the second biggest sub-sector, decreased by 34.0%.



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 2020 with share of 37.7%. 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.

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. However in last two years emissions decreased by 2.6 and 2.4%.

In the CRF category Other sectors, which accounts for 11.0% of emissions, Residential sector 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 48.3% since 1986.

Very small emissions (0.02%) 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<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
1. Energy	16,472	14,647	15,184	14,831	16,552	16,407	13,435	13,692	12,538
A. Fuel Combustion	15,879	14,135	14,697	14,359	16,026	15,885	13,065	13,313	12,158
1. Energy Industries	6,842	6,377	5,727	5,595	6,452	6,349	4,568	4,582	4,517
2. Man. Ind. and Const.	4,349	3,097	2,632	2,296	2,463	1,934	1,614	1,757	1,715
3. Transport	2,052	2,738	3,996	3,684	4,406	5,303	5,359	5,632	4,581
4. Other Sectors	2,594	1,891	2,341	2,781	2,701	2,295	1,520	1,339	1,342
5. Other	41	32	1	3	3	3	4	4	3
B. Fugitive Emissions	593	512	487	472	526	522	370	378	381
1. Solid Fuels	551	461	442	424	474	474	335	339	341
2. Oil and Natural Gas	42	50	45	48	53	48	36	39	39

Fugitive emissions in the Republic of Slovenia are of minor importance thus they represent only 3.0% of emissions in the sector and have decreased by 35.8% compare to emissions in 1986. The biggest fraction (73.0%) 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<sub>2</sub> due to the SO<sub>2</sub> scrubbing (16.7%) and emissions from oil and natural gas (10.3%). 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<sub>2</sub> emissions from fuel combustion of biomass were calculated, but were not included in the total of CO<sub>2</sub> emissions (they are reported as memo item). However, other two greenhouse gases (CH<sub>4</sub>, N<sub>2</sub>O) were included in accordance with the IPCC methodology.

### 3.2 Fuel Combustion (CRF 1A)

In the Fuel Combustion sector, mainly national/plant specific CO<sub>2</sub> 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 primarily 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 ETS reports. 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<sub>2</sub> EFs while in road transport CO<sub>2</sub> 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 result 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 did not happen. The result of the project are the instructions that every MS should determine their own EF, what can be done in the following three steps:

Step 1: Use fuel samples collected under the Fuel Quality Directive (FQD).

Step 2: Analyse samples for carbon content.

Step 3: Adjust carbon content for biofuels.

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 prepares reports for FQD are of the opinion that fuel should be sampled separately for this purpose. They were willing to take on these tasks but not before the end of the Covid-19 epidemic. 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 postponed 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<sub>2</sub> EF for domestic lignite**

With regard to the need to upgrade GHG emissions inventories, national CO<sub>2</sub> emission factors for domestic lignite were developed in 2004. CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> EF for all types of solid fuels.

In the Table 3.2.1 and Figure 3.2.1 the national CO<sub>2</sub> emission factors used for domestic lignite are presented while all other country specific or plant specific CO<sub>2</sub> emission factors for solid fuels are presented under relevant subchapters.



**Figure 3.2.1: CO<sub>2</sub> EF and NCV for domestic lignite from Velenje pit for 1986-2020.**

**Table 3.2.1: National CO<sub>2</sub> EFs for domestic lignite from Velenje pit in t CO<sub>2</sub>/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					

### **Country specific CO<sub>2</sub> EF for natural gas**

We are using country specific CO<sub>2</sub> 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<sub>2</sub> pri energetskega 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<sub>2</sub> 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<sub>2</sub> emission factor for natural gas is presented.

**Table 3.2.2: National CO<sub>2</sub> EFs for combustion of natural gas in t CO<sub>2</sub>/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					
56.454	56.131	56.148	56.361	56.162					

### **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

The Fisheries Research Institute of Slovenia – fuel used for fishing

Slovenian Army and Police – consumption of jet kerosene

### 3.2.1 Comparison of the Sectoral Approach with the Reference Approach

The total difference of CO<sub>2</sub> emissions between the sectoral approach and the reference approach in 2020 amounted to -0.18 per cent related to the energy consumption (Table 3.2.3) and to 0.29 per cent related to the CO<sub>2</sub> 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.

For reference approach for 2020 mostly the same data has been used as reported in the Joint questionnaires to IEA. All NCVs are from SORS except for lubricants and bitumen, where IPCC default values are used. For Carbon content mostly IPCC default values have been used. Exception are petroleum coke, lignite, and natural gas and fossil part of waste, where CS values are used. Oxidation value is 1 except for lignite where PS oxidation factor is used, because all lignite has been combusted in one thermal power plant.

In the Annex 4 to the NIR the data on Slovenian energy balance for 2020 is presented as reported to the Eurostat in the Joint questionnaires (Tables A4.1-A4.4). In the Table A4.5 the data from RA and EB are compared and all differences are explained.

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

Fuels	1986	1990	1995	2000	2005	2010	2015	2020
Liquid	3.16	2.12	0.09	2.34	-0.47	0.57	0.15	-0.02
Solid	0.71	0.08	-0.94	0.01	-1.30	-0.83	-0.03	0.00
Gaseous	-4.04	-8.25	-0.50	0.33	0.62	-0.07	-0.01	0.00
Other fossil	-100	-100	-100	-90.91	16.46	-29.33	14.07	-10.58
<b>Total</b>	<b>0.87</b>	<b>-0.62</b>	<b>-0.37</b>	<b>1.18</b>	<b>-0.51</b>	<b>-0.18</b>	<b>0.21</b>	<b>-0.18</b>

**Table 3.2.4: Differences in CO<sub>2</sub> emissions, % (Reference approach/National Approach)**

Fuels	1986	1990	1995	2000	2005	2010	2015	2020
Liquid	1.55	0.96	-1.26	0.95	-0.93	0.18	-0.21	0.38
Solid	0.61	0.06	-0.74	-0.31	-1.68	-1.47	-0.25	0.56
Gaseous	-3.98	-8.21	-0.42	0.42	0.83	0.08	-0.01	-0.01
Other fossil	-100	-100	-100	-90.91	16.46	-29.53	12.91	-7.01
<b>Total</b>	<b>0.42</b>	<b>-0.66</b>	<b>-1.00</b>	<b>0.29</b>	<b>-1.00</b>	<b>-0.68</b>	<b>-0.07</b>	<b>0.29</b>

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 CRF 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 emissions decreased due to the Covid-19 pandemic.

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<sub>2</sub> eq.**

	2005	2010	2015	2016	2017	2018	2019	2020
<b>fuel in TJ</b>	880	768	2,668	5,122	6,456	9,429	7,974	5,730
<b>kt CO<sub>2</sub> eq.</b>	69	60	209	400	505	734	619	444

#### 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 2020 in different CRF categories.**

Jet kerosene	amount	unit	amount	unit
1A3a Domestic navigation	76	t	3	TJ
1A5b Military use of fuel	1,011	t	44	TJ
Memo – international aviation	8,339	t	363	TJ
Memo – multilateral operation	139	t	6	TJ
<b>Total</b>	<b>9,565</b>	<b>t</b>	<b>416</b>	<b>TJ</b>

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 CRF categories in 2020 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<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>fuel in TJ</b>	812	684	799	962	852	1017	1037	1080	363
<b>kt CO<sub>2</sub> eq.</b>	59	49	58	69	61	73	75	78	26

### **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<sub>2</sub> eq.**

	1997	2000	2005	2010	2015	2019	2020
<b>fuel in TJ</b>	3	7	6	5	7	8	6
<b>kt CO<sub>2</sub> eq.</b>	0.2	0.5	0.4	0.4	0.5	0.6	0.4

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

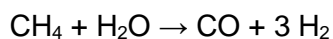


**Figure 3.2.2: Methanol production in Nafta-Petrochem Lendava.**

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<sup>3</sup> of natural gas in 2010, when this production stopped, and there has been no methanol production in Slovenia since 2011.

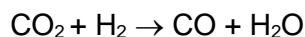
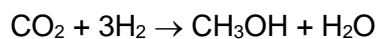
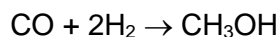
Natural gas was entirely used as the raw material for transformation into methanol. In every cycle only a fifth of it is transformed to the product, while the remaining natural gas is returned into the process. The schematic diagram of the process is shown in the Figure 3.2.3.

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



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:



is operated at high pressure and unconverted gas is recycled.

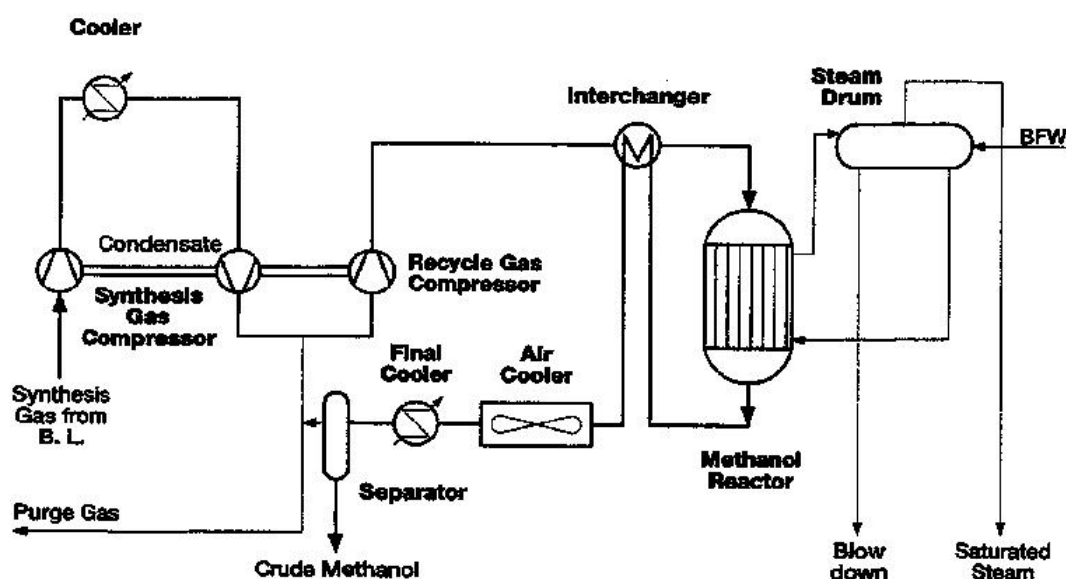


Figure 3.2.3: Schematic diagram of methanol production.

Stored CO<sub>2</sub> 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<sub>2</sub> 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	1995	2000	2005	2010	2015	2019	2020
Natural Gas	1000 m <sup>3</sup>	67666	69524	91577	136740	164407	97004	6176	6958	6522
Carbon EF	t C/TJ	15.195	15.195	15.194	15.172	15.300	15.311	15.311	15.371	15.317
Excluded CO <sub>2</sub>	kt	125.4	131.2	172.6	257.7	292.5	182.8	11.8	13.4	12.5

The remaining amount of non-energy use of natural gas is used in the chemical industry also as a raw 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	2011	2012	2015	2019	2020
Methanol prod.	1000 Sm <sup>3</sup>	145,903	89,475	0	0	0	0	0
Other org. chem.	1000 Sm <sup>3</sup>	410	0	0	0	0	0	0
Inorganic chem.	1000 Sm <sup>3</sup>	8,314	7,465	6,164	5,305	5,765	6,933	6,521
Rubber and Plastics	1000 Sm <sup>3</sup>	590	61	0	0	0	0	0
Other	1000 Sm <sup>3</sup>	0	0	0	0	411	22	2
Total	1000 Sm <sup>3</sup>	155,217	97,001	6,164	5,305	6,176	6,957	6,523
Total	TJ	5,290	3,306	210	181	210	237	222

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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>. Therefore, all excluded CO<sub>2</sub> 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	1995	2000	2005	2010	2015	2019	2020
Apparent consumption	kt	6.6	7.2	4.2	11	28	12	27	39.5	37.3
Road transport	kt	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
IPPU	kt	6.5	7.1	4.1	10.9	27.9	11.9	26.9	39.5	37.3

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 CRF 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<sub>2</sub> 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 CRF tables. In 2020, 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 (CRF 1A1)

#### 3.2.4.1 Category description

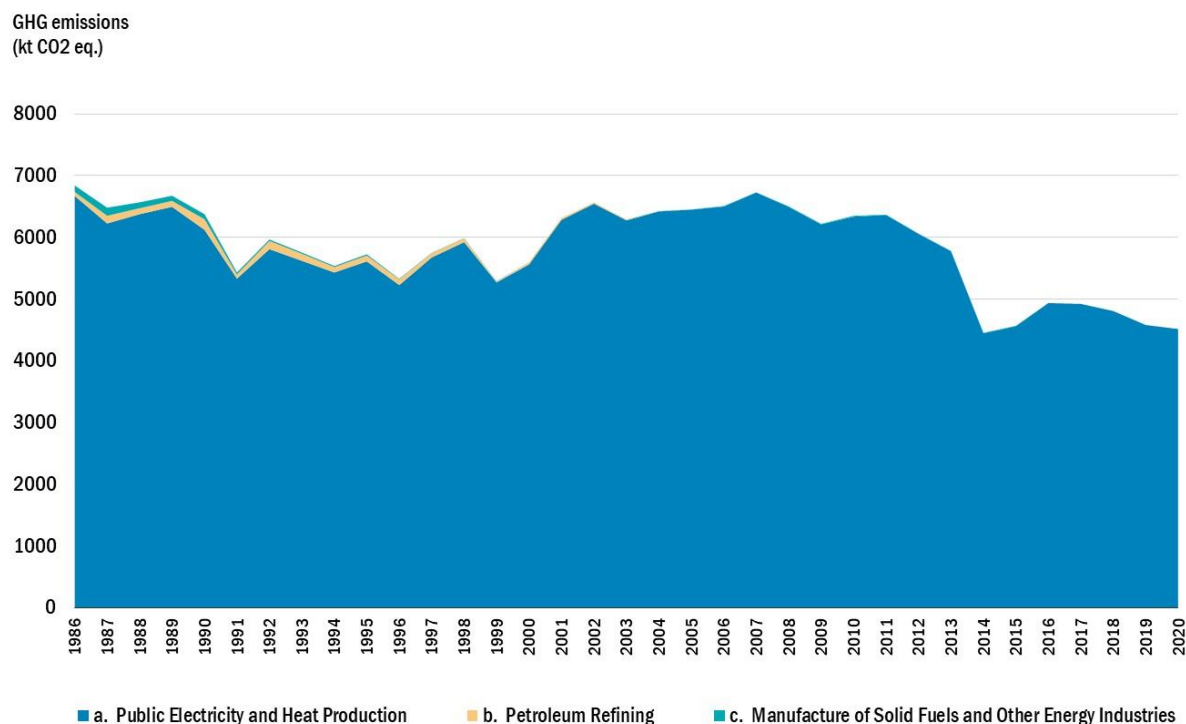
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

- Public Electricity and Heat Production (CRF 1A1a)
- Petroleum Refining (CRF 1A1b)
- Manufacture of solid fuels and Other Energy Industries (CRF 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 2020 in Energy industries.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
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<sub>2</sub> 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 2020. 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<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>1. Energy Industries</b>	<b>6842</b>	<b>6377</b>	<b>5727</b>	<b>5595</b>	<b>6452</b>	<b>6349</b>	<b>4568</b>	<b>4582</b>	<b>4517</b>
a. Public Electricity and Heat Production	6673	6123	5612	5563	6450	6335	4562	4581	4517
b. Petroleum Refining	63	170	93	32	NO	NO	NO	NO	NO
c. Manufacture of Solid Fuels and Oth. En. Ind.	106	82	21	0.4	1.6	14.7	6.1	0.2	0.1

### 3.2.4.2 Methodological issues

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

$$\text{Emissions} = \text{Quantity of Fuel Combusted} \times \text{NCV} \times \text{EF per energy of Fuel} \times \text{OF}$$

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

#### **Activity data**

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 NIR.

#### **Net calorific values**

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	Bitumin- ous 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	41.420	46.050	34.086	10.474
2016	11.733	-	18.595	25.898	42.600	41.420	46.050	34.087	10.519
2017	11.640	-	18.230	26.293	42.600	41.420	46.050	34.085	10.706
2018	11.521	-	18.238	25.800	42.600	41.420	46.050	34.084	10.583
2019	11.716	-	18.247	25.800	42.600	41.420	46.050	34.081	10.502
2020	11.329	-	17.929	25.800	42.600	41.420	46.050	34.087	10.608

**Emission factors**

For coal and natural gas a country specific/plant specific CO<sub>2</sub> 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 1986-2020 are presented.

**Table 3.2.15: EFs used for the period 1986-2020**

	Unit	Coal	Gas Oil	Residual Fuel Oil	LPG	Natural Gas	Solid Bio-fuels	Gas Biomass	Fossil part of MSW
<b>CO<sub>2</sub> EF</b>	t/TJ	NIR, Tables: 3.2.1, 3.2.17-20	74.1	77.4	63.1	NIR, Table 3.2.2	112	54.6	91.7
<b>CH<sub>4</sub> EF</b>	t/TJ	0.001	0.003	0.003	0.001	0.001	0.03	0.001	0.03
<b>N<sub>2</sub>O EF</b>	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 (CRF 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<sub>2</sub> 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<sub>2</sub> 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
<b>Oxidation factor</b>	0.997	0.989	0.990	0.991	0.993	0.997	0.995	0.997	0.994	0.995

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<sub>2</sub> 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<sub>2</sub> EFs for domestic brown coal from Trbovlje pit used in TET.**

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<b>t CO<sub>2</sub>/TJ</b>	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
<b>Oxidation factor</b>	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<sub>2</sub> 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<sub>2</sub> EFs for imported sub-bituminous coal used in TE-TOL.**

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
<b>t CO<sub>2</sub>/TJ</b>	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
<b>t CO<sub>2</sub>/TJ</b>	97.240	96.787	96.796	96.763	96.786	97.286				

Since 2009 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<sub>2</sub> EFs for imported sub-bituminous and bituminous coal used in one cogeneration heat plant.**

Coal type	Unit	2009	2010	2011	2012	2013	2014	Since 2015
Sub-bituminous	t CO <sub>2</sub> /TJ	99.047	97.310	98.331	99.407	NO	NO	NO
Bituminous	t CO <sub>2</sub> /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<sub>2</sub> EF 91.7 t CO<sub>2</sub>/TJ (default), CH<sub>4</sub> EF 0.03 t CH<sub>4</sub> /TJ and N<sub>2</sub>O EF 0.004 N<sub>2</sub>O/TJ.

### ***3.2.4.2.2 Petroleum Refining (CRF 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 NIR.

**3.2.4.2.3 Manufacture of Solid Fuels and Other Energy Industries (CRF 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 CRF 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 CRF 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 NIR.

**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 2022 submission for the base year and the last reporting year.**

	1986				2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O EF	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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<sub>2</sub> emission trading on the territory of the European Union. For this reason, the plant specific CO<sub>2</sub> 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  $\pm 7.5\%$  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  $\pm 5.0\%$  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  $\pm 2.5\%$  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  $\pm 1.5\%$  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 2005-2020.**

	<b>AD</b>	<b>NCV</b>	<b>CO<sub>2</sub> EF</b>
<b>Natural gas</b>	Tier 4	Tier 2a	Tier 2a
<b>Solid fuel</b>	Tier 3	Tier 3	Tier 3
<b>Fuel oil</b>	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**

#### 1.A.1 Energy industries

Following recommendation from the UNFCCC review, composition data for the natural gas for the period 1998-2019 has been obtained and accordingly CS CO<sub>2</sub> emission factor have been updated. In addition an error in CO<sub>2</sub> emission factor for the period 1986-1997 have been corrected and therefore CO<sub>2</sub> emission from combustion of natural gas have been recalculated for the entire period 1986-2019 and for the all categories.

### **3.2.4.6 Category-specific planned improvement**

No improvement is planned for this category.

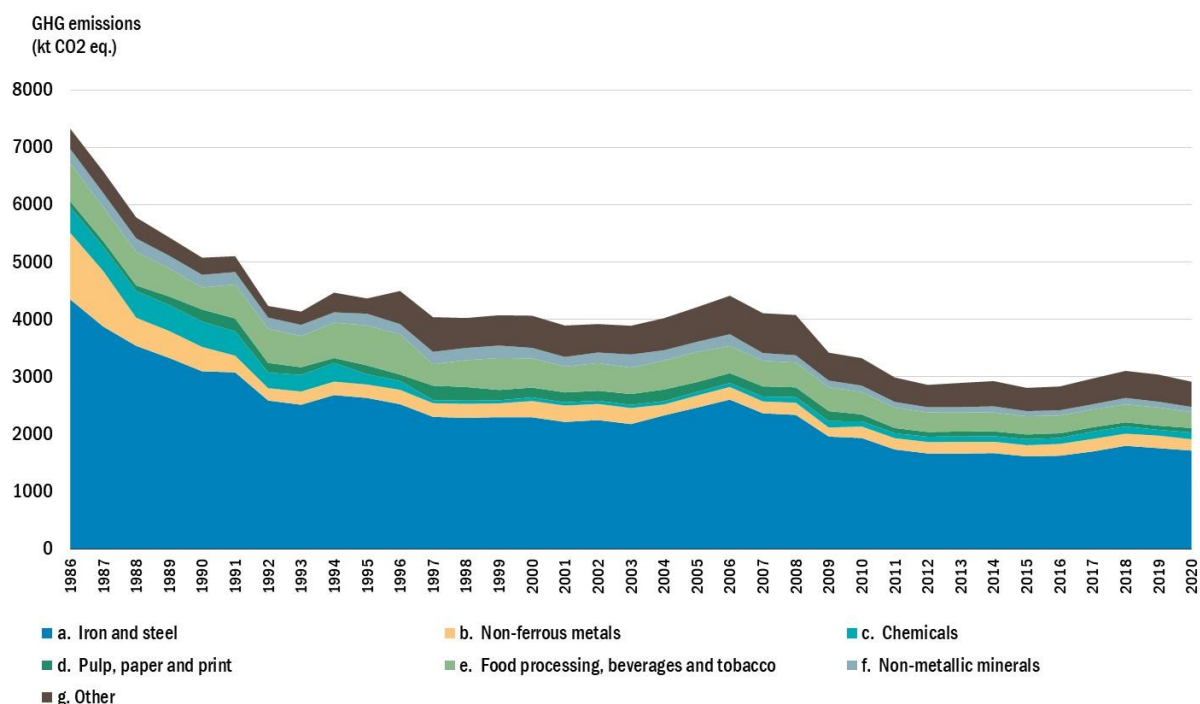
### 3.2.5 Manufacturing Industries and Construction (CRF 1A2)

#### 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 2020.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
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**

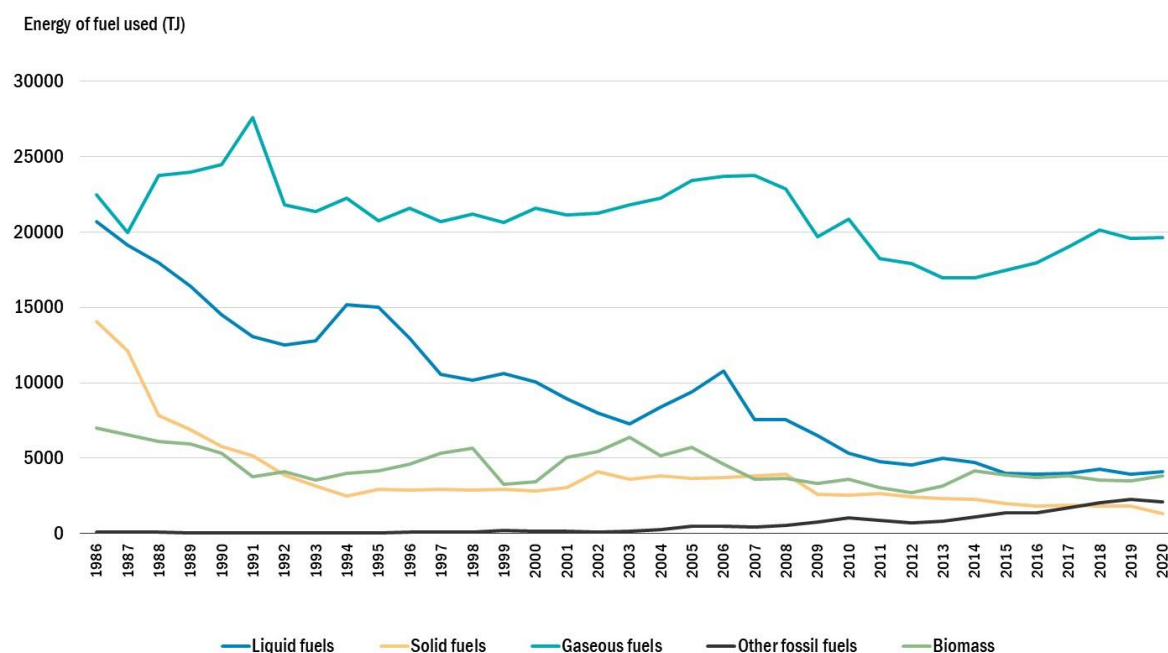
There was an appreciable reduction of GHGs from Manufacturing industry between 1986 and 2001 (-50.3%). After 2001, a stabilisation of emissions was observed until 2008. Due to the global financial crisis, emissions from Manufacturing industry and construction decreased

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 construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again – however due to the Covid-19 measures emissions in 2020 was by 2.4% lower than in the previous year.

**Table 3.2.25: GHG emissions from Manufacturing Industries and Construction in kt CO<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>2. Manufacturing Ind. and Constr.</b>	<b>4349</b>	<b>3097</b>	<b>2632</b>	<b>2296</b>	<b>2463</b>	<b>1934</b>	<b>1614</b>	<b>1757</b>	<b>1715</b>
a. Iron and Steel	1160	424	234	284	211	201	196	219	197
b. Non-Ferrous Metals	448	441	179	63	62	90	106	101	119
c. Chemicals	100	211	155	171	172	121	81	72	78
d. Pulp, Paper and Print	662	383	698	509	526	390	317	318	276
e. Food Processing, Bev. and Tob.	251	222	203	183	175	112	90	99	92
f. Non-metallic minerals	354	298	266	561	604	478	405	473	439
g. Other	1373	1118	898	525	713	542	419	475	514

In the Figure 3.2.6 energy from different types of fuel used in the manufacturing industries and construction 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:

$$\text{Emissions} = \text{Quantity of Fuel Combusted} \times \text{NCV} \times \text{EF per energy of Fuel} \times \text{OF}$$

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 CRF**

CRF 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 CRF 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 CRF**

CRF 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	CRF 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 2008 - 2020

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

CRF 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 CRF 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	27.386		29.328	31.105

**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	41.42	42.60	43.85	46.05	34.084	11.55
2019	42.60	41.42	42.60	43.85	46.05	34.081	11.58
2020	42.60	41.42	42.60	43.85	46.05	34.087	11.59

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 2020 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 2020.**

Industry	Unit	Sub-bituminous Coal - imported	Other Bituminous Coal	Coke	Petroleum coke
Iron and steel	TJ/kt			29.390	
Non-Ferrous metals	TJ/kt		32.500		
Pulp, Paper and Print	TJ/kt	17.666	24.625		
Non-metallic minerals	TJ/kt			29.300	31.105

**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<sub>2</sub> 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 Bituminous Coal	Anthracite	Coke
CO <sub>2</sub> EF	t/TJ	Table 3.2.1	101*	101*	96.1*	94.6*	98.3*	107.0*
CH <sub>4</sub> EF	t/TJ	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N <sub>2</sub> O 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 <sub>2</sub> EF	t/TJ	97.9*	74.1	77.4	74.1	69.3	63.1	Table 3.2.2
CH <sub>4</sub> EF	t/TJ	0.003	0.003	0.0030	0.00415	0.05	0.001	0.001
N <sub>2</sub> O 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 <sub>2</sub> EF	t/TJ	112.0	54.6	100.0	73.3	103.2*	85.0	91.7*
CH <sub>4</sub> EF	t/TJ	0.03	0.001	0.03	0.03	0.03	0.03	0.03
N <sub>2</sub> O EF	t/TJ	0.004	0.0001	0.004	0.004	0.004	0.004	0.004

\*Since 2005, CO<sub>2</sub> EFs for solid fuels and petrol coke have mostly been taken from EU-ETS. CO<sub>2</sub> IEFs which have been used in 2020 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<sub>2</sub> EF for solid fuel used in manufacturing industry in 2020.**

	Unit	Sub-bituminous Coal - imported	Other Bituminous Coal	Petroleum Coke
Pulp. Paper and Print	t/TJ	99.721	96.505	
Non-metallic minerals	t/TJ			95.052

**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 NIR, 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	16.72			3.52
2019	37.373		25.00	27.20	19.11	6.86			3.56
2020	38.173		25.00	27.20	16.52	8.76			3.24

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<sub>2</sub> 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 pharmaceutical industry and CO<sub>2</sub> 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 <sub>2</sub> EF	73.3	103.2	85	91.7	100	100
CH <sub>4</sub> EF	0.030	0.030	0.030	0.030	0.030	0.030
N <sub>2</sub> O EF	0.004	0.004	0.004	0.004	0.004	0.004

Since 2010 a plant specific CO<sub>2</sub> 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<sub>2</sub> EFs for solid waste incinerated in the cement plant since 2010**

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
t CO <sub>2</sub> /TJ	60.43	49.47	49.44	60.74	60.74	58.69	55.99	55.91	53.61	52.79	52.18

For waste oil which is combusted in the cement plant since 2014 the PS CO<sub>2</sub> EF from EU-ETS have been used. They are presented in the Table 3.2.38.

**Table 3.2.38: Plant specific CO<sub>2</sub> EFs for incineration of waste oil in the cement plant since 2014**

	Unit	2014	2015	2016	2017	2018	2019	2020
CO <sub>2</sub> EF	t CO <sub>2</sub> /TJ	90.37	84.49	87.36	75.61	74.20	74.20	74.256

### **Inclusion of auto producers into Manufacturing Industries sector**

In accordance with IPCC Reference manual, 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 2000-2020

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.

Following the recommendations of the expert review team, the data on fuel consumption by type of industry, fuel type, and year are reported in the Annex 3 to the NIR.

### **Off road vehicle and other machinery**

Following the new CRF categorisation the CRF 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 <sub>2</sub> EF	74.1	69.3
CH <sub>4</sub> EF	0.00415	0.05
N <sub>2</sub> O 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 2022 submission for the base year and the last reporting year in per cents**

	1986				2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O EF	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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 Manufacturing Industries and Construction, CO<sub>2</sub>

Following recommendation from the UNFCCC review, composition data for the natural gas for the period 1998-2019 has been obtain and accordingly CS CO<sub>2</sub> emission factor have been updated. In addition an error in CO<sub>2</sub> emission factor for the period 1986-1997 have been corrected and therefore CO<sub>2</sub> emission from combustion of natural gas have been recalculated for the entire period 1986-2019 and for the all categories.

##### 1.A.2.c Manufacturing Industries and Const., Chemical industry, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

For the period 2012 to 2019 data on other fuel (waste solvents) has been obtained and all GHG emissions for this category have been recalculated for this period.

#### **3.2.5.6 Category-specific planned improvement**

No improvement is planned for these categories.

### 3.2.6 Transport (CRF 1.A.3)

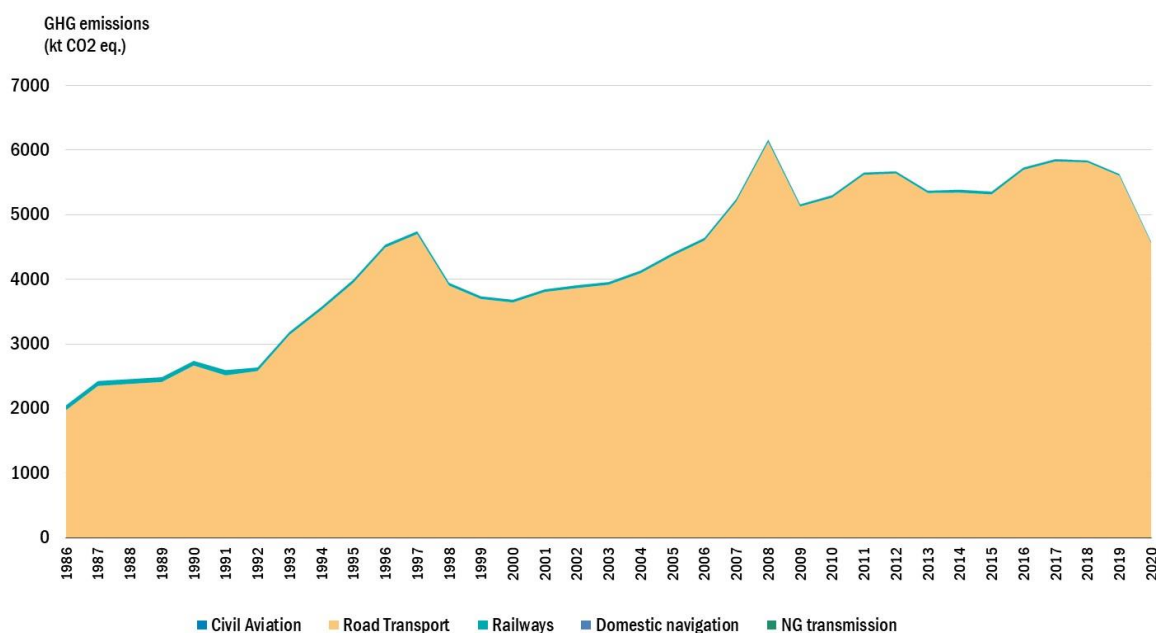
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

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

**Table 3.2.41: Method, EFs used for key categories for the year 2020 in the Transport sector.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
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 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.

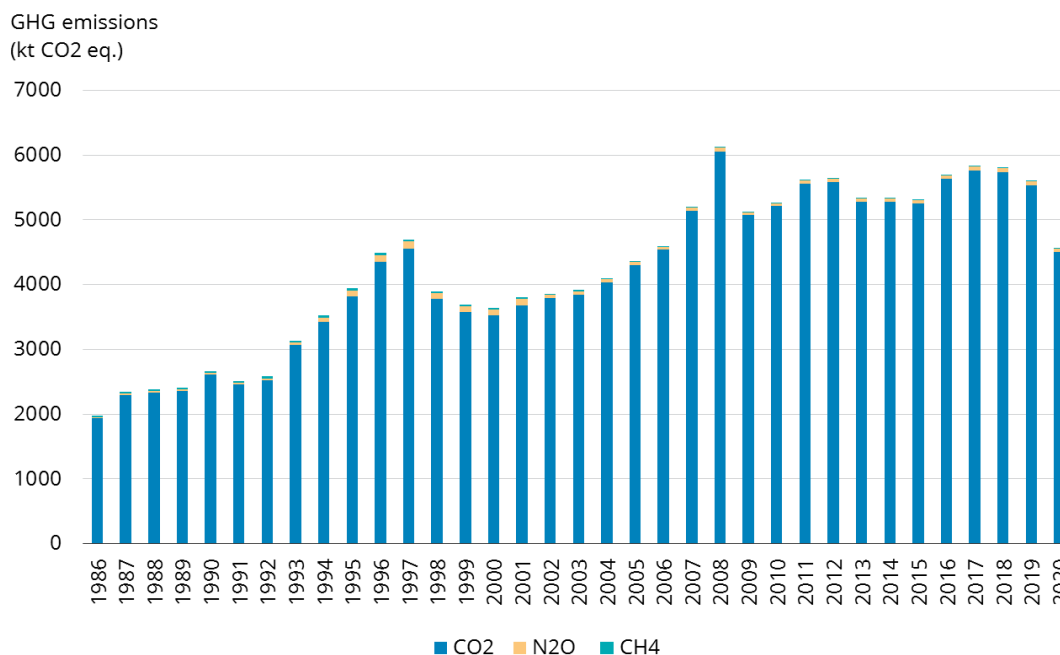
**Table 3.2.42: GHG emissions from Transport in kt CO<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
3. Transport	2,052	2,738	3,996	3,684	4,406	5,303	5,359	5,632	4,581
a. Civil Aviation	1	1	2	3	3	2	2	2	2
b. Road Transportation	1,974	2,664	3,945	3,639	4,361	5,264	5,313	5,603	4,559
c. Railways	77	73	49	43	42	33	41	26	19
d. Domestic navigation	0.01	0.01	0.02	0.01	0.03	0.04	0.05	0.09	0.09
e. NG transmission	NO	NO	NO	NO	IE	4	3	1	1

### 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<sub>x</sub>), nitrous oxides (NO<sub>x</sub>), carbon monoxide (CO), non-volatile organic compounds (NMVOC), particulate matters (PM<sub>2.5</sub> and PM<sub>10</sub>) and are, consequently, indirectly responsible for the formation of ozone (O<sub>3</sub>) in the lower troposphere.



**Figure 3.2.8: CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> emissions for road transport 1986–2020.**

From 1986 to 2020 the road transport emissions of CO<sub>2</sub> and N<sub>2</sub>O increased by 133% and 144%, respectively. Emissions of CH<sub>4</sub> have decreased by 81%. 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. Referring to the fourth IPCC assessment report, 1 g CH<sub>4</sub> and 1 g N<sub>2</sub>O have the greenhouse effect of 25 and 298 g CO<sub>2</sub>, respectively. In spite of the relatively large CH<sub>4</sub> and N<sub>2</sub>O global warming potentials, the largest contribution to the total CO<sub>2</sub> emission equivalents for road transport comes from CO<sub>2</sub> (Figure 3.2.8).

Due to the direct dependency of CO<sub>2</sub> emissions on fuel consumption, the total growth in CO<sub>2</sub> emissions reflects the trend of increased fuel consumption till 2008. In 2009 and 2020 significant drops in CO<sub>2</sub> emissions occurred due to the smaller fuel consumption due to the economic crisis and a Covid-19 pandemic crisis. 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 2-wheelers in decreasing order. In 2020, the emission shares were about 61, 29, 9 and 1%, respectively.

CO<sub>2</sub> 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. During the period 2000–2008, an extensive switch from petrol powered to diesel powered cars could be observed. 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<sub>2</sub> emissions in this period.

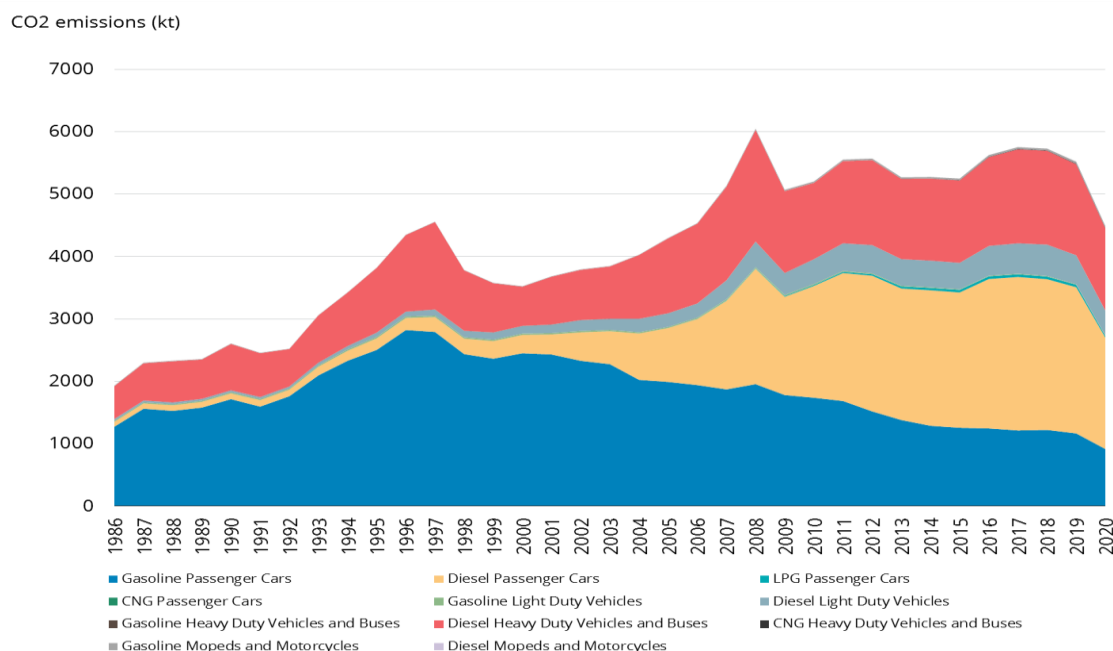
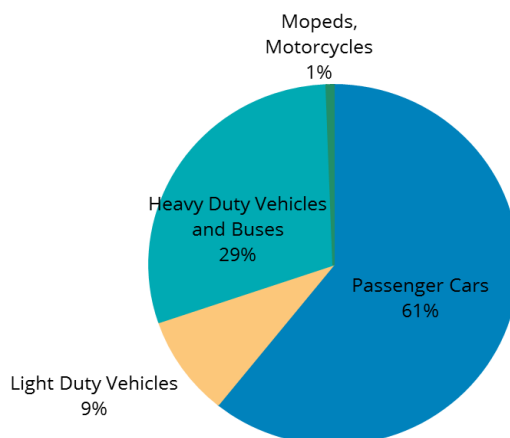


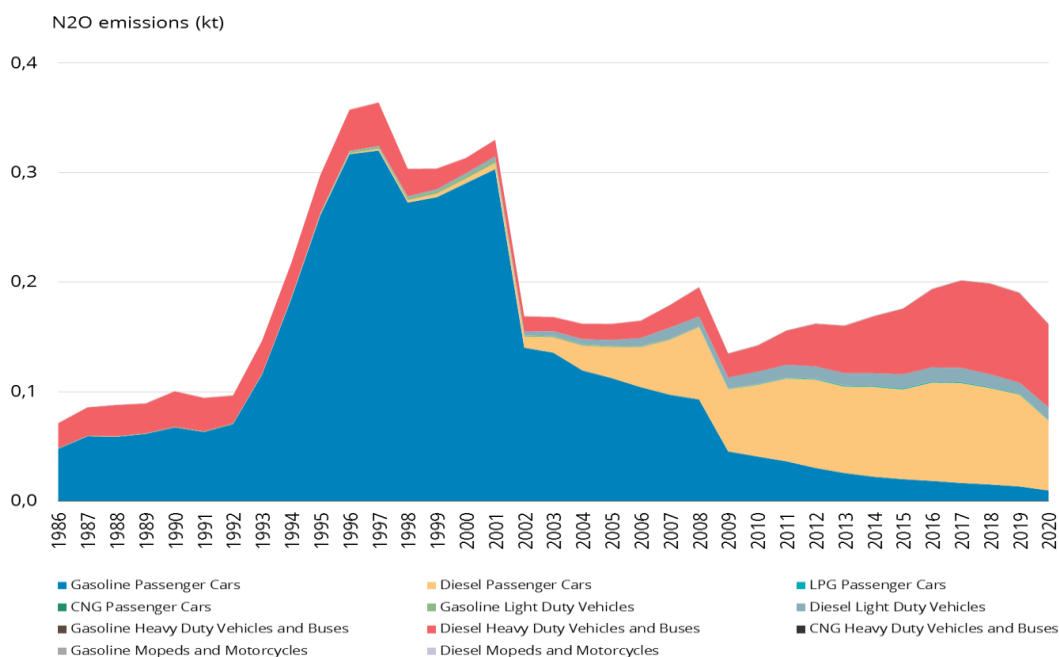
Figure 3.2.9: CO<sub>2</sub> emissions (kt) per vehicle type for road transport 1986–2020.



**Figure 3.2.10: CO<sub>2</sub> emission share per vehicle type for road transport for 2020.**

The road transportation sector also includes CO<sub>2</sub> 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 2020 CO<sub>2</sub> emissions from lube oil in two-stroke engines represent only 0.002% of total CO<sub>2</sub> emissions from road transportation.

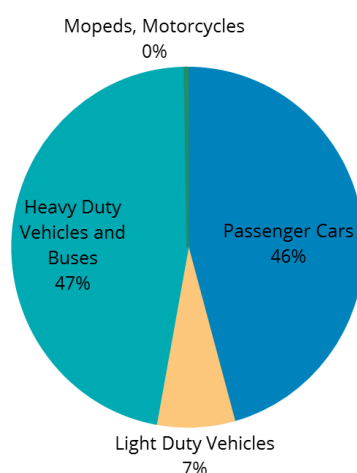
N<sub>2</sub>O emissions are not dependent only on fuel consumption, but also on vehicle technology, operating characteristics, fuel characteristics, combustion, and emission control technology.



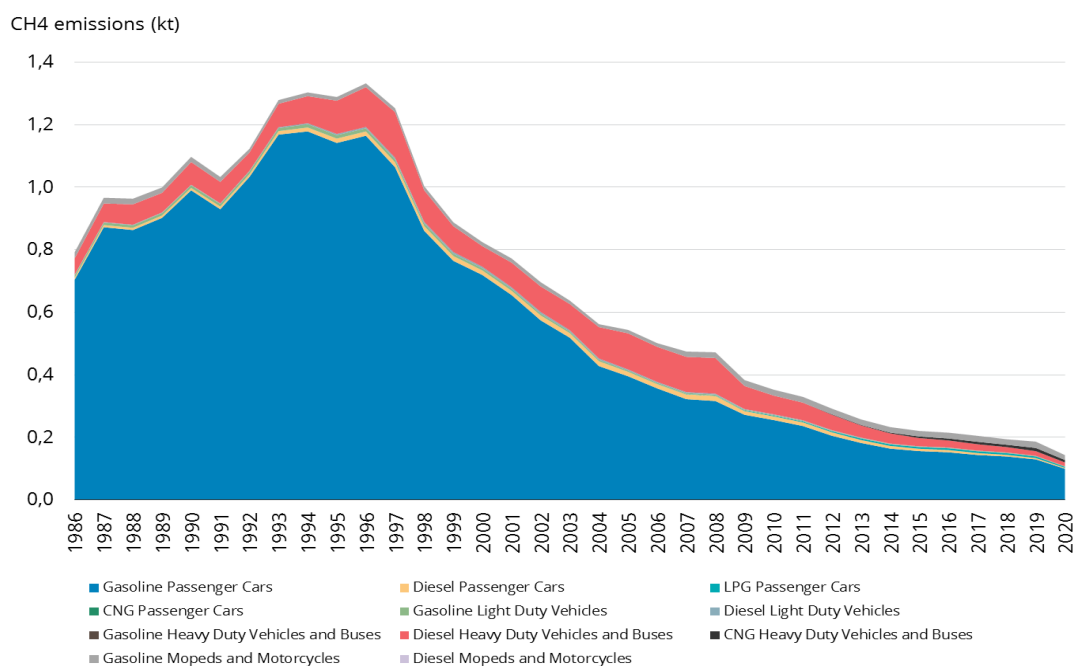
**Figure 3.2.11: N<sub>2</sub>O emissions (kt) per vehicle type for road transport 1986–2020.**

An undesirable environmental side effect of the introduction of catalyst cars is the increase in the emissions of  $\text{N}_2\text{O}$ .  $\text{N}_2\text{O}$  emissions have increased significantly from 1991 onwards, mostly due to the growing number of passenger cars with catalysts. In 2002, a huge drop in  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  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 2020 emission shares for heavy duty vehicles and buses are 47% and passenger cars 46%. Light duty vehicles contributed 7% to the total road transport  $\text{N}_2\text{O}$ .  $\text{N}_2\text{O}$  emissions from mopeds and motorcycles are negligible (Figures 3.2.11 and 3.2.12).

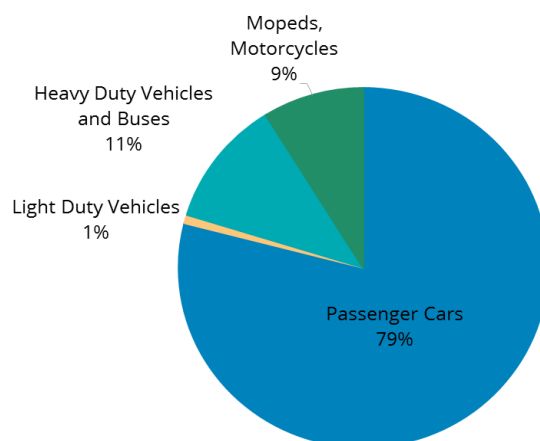


**Figure 3.2.12:  $\text{N}_2\text{O}$  emission share per vehicle type for road transport for 2020.**



**Figure 3.2.13: CH<sub>4</sub> emissions (kt) per vehicle type for road transport 1986–2020.**





**Figure 3.2.14: CH<sub>4</sub> emission share per vehicle type for road transport for 2020.**

CH<sub>4</sub> emissions, similarly to N<sub>2</sub>O, 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<sub>4</sub> 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<sub>4</sub> emission factors than conventional gasoline vehicles. The 2020 emission shares for CH<sub>4</sub> were about 79, 11, 9 and 1% for passenger cars, heavy duty vehicles and buses, 2-wheelers and light duty vehicles, respectively (Figures 3.2.13 and 3.2.14).

### **3.2.6.1.2 Methodological issues**

COPERT 5 (version 5.5.1) methodology has been used for the calculation of the national greenhouse gas emissions from road transport for the entire 1986-2020 period. The methodology is fully incorporated in the computer software program COPERT 5 (version 5.5.1.) 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 (CO, NO<sub>x</sub>, NMVOC, particulate matter (PM<sub>2.5</sub>, PM<sub>10</sub>, TSP, Black carbon), NH<sub>3</sub>, SO<sub>x</sub>, heavy metals) as well as greenhouse gas emissions (CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>) produced by the different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles and buses, mopeds and motorcycles). The program also provides speciation of polycyclic aromatic hydrocarbons (PAHs), dioxins/furans, hexachlorobenzene (HCB) and polychlorinated biphenyl (PCB). 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<sub>2</sub> 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. COPERT methodology is also a part of the EMEP/EEA air pollutant emission inventory guidebook (formerly referred to as the EMEP CORINAIR Guidebook). The Guidebook is prepared by the UNECE/EMEP Task Force on Emission Inventories and Projections (TFEIP) and published by the European Environment Agency. It is intended to support reporting under the UNECE Convention on Long-Range Transboundary Air Pollution and the EU directive on the reduction of national emissions of certain atmospheric pollutants as well as under United Nations Framework Convention on Climate Change (UNFCCC). 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 2019, Technical guidance to prepare national emission inventories, Chapters: 1.A.3.b.i-iv Road transport 2019, 1.A.3.b.v Gasoline evaporation 2019, 1.A.3.b.vi-vii Road tire and brake wear 2019
- <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**

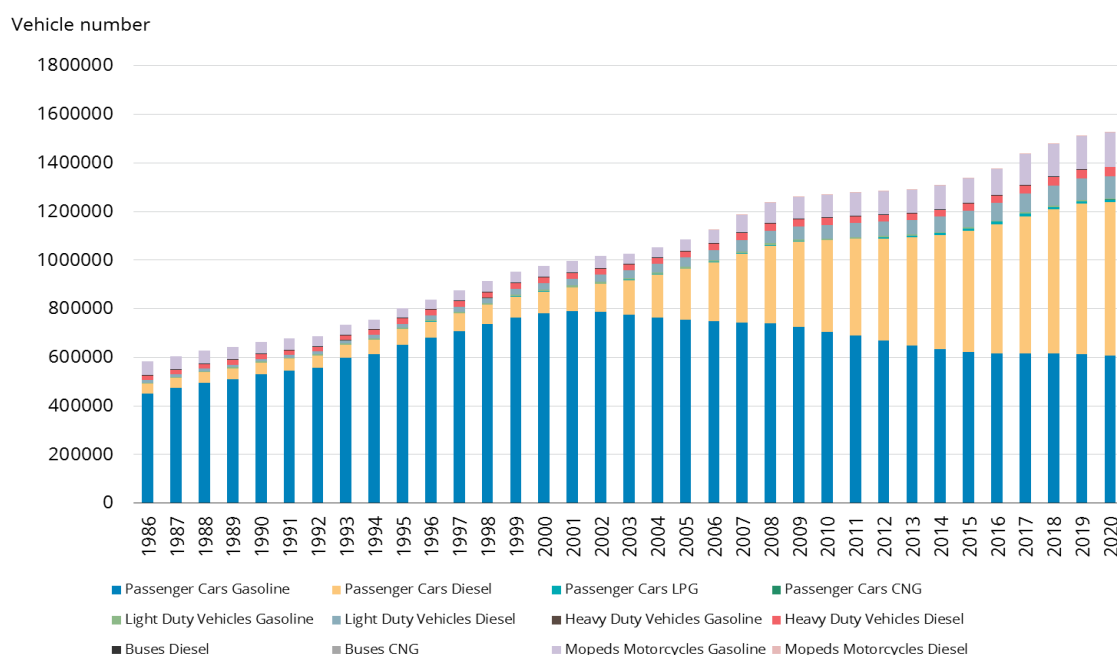
### **Vehicle fleet**

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 1986–2020 are shown in Annex 3: Road transport: Fleet data (number of vehicles) 1986–2020.

The fleet composition for the years 1992–2020 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).

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. LPG and CNG passenger cars represent only a small share of all passenger cars.



**Figure 3.2.15: Vehicle fleet 1986–2020.**

### Mileage

Annual mileage (km/year) for each vehicle category for 2015–2020 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 1986–2020.

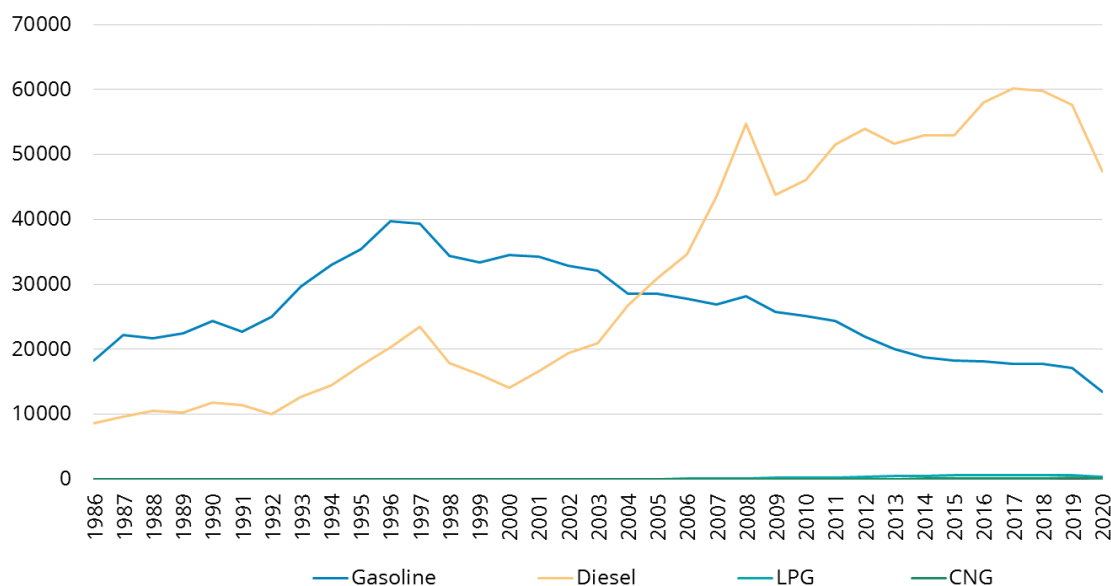
### Speed

Three driving modes are individualized in accordance with COPERT 5 methodology: urban (peak, 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 1986–2020.

### Fuel Consumption

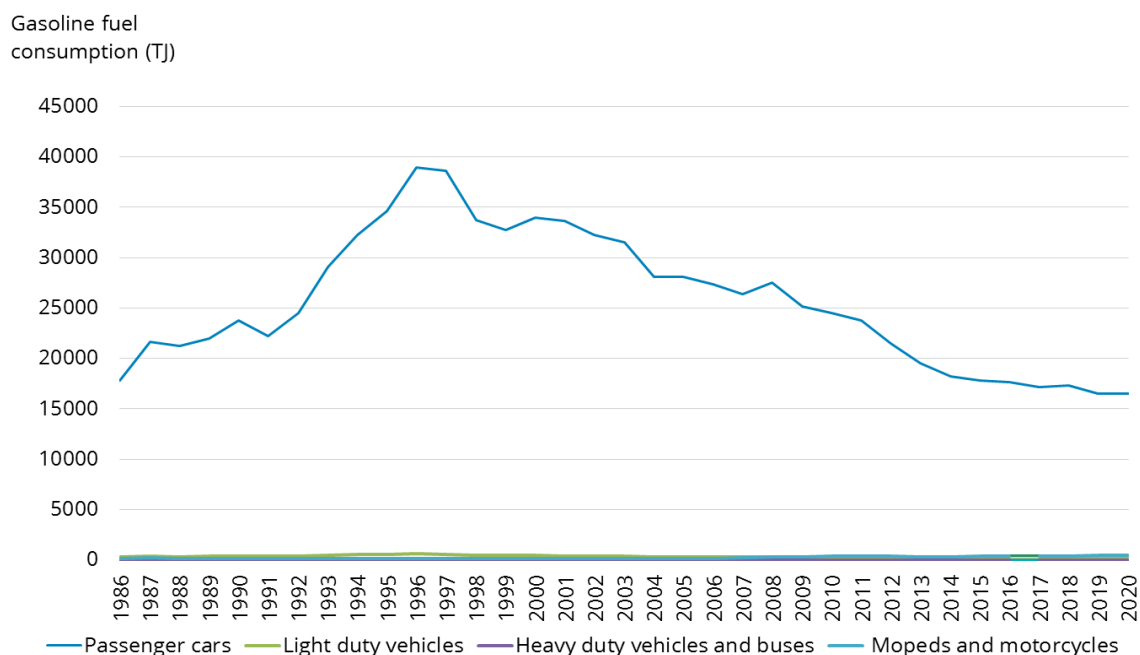
The statistical data on the total volume of the fuel consumed in the Republic of Slovenia has been obtained from SORS. From the total volume of the fuel sold, the consumption in the fields of agriculture, forestry and construction has been excluded.

Fuel consumption (TJ)



**Figure 3.2.16: Fuel consumption in road transport for 1986–2020.**

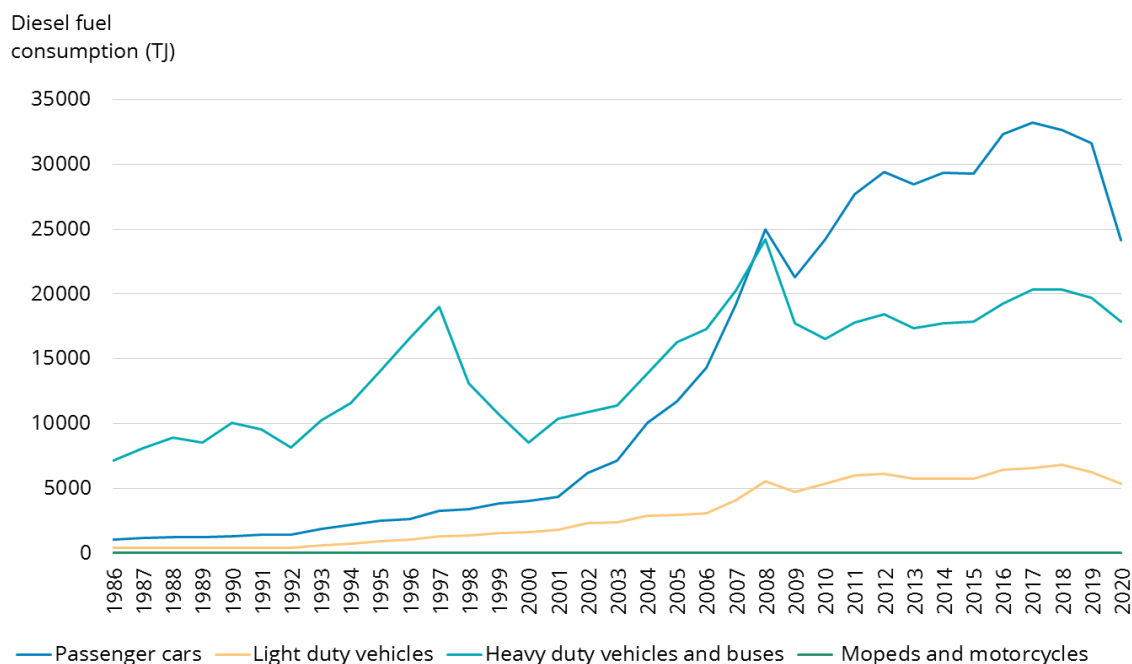
Figure 3.2.16 shows the total fuel consumption in road transport. Diesel, gasoline, liquefied petroleum gas (LPG) and compressed natural gas (CNG) have been used as fuels in road transportation. The fuel consumption began to grow markedly during the years 1991–1997 due to fuel being sold to foreigners 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 10% 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 2020, the fuel use shares for diesel and gasoline were about 77% and 22%, respectively. The share of LPG was below 0.6%. CNG was reported for the first time in 2012. The share of CNG is only 0.2%.



**Figure 3.2.17: Gasoline fuel consumption per vehicle type for road transport 1986–2020.**

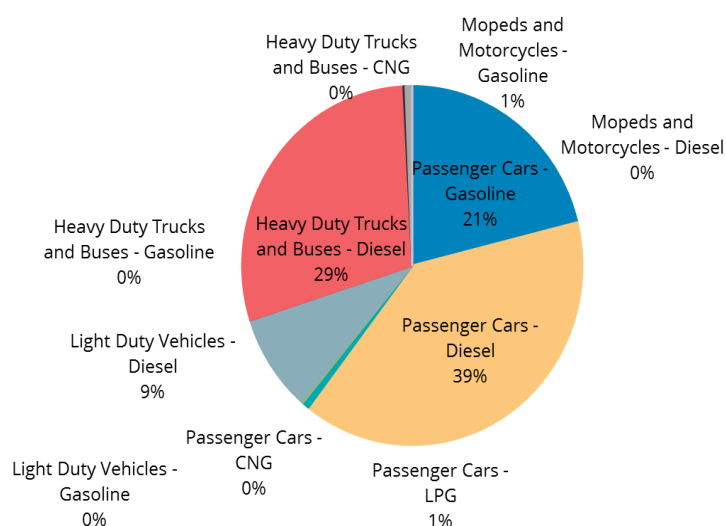
As shown in Figures 3.2.17 and 3.2.18, the passenger cars represent the most fuel-consuming vehicle category, followed by heavy duty vehicles, light duty vehicles, buses, motorcycles and mopeds, in decreasing order. Passenger cars dominate the overall gasoline consumption trend. The development in diesel 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 buses and light duty vehicles 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 1986–2020.

In 2020 the fuel consumption shares for diesel passenger cars, diesel heavy duty vehicles and buses, gasoline passenger cars were about 39, 29 and 21%, respectively (Figure 3.2.19).



**Figure 3.2.18: Diesel fuel consumption per vehicle type for road transport 1986–2020.**

In addition to fossil fuels biofuels have also been used in road transportation in Slovenia. Biodiesel has been used since 2006 and biogasoline since 2008. 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.



**Figure 3.2.19: Fuel consumption share per vehicle type for road transport in 2020.**

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.

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.

**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
	2002-2020	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
	2009-2020	0.001
Diesel	1986-1994	1
	1995	0.25
	1996-2001	0.20
	2002-2004	0.035
	2005-2008	0.005
	2009-2020	0.001

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.

Other input data

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.

**Emission factors**

All emission factors used in the emission inventory for road transport were default emission factors offered by the COPERT 5 (version 5.5.1) 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 2022 submission for the base year and the last reporting year in per cents.**

	1986 and 2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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 5.5.1) was used for emissions calculation for 2022 submission.

Since the new model has been applied thorough examination of all input data, the model calculation and the data reported in CRF tables as part of the QA/QC procedure was performed. All emissions distributed among different vehicle categories and fuel types were checked.

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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions reported in the CRF Tables are accurate. CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> 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.

### **3.2.6.1.5 Category-specific recalculations**

Recalculation of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O emissions for the whole period 1986-2019 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.5.1) was used for emissions calculation. COPERT 5 (version 5.5.1) replaced previous applied COPERT 5 (version 5.4.36).

### 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 (CRF 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 (CRF 1A3a)
- Railways (CRF 1A3c)
- Domestic navigation (CRF 1A3d)
- Other Transportation / Pipeline transport (CRF 1A3e.i)

#### Domestic aviation

GHG emissions from aviation are included in many CRF 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 3.2.46.

**Table 3.2.46: GHG Emissions from domestic aviation in the period 1986-2020.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
Av. gasoline in TJ	9	15	28	40	24	23	20	21	19
Jet kerosene in TJ	NO	NO	NO	NO	15	4	8	7	3
Gg CO <sub>2</sub> eq.	0.6	1.1	2.0	2.8	2.7	2.3	2.0	2.0	1.6

#### Railways

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. In 2020 due to the Covid-19

measures the steam locomotive has not been used and a use of gas oil decreased. Fuel in TJ and GHG emissions from the railways are presented in table 3.2.47.

There was a strong increase in diesel consumption in 2014. The reason for this increase is a severe 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 3.2.47: GHG Emissions from railways in the period 1986-2020.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>fuel in TJ</b>	931	879	588	514	505	403	498	313	231
<b>Gg CO<sub>2</sub> eq.</b>	77	73	49	43	42	33	41	23	19

### Domestic navigation

In the previous submissions emissions from 1.A.d Domestic Navigation were included into the road transport and the notation key IE has been used. For the present 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.

### 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 3.2.48.

**Table 3.2.48: GHG Emissions from compressor station in the period 1986-2020.**

	1986 - 2001	2002 - 2007	2010	2015	2019	2020
<b>fuel in TJ</b>	NO	IE	79	53	11	16
<b>Gg CO<sub>2</sub> eq.</b>	NO	IE	4.4	2.9	0.6	0.9

### **3.2.6.2.2 Methodology issues**

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

$$\text{Emissions} = \text{Quantity of Fuel used} \times \text{Net Calorific value} \times \text{EF per energy of Fuel}$$

### **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 2020 inventory are presented in table 3.2.49.

**Table 3.2.49: NCVs for fuel used in all other transportation in 2020.**

	Unit	Aviation Gasoline	Jet kerosene	Gas/Diesel Oil	Coal	Gasoline	Natural gas
NCV	TJ/kt or TJ/ 10 <sup>6</sup> Sm <sup>3</sup>	43.54	43.54	42.6	NO	43.85	34.087

### **Emission factors**

All emission factors have been taken from the 2006 IPCC Guidelines except for CO<sub>2</sub> EF for natural gas which is country specific (Table 3.2.50).

**Table 3.2.50: EFs for fuel used in all other transportations in the period 1986-2020.**

	Unit	Aviation Gasoline	Jet kerosene	Gas/Diesel Oil	Coal	Gasoline	Natural gas
CO <sub>2</sub> EF	t/TJ	69.3	71.5	74.0	101	69.3	Table 3.2.2
CH <sub>4</sub> EF	t/TJ	0.0005	0.0005	0.00415	0.002	0.048	0.001
N <sub>2</sub> O EF	t/TJ	0.002	0.002	0.0286	0.0015	0.002	0.0001
Source	CO <sub>2</sub>	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 <sub>4</sub> , N <sub>2</sub> O	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 powered train has been used only for touristic purpose and due to the Covid-19 measures it was not used in 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.

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 3.2.51.

**Table 3.2.51: Uncertainties of activity data and emission factors as used in the 2022 submission for the base year and the last reporting year in per cents.**

	1986 and 2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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

#### **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**

##### 1.A.3.f Domestic navigation, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Data on consumption of liquid fuel for domestic navigation has been obtained and corresponding emissions have been included in the category for the entire reporting period.

#### **3.2.6.2.6 Category-specific planned improvements**

No improvement is planned for this category.

### 3.2.7 Other Sectors (CRF 1A4)

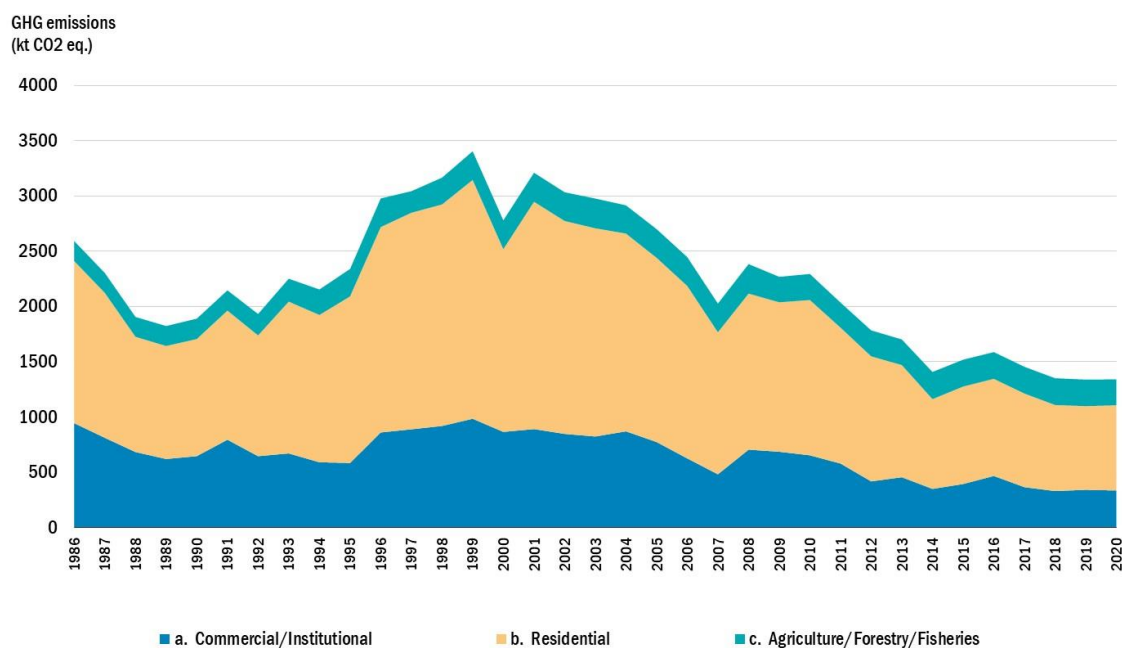
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

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

**Table 3.2.52: Method, EF used and key categories indications for the year 2020 in the Other sectors.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
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	-
Solid	T1	D	T	T1	D	T	T1	D	-
Biomass	T1	D	-	T2	CS	L	T1	D	-

In this sector CO<sub>2</sub> 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 is a key category according to the level, while methane emissions from the solid fuel is key category according to trend, only. The amount of solid fuel which is used in the residential sector is small and CO<sub>2</sub> emissions are almost negligible, thus the use of default EF seems appropriate (Table 3.2.52). The GHG emissions are presented in the Table 3.2.53 and on the Figure 3.2.20.



**Figure 3.2.20: GHG emissions from Other Sectors.**

Table 3.2.53: GHG emissions from Other Sectors in kt CO<sub>2</sub> eq.

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>4. Other Sectors</b>	<b>2594</b>	<b>1891</b>	<b>2341</b>	<b>2781</b>	<b>2701</b>	<b>2295</b>	<b>1520</b>	<b>1339</b>	<b>1342</b>
<b>a. Commercial/Institutional</b>	945	647	585	866	774	654	395	342	336
<b>b. Residential</b>	1468	1060	1507	1653	1667	1405	882	758	771
<b>c. Agriculture/Forestry/Fisheries</b>	181	185	248	261	259	236	244	240	235

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

#### 3.2.7.1.1 Category description

Emissions from these two subsectors were in 2020 for 54.1% lower than in 1986 despite that the energy of the fuel used was lower by 26.2% 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:

$$\text{Emissions} = \text{Quantity of Fuel used} \times \text{Net Calorific value} \times \text{EF per energy of Fuel}$$

#### 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.

**Net calorific values**

The net calorific values have been taken from SORS. 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. All NCVs are presented in the Table 3.2.54.

**Table 3.2.54: 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	14
2001	10.660		18.834	41.90	40.00	46.05	34.080	14
2002	10.350		19.000	41.90	40.00	46.05	34.080	14
2003	10.138		19.000	41.90		46.05	34.080	14
2004	10.301		19.000	41.90		46.05	34.080	14.04
2005	10.803		17.000	42.60		46.05	34.080	14.07
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	14,78
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	15.80
2019			18.281	42.60		46.050	34.081	14.84
2020			18.198	42.60		46.050	34.087	14.84



### 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<sub>2</sub> EFs have been used for domestic lignite and natural gas, and country specific CH<sub>4</sub> emissions factor for wood biomass combustion in the residential sector. Emission factors are presented in the Table 3.2.55-57.

**Table 3.2.55: 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 <sub>2</sub> EF	t/TJ	Table 3.2.1	101	74.0	77.1	63.1	Table 3.2.2	112	54.6
CH <sub>4</sub> EF	t/TJ	0.01	0.01	0.01	0.03	0.005	0.005	0.3	0.005
N <sub>2</sub> O EF	t/TJ	0.0015	0.0014	0.0006	0.0006	0.0001	0.0001	0.0040	0.0001

**Table 3.2.56: EFs for the fuel used in Residential Sector if different from Commercial.**

	Unit	Lignite (Velenje)	Sub- bituminous Coal - domestic	Wood biomass
CH <sub>4</sub> EF	t/TJ	0.3	0.3	Table 3.2.56

**Table 3.2.57: CS EFs in t CH<sub>4</sub>/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	0.2803	0.2772	0.2763	0.2680	0.2707
2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
0.2716	0.2694	0.2623	0.2553	0.2471					

The country specific CH<sub>4</sub> 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 3.2.58.

For this study a literature search on CH<sub>4</sub> 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<sub>4</sub> 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 – 2020, while for years before data was estimated taking into account, that in 1986 only conventional boilers and stoves have existed.

**Table 3.2.58: CH<sub>4</sub> EFs for wood biomass combustion for different combustion technologies.**

Device label	Name of the boiler according to the EMEP/EEA GL 2019	CH <sub>4</sub> EF g CH <sub>4</sub> /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 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 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 3.2.59.

Uncertainty of EF are mostly taken from 2006 IPCC GL. An exception is CH<sub>4</sub> 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).

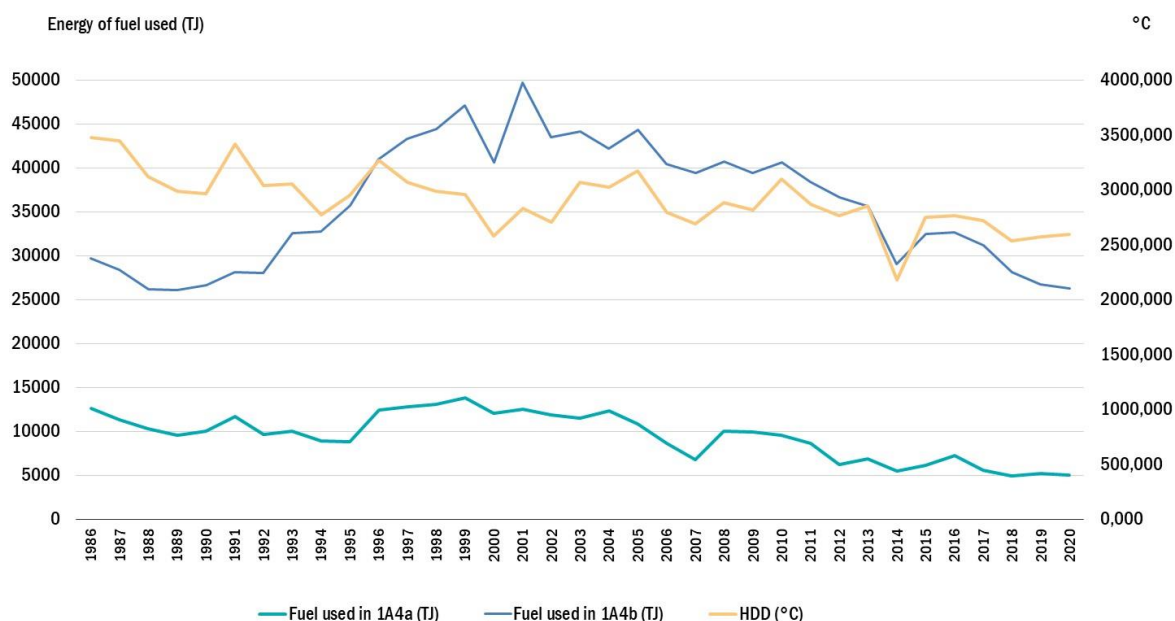
**Table 3.2.59: Uncertainties of activity data and emission factors as used in the 2022 submission for the base year and the last reporting year in per cents.**

	1986 and 2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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

### 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.

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.



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

### **3.2.7.1.5 Category-specific recalculations**

Following recommendation from the UNFCCC review, composition data for the natural gas for the period 1998-2019 has been obtained and accordingly CS CO<sub>2</sub> emission factor have been updated. In addition an error in CO<sub>2</sub> emission factor for the period 1986-1997 have been corrected and therefore CO<sub>2</sub> emission from combustion of natural gas have been recalculated for the entire period 1986-2019 and for the all categories.

### **3.2.7.1.6 Category-specific planned improvements**

No improvements are planned for this category.

## **3.2.7.2 Agriculture / Forestry / Fishing (CRF 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:

$$\text{Emissions} = \text{Quantity of Fuel used} \times \text{Net Calorific value} \times \text{EF per energy of Fuel}$$

### **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 3.2.60. Since 2001 data on fuel are available from SORS.

**Table 3.2.60: 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
<b>Estimated Consumption of Gasoline in Total Agriculture (1000 t)</b>	<b>12.016</b>	<b>9.227</b>	<b>6.647</b>	<b>3.626</b>
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
<b>Estimated consumption of Diesel Fuels in Total Agriculture (1000 t)</b>	<b>108.326</b>	<b>85.255</b>	<b>65.353</b>	<b>62.596</b>

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 3.2.61. Since 2001 data on fuel are available from SORS.

**Table 3.2.61: 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 <sup>3</sup> )	1438	1230	862	907
Consumption of Fuel per Cut Quantities (tons per 1000 m <sup>3</sup> )	4.8	4.8	4.3	3.1
Total Cut (1000 m <sup>3</sup> )	3501	2435	2092	2609
Total Consumption of Fuel in Forestry (1000 t)	16.804	11.720	8.931	8.077
<b>Gasoline (1000 tonnes)</b>	<b>1.680</b>	<b>1,172</b>	<b>0.893</b>	<b>0.808</b>
<b>Diesel (1000 tonnes)</b>	<b>15.124</b>	<b>10.548</b>	<b>8.038</b>	<b>7.272</b>

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<sup>3</sup> 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<sup>3</sup> 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.

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 3.2.62.

**Table 3.2.62: Consumption of diesel in Fishing**

	1986	1990	1995	2000	2005	2010	2015	2020
Consumption of Diesel in Fishing (kt)	203	203	203	270	355	510	202	197

### **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 3.2.63.

**Table 3.2.63: Default EFs for gasoline and diesel oil used in the agriculture and forestry.**

	Diesel	Motor gasoline
	t/TJ	t/TJ
CO <sub>2</sub> EF	74.1	69.3
CH <sub>4</sub> EF	0.00415	0.08
N <sub>2</sub> O 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 3.2.64).

**Table 3.2.64: Uncertainties of activity data and emission factors as used in the 2020 submission for the base year and the last reporting year in per cents.**

	1986 and 2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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****1A4.c.iii Other sectors, Fishing, gas diesel oil, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O**

Updated data on fuel used for fishing in 2019 has been obtained and corresponding GHG emissions have been recalculated for this year.

**3.2.7.2.6 Category-specific planned improvements**

No improvement is planned for this category.

### 3.2.8 Other (CRF 1A5)

#### 3.2.8.1.1 Category description

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

- Other mobile (CRF 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 3.2.65.

**Table 3.2.65: GHG Emissions in the period 1986-2020.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
fuel in TJ	575	444	19	43	46	40	51	56	44
Gg CO <sub>2</sub> eq.	41	32	1	3	3	3	4	4	3

#### 3.2.8.1.2 Methodology issues

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

$$\text{Emissions} = \text{Quantity of Fuel used} \times \text{Net Calorific value} \times \text{EF per energy of Fuel}$$

#### 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 3.2.66.

**Table 3.2.66: Default EFs for jet kerosene used in the Slovenian Army and Police.**

	Jet kerosene
	t/TJ
CO <sub>2</sub> EF	71.5
CH <sub>4</sub> EF	0.0005
N <sub>2</sub> O 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 3.2.67).

**Table 3.2.67: Uncertainties of activity data and emission factors as used in the 2022 submission for the base year and the last reporting year in per cents.**

	1986				2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O EF	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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, (CRF 1.B)

This chapter presents the fugitive emissions of greenhouse gases from:

- Solid fuels (CRF 1.B.1)
- Oil and natural gas (CRF 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<sub>2</sub> 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.

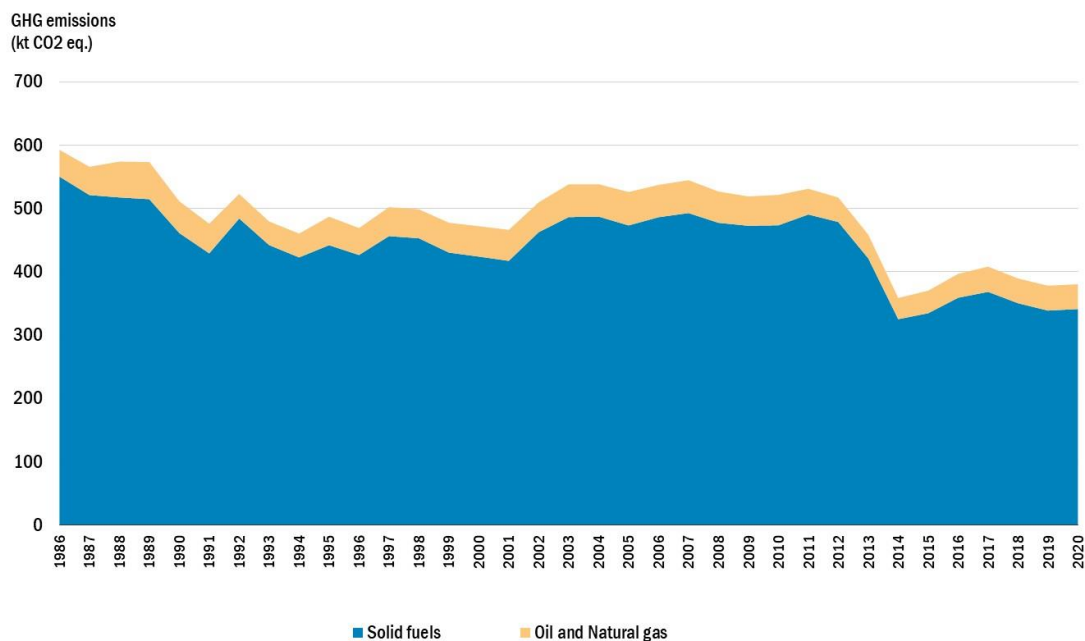
**Table 3.3.1: Method, EF used and key categories indications for the year 2020 in the Fugitive emissions sectors.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
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
SO <sub>2</sub> scrubbing	T3	PS	L <sub>sub</sub> , T	NO	NO	NA	NO	NO	NA
Oil and Natural Gas	T1	D	-	T1	D	-	T1	D	-

GHG emissions in kt of CO<sub>2</sub> 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<sub>2</sub> eq.**

in kt CO <sub>2</sub> eq.	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>Total</b>	<b>593</b>	<b>512</b>	<b>487</b>	<b>472</b>	<b>526</b>	<b>522</b>	<b>370</b>	<b>378</b>	<b>381</b>
Solid Fuels	551	461	442	424	474	474	335	339	341
Oil and Natural gas	42	50	45	48	53	48	36	39	39



**Figure 3.3.1: Fugitive emissions in kt CO<sub>2</sub> eq.**

Fugitive emissions from fuel represent only 2.4% of emissions in the sector and have decreased by 35.8% compared to the emissions in 1986. The decrease of emissions is mainly due to the gradual closure of coal mines.

### 3.3.1 Solid Fuels (CRF 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<sub>2</sub> 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<sub>4</sub> emissions that arise during mining and post-mining activities although CO<sub>2</sub> emissions occur as well. In 2015 submission CH<sub>4</sub> 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 – 2020 in kt CO<sub>2</sub> eq.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>Mining (CH<sub>4</sub>)</b>	103.3	53.1	256.0	200.4	208.2	208.6	159.2	157.9	159.5
<b>Mining (CO<sub>2</sub>)</b>	123.1	100.6	88.1	80.7	83.1	82.4	61.4	60.9	61.6
<b>Post-Mining (CH<sub>4</sub>)</b>	324.0	307.4	67.9	99.7	96.0	88.3	53.1	52.6	53.2
<b>Abandoned coal mines (CH<sub>4</sub>)</b>	0.2	0.4	0.2	6.7	4.0	2.8	5.8	4.0	3.7
<b>Total</b>	<b>550.6</b>	<b>461.4</b>	<b>412.2</b>	<b>387.6</b>	<b>391.2</b>	<b>382.1</b>	<b>279.5</b>	<b>275.5</b>	<b>278.0</b>

**Table 3.3.4: Emission of CO<sub>2</sub> from SO<sub>2</sub> scrubbing 1986 – 2020 in kt CO<sub>2</sub>.**

	1986	1990	1995	2000	2005	2010	2015	2019	2020
<b>SO<sub>2</sub> scrubbing</b>	NO	NO	30.0	36.7	82.3	91.5	55.3	63.5	63.4

#### 3.3.1.2 Methodology issues

##### Mining and post mining

$$\text{Methane emissions (t)} = (EF_1 + EF_2) * \text{excavated coal (t)} * 0.67(\text{kg/m}^3)$$

$$\text{CO}_2 \text{ emissions (t)} = EF_3 (\text{m}^3 \text{ CO}_2/\text{t}) * \text{excavated coal (t)} * 1.84(\text{kg/m}^3)$$

EF<sub>1</sub> = Methane emission factor in coal excavation (m<sup>3</sup> CH<sub>4</sub>/t)

EF<sub>2</sub> = Methane emission factors in post-mining activities for coal (m<sup>3</sup> CH<sub>4</sub>/t)

EF<sub>3</sub> = CO<sub>2</sub> emission factor in coal excavation (m<sup>3</sup> CO<sub>2</sub>/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 – 2020**

Pit	1986	1990	1995	2000	2005	2010	2015	2019	2020	Closed in
Velenje	5,001	4,210	3,917	3,743	3,945	4,011	3,168	3,143	3,175	
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
<b>Total Coal Excavation (Gg)</b>	<b>6,828</b>	<b>5,561</b>	<b>4,883</b>	<b>4,480</b>	<b>4,540</b>	<b>4,430</b>	<b>3,168</b>	<b>3,143</b>	<b>3,175</b>	

### **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<sub>4</sub> concentrations are generally the highest. The air flow was measured with congestive pressure (Pittot Prandtl tube). The proportions of CH<sub>4</sub> 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<sup>3</sup>/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<sub>2</sub> 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<sub>4</sub> in Coal Excavation 1986 – 2020 (m<sup>3</sup> CH<sub>4</sub>/t coal)**

Pit	1986	1990	1995	1997-2020
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<sub>4</sub> in Post Mining Activities 1986 – 2020 (m<sup>3</sup> CH<sub>4</sub>/t coal)**

Pit	1986	1990	1995	1997-2020
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<sub>2</sub> in Coal Excavation 1986 – 2020 (m<sup>3</sup> CO<sub>2</sub>/t coal)**

Pit	1986-2020
Velenje	10.54
Trbovlje - Hrastnik	6.03
Zagorje	9.51
Senovo	16.16
Kanižarica	8.21
Laško	30.80

### **Abandoned underground mines**

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 tonnes	Measured emissions on the last year of operation in kt CH <sub>4</sub>
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 2020.**

Coal mine	type of coal	Measured emissions on the last year of operation in kt CH <sub>4</sub>	T (years since abandonment)	EF
Trbovlje-Hrastnik	brown	0.22	7	0.346
Zagorje	brown	0.39	23	0.139
Senovo	brown	0.07	25	0.129
Kanižarica	brown	0.04	25	0.129
Laško	brown	0.01	31	0.107
Šega	brown	0.01	57	0.061
Krmelj	brown	0.043	58	0.060
Leše	brown	0.006	84	0.042

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 2020 are presented in the Table 3.3.10.

### **SO<sub>2</sub> scrubbing**

Using a technology for reduction of SO<sub>2</sub> emissions in the process of consumption of coal is causing the emissions of CO<sub>2</sub>. CO<sub>2</sub> emissions from the SO<sub>2</sub> scrubbing have been calculated from consumption of limestone and the appropriate emission factor.

The activity data on CaCO<sub>3</sub> 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<sub>2</sub> in Slovenia. The data on CaCO<sub>3</sub> and MgCO<sub>3</sub> for the period 2005–2020 have been obtained from the verified ETS reports. The default emission factors, 439.71 kg CO<sub>2</sub>/ton limestone and 521.97 kg CO<sub>2</sub>/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<sub>2</sub> 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.

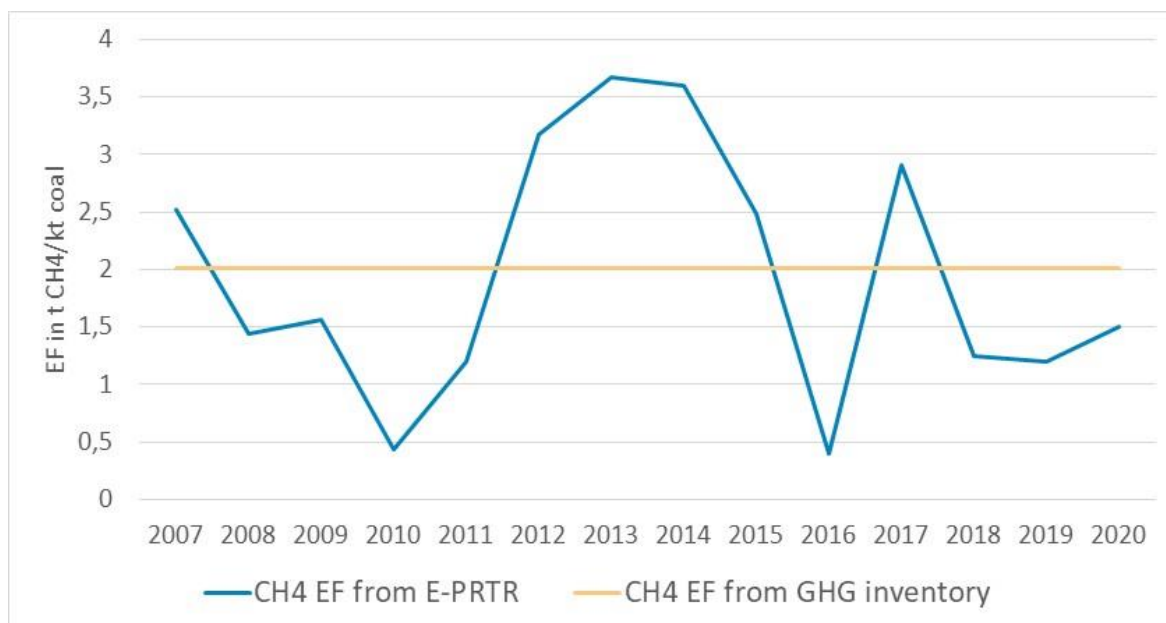
**Table 3.3.11: Uncertainties of activity data and emission factors as used in the 2022 submission for the base year and the last reporting year.**

	1986				2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O EF	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O EF
Coal Mining and Handling	10	150	30	NA	10	150	30	NA
Other – SO <sub>2</sub> 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<sub>4</sub> emissions from this category.



**Figure 3.3.2: CH<sub>4</sub> EF in t CH<sub>4</sub> / kt of excavated coal from Velenje coal mine as calculate from emissions reported to E-PRTR and EF used in GHG inventory.**

CO<sub>2</sub> emissions from 1B1c Other / SO<sub>2</sub> scrubbing were a key source in 2020. Due to the fact, that AD are obtained from the verified ETS reports, additional QA is not necessary. We have compared the final CO<sub>2</sub> emissions from ETS report and from GHG inventory and the difference in 2020 was 0.064%. The reason is a different EFs used: in ETS the EF factors are rounded and are 440 instead of 439.71 kg CO<sub>2</sub>/t CaCO<sub>3</sub> and 522 instead of 521.97 kg CO<sub>2</sub>/t MgCO<sub>3</sub>.

### 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 (CRF 1.B.2)

#### 3.3.2.1 Category description

Fugitive emissions of GHG from Oil and Natural Gas in the period 1986-2020 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<sub>4</sub> 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 – 2020 (kt CO<sub>2</sub> eq.)**

		1986	1990	1995	2000	2005	2010	2015	2020
OIL	Production	0.00004	0.00004	0.00003	0.00001	0.00001	0.00000	0.00000	0.00000
	Transport	0.032	0.025	0.026	0.059	0.065	0.062	0.060	0.061
	Refining	0.341	0.341	0.331	0.093	NO	NO	NO	NO
	Venting	0.065	0.063	0.047	0.020	NO	NO	NO	NO
	Flaring	0.149	0.145	0.108	0.050	NO	NO	NO	NO
NATURAL GAS	Production	2.247	7.204	4.141	0.968	0.142	0.224	0.101	0.179
	Transmission	9.980	10.705	9.814	11.300	12.654	11.178	7.747	8.459
	Distribution	22.911	24.576	24.052	27.937	31.436	29.185	22.482	24.891
	Venting	6.655	7.139	6.545	7.536	8.439	7.455	5.166	5.641
	Flaring	0.011	0.034	0.025	0.010	0.005	0.008	0.004	0.007
<b>TOTAL</b>		42.391	50.232	45.090	47.974	52.741	48.112	35.559	39.238

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 1177 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<sub>1</sub>: venting, flaring and fugitive GHG emissions from crude oil production,
- emissions<sub>2</sub>: fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions from crude oil refining,
- emissions<sub>3</sub>: CO<sub>2</sub> emissions from the transport of LPG
- emissions<sub>4</sub>: flaring and fugitive GHG emissions from natural gas production,
- emissions<sub>5</sub>: venting and fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions from NG transmission,
- emissions<sub>6</sub>: fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions from NG distribution.

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

*emissions<sub>1</sub> = crude oil produced (ton) x density (t/1000 m<sup>3</sup>) x EFs (Gg/1000 m<sup>3</sup>)*

*emissions<sub>2</sub> = oil refined (ton) x density (t/1000 m<sup>3</sup>) x EFs (Gg/1000 m<sup>3</sup>)*

*emissions<sub>3</sub> = LPG consumed (ton) x density (t/1000 m<sup>3</sup>) x EFs (Gg/1000 m<sup>3</sup>)*

*emissions<sub>4</sub> = natural gas production (1000 m<sup>3</sup>) x EFs (Gg/10<sup>6</sup> m<sup>3</sup>)*

*emissions<sub>5</sub> = marketable gas (1000 m<sup>3</sup>) x EFs (Gg/10<sup>6</sup> m<sup>3</sup>)*

*emissions<sub>6</sub> = natural gas utility sale (1000 m<sup>3</sup>) x EFs (Gg/10<sup>6</sup> m<sup>3</sup>)*

#### **Activity data**

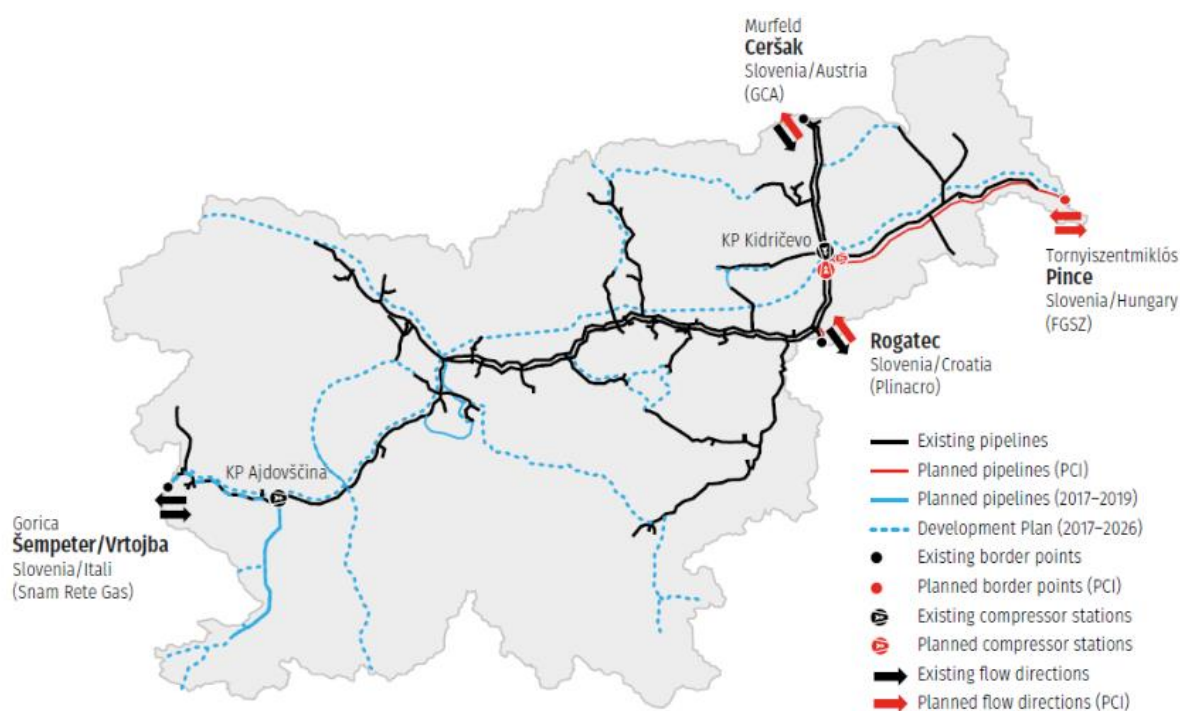
The data on the amount of crude oil produced and refined and LPG consumed have been obtained from SORS. As all data are available in tonnes the following densities have been used to transform ton to m<sup>3</sup>: crude oil: 0.85 t/m<sup>3</sup> and LPG: 0.58 t/m<sup>3</sup>.

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<sup>3</sup>. 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<sub>2</sub> Emission Factor in Energy Use and CH<sub>4</sub> 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	1995	2000	2005	2010	2015	2020
<b>Length (km)</b>	740	784	927	948	960	1,018	1,155	1,177
<b>Built before 1992</b>	100%	100%	85%	83%	82%	78%	68%	67%
<b>Built between 1992 and 2004</b>			15%	17%	18%	17%	15%	14%
<b>Built since 2005</b>						6%	17%	18%



Source: Plinovodi

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

In 2020, a company Plinovodi d.o.o. operates and owns 1177 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	1995	2000	2005	2010	2015	2020
Length (km)	401	514	903	2,079	3,413	4,246	4,633	4,953
Built before 1992	100%	100%	61%	26%	16%	13%	12%	11%
Built between 1992 and 2004			39%	74%	75%	60%	55%	52%
Built since 2005					9%	27%	33%	37%

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 countries 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 countries 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<sup>3</sup>.**

		CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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<sub>2</sub>O emissions from transport of LPG have not been reported because CRF tables do not enable to import N<sub>2</sub>O 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<sup>3</sup>.**

		gas	1986-1991	1992-2004	2005-2020
Gas production	Fugitives	CO <sub>2</sub>	0.097	interpolation	0.048
	Flaring	CO <sub>2</sub>	1.4	interpolation	1.2
Gas production	Fugitives	CH <sub>4</sub>	12.19	interpolation	1.34
	Flaring	CH <sub>4</sub>	0.00088	interpolation	0.00076
Gas production	Fugitives	N <sub>2</sub> O	NO	NO	NO
	Flaring	N <sub>2</sub> O	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<sup>3</sup>.**

		gas	Built before 1992	Built between 1992 and 2004	Built since 2005
Transmission	Fugitives	CO <sub>2</sub>	0.00088	0.00088	0.00088
	Venting	CO <sub>2</sub>	0.0031	0.0031	0.0031
Transmission	Fugitives	CH <sub>4</sub>	0.48	0.273	0.066
	Venting	CH <sub>4</sub>	0.32	0.182	0.044
Distribution	All	CO <sub>2</sub>	0.051	0.051	0.051
	All	CH <sub>4</sub>	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<sub>4</sub> 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 2022 submission for the base year and the last reporting year in per cents.**

	1986 and 2020			
	AD	CO <sub>2</sub> EF	CH <sub>4</sub> EF	N <sub>2</sub> O 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<sub>4</sub> 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 <sub>4</sub> (1000 m <sup>3</sup> )
production	16,027	1000 m <sup>3</sup>	0.05	% of net prod.	8
transmission	1,175	km	200	m <sup>3</sup> /km	235
Compressor stations	19.5	MW	6000	m <sup>3</sup> /MW	117
MRS	254	stations	1000	m <sup>3</sup> /station	254
distribution	4,827	km	100	m <sup>3</sup> /km	483
gas use	269,284	appliances	2	m <sup>3</sup> /appliance	539
<b>TOTAL</b>					<b>1,639</b>
<b>TOTAL CH<sub>4</sub> emissions in 2018 from NIR (1.5563 kt CH<sub>4</sub>, density: 0.6788 t/1000m<sup>3</sup>)</b>					<b>2,293</b>

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**

#### 1.B.2.Venting and Flaring, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

For the year 2019 updated data for natural gas production and use has been obtained and fugitive GHG emissions for 2019 have been recalculated accordingly.

### **3.3.2.6 Category-specific planned improvements**

No improvement is planned for this category.

## **3.4 CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage**

There are no plants for recovery and storage of CO<sub>2</sub> in Slovenia.

## 4 INDUSTRIAL PROCESSES AND PRODUCT USE (CRF sector 2)

### 4.1 Overview of Sector

This chapter presents the processes emissions of greenhouse gases in:

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

and emissions due to the product use:

- Non-energy products from fuels and solvent use (CRF 2.D),
- Product uses as substitutes for ODS (CRF 2.F),
- and Other product manufacture and use (CRF 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<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and PFCs. Some industrial sources also produce NO<sub>x</sub>, NMVOCs, CO, and SO<sub>2</sub>.

Some fluorinated compounds (Hydro-fluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF<sub>6</sub>)) 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<sub>2</sub>O) 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 2020 in the IPPU sector.**

		CO <sub>2</sub>		
		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>sub</sub>
	10. Hydrogen production	T2	CS	-
C. Metal industry	1. Iron and steel production	T2	PS	-
	3. Aluminium production	T2	D, PS	L <sub>sub</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 <sub>2</sub> O		
		Method	EF	Key category
G. Other product manufacture and use	3. N <sub>2</sub> O 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
		SF <sub>6</sub>		
		Method	EF	Key category
G. Other product manufacture and use	1. Electrical equipment	T2	CS	-

The emissions from Industrial processes and product use (CRF sector 2) in Slovenia account for 7.4% of the total national GHG emissions, excluding LULUCF. They amounted to 1,408 kt CO<sub>2</sub> equivalents in 1986 and 1,175 kt CO<sub>2</sub> equivalents in 2020. The main source of emissions is mineral industry with 47.7% of emissions, followed by consumption of F-gases (product uses as substitutes for ODS) with 25.1% and metal industry with 12.2%. Significantly smaller are the contributions from chemical industry (5.3%) and from other product

manufacture and use (7.0%), while use of non-energy products from fuels and solvent contributes 2.6% to the total emissions from this sector.

The main source of emissions from industrial processes and product use sector is cement industry, which is responsible for 40.7% of the GHG emissions from this sector. 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. The process emissions of GHG (in kt CO<sub>2</sub> eq.) for 1986-2020 are shown in Figure 4.1.1.

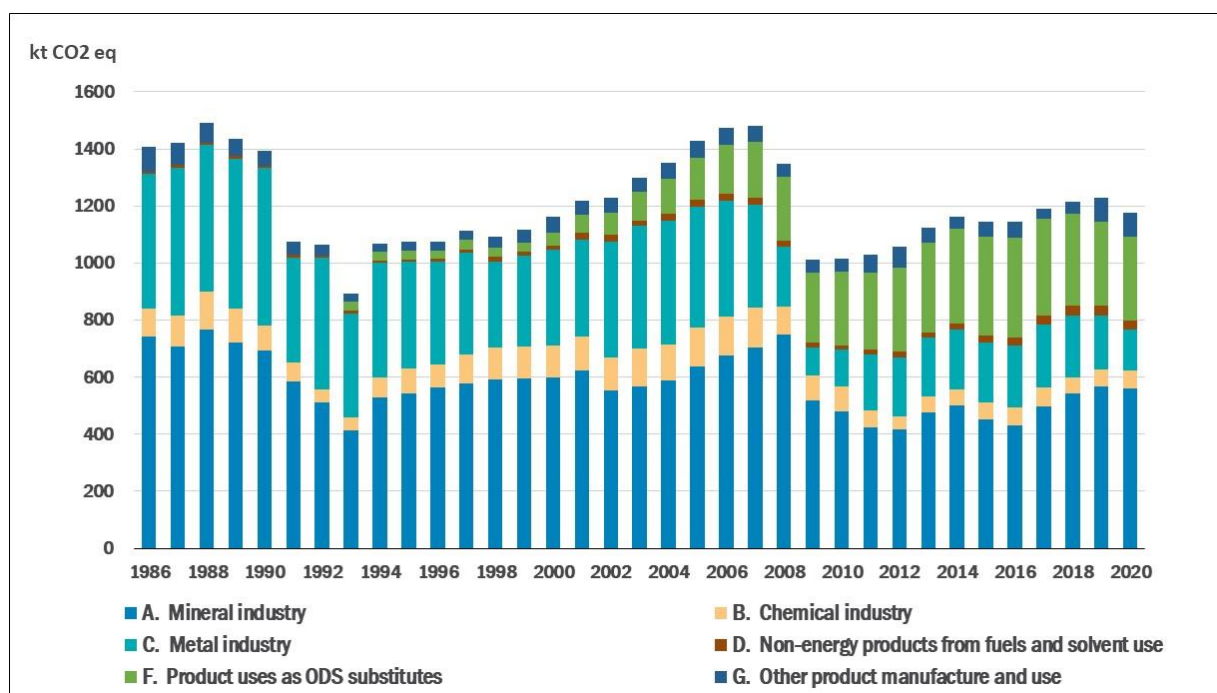


Figure 4.1.1: Process emissions of GHG from different types of industries and product use.

## 4.2 MINERAL INDUSTRY (CRF 2.A)

### 4.2.1 Cement Production (CRF 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 ( $\text{CaCO}_3$ ), is prepared by mixing limestone and clay components: from such with 35% of  $\text{CaCO}_3$  to limestone with more than 95% of  $\text{CaCO}_3$ . The limestone, which is a source of  $\text{CaO}$ , normally has an admixture of dolomite, which introduces  $\text{MgO}$  into the system. The clay components are bearers of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$ . 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  $\text{CaCO}_3$ , the main constituent of limestone, to lime ( $\text{CaO}$ ), while  $\text{CO}_2$  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.  $\text{CO}_2$  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 (CRF code: 1A2).

$\text{CO}_2$  emissions from carbon present in the raw materials are reported under the category Cement Production (CRF code: 2A1) and described in the following paragraph. In Slovenia, there have been two cement producers until 2015. In the year 2020 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–

2020 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<sub>2</sub>/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 2005–2020 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<sub>2</sub> emissions using IPCC methodology. In the year 2020 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.**

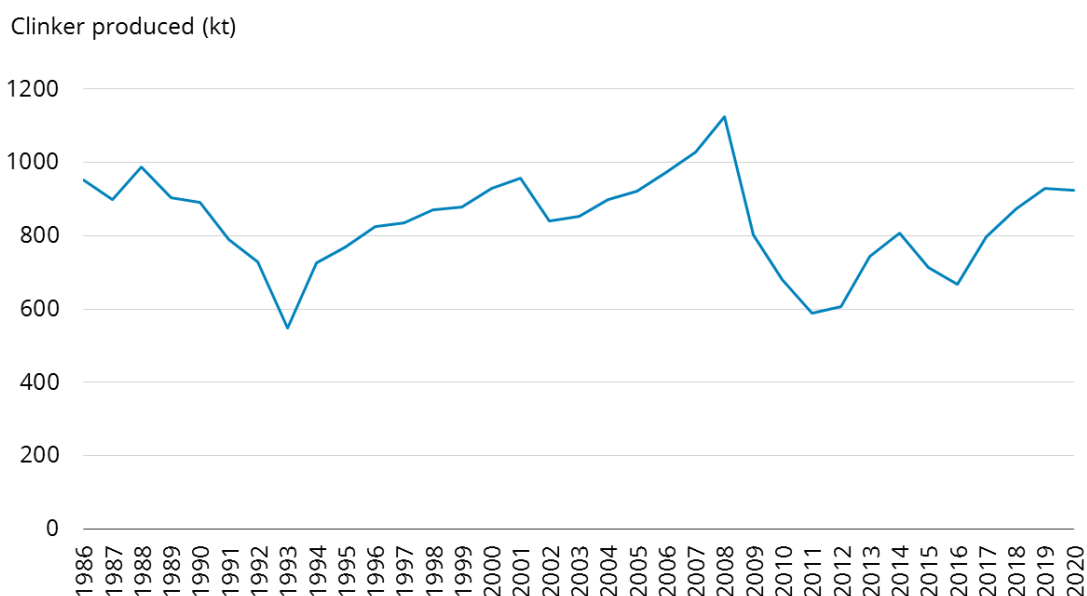
Year	Implied emission factor (t CO <sub>2</sub> /t of clinker)		
	Producer 1	Producer 2	TOTAL
1986 - 1998			0.528
1999	0.520	0.544	0.528
2000	0.518	0.544	0.528
2001	0.518	0.544	0.528
2002	0.518	0.544	0.527
2003	0.519	0.544	0.529
2004	0.517	0.541	0.527
2005	0.518	0.542	0.528
2006	0.517	0.539	0.526
2007	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

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<sub>2</sub> 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<sub>2</sub> emissions from CKD for 2019 and 2020 are included in the emission calculation for cement production and reported under the category Cement Production (CRF code: 2A1).

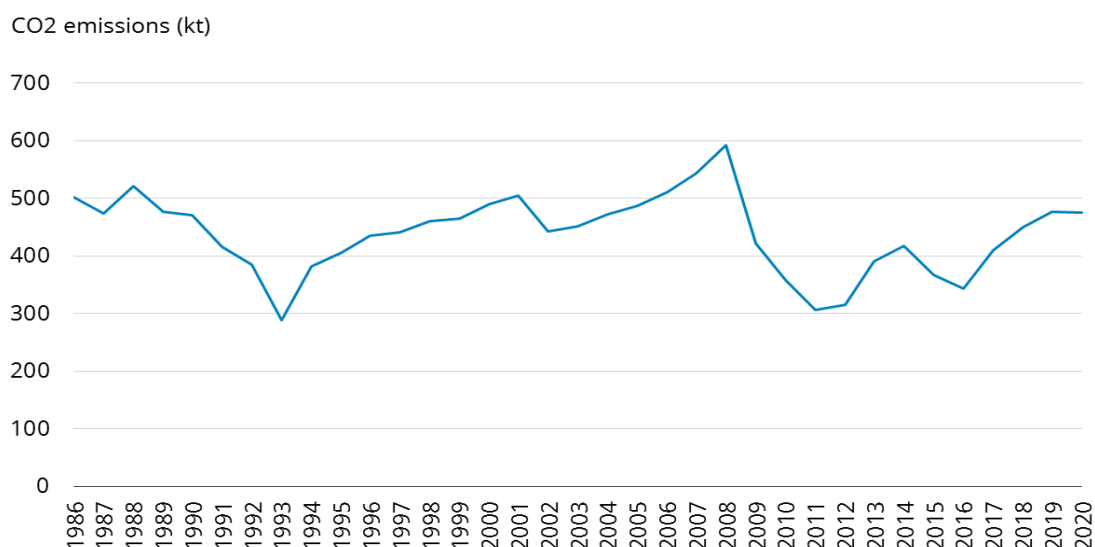
To calculate emissions from cement production after 2005 we have been using data obtained by ETS. The data on clinker production and plant specific emission factors for both cement factories have been annually verified by independent verifiers. The expert review team (ERT) recommended showing that the estimated CO<sub>2</sub> 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.

[https://www.gov.si/assets/organi-v-sestavi/ARSO/Podnebne-spremembe/Porocilo\\_o\\_izpolnitvi\\_obveznosti\\_za\\_leto\\_2020.pdf](https://www.gov.si/assets/organi-v-sestavi/ARSO/Podnebne-spremembe/Porocilo_o_izpolnitvi_obveznosti_za_leto_2020.pdf)

The annual amount of clinker produced and CO<sub>2</sub> emissions arising from cement production are shown in Figures 4.2.1 and 4.2.2.



**Figure 4.2.1: Clinker production in kilotons/year.**



**Figure 4.2.2: CO<sub>2</sub> 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 2020 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 2020 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 (CRF 2.A.2)

#### 4.2.2.1 Category descriptions

CO<sub>2</sub> emissions from the production of lime are reported under Lime Production (CRF 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 2020 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<sub>2</sub>.

#### 4.2.2.2 Methodological issues

#### CARBON DIOXIDE EMISSIONS

The estimation of CO<sub>2</sub> emissions for the period 2005-2020 has been based on the data provided by the lime plants in the scope of ETS scheme delivered in verified ETS reports.

**Table 4.2.2: Lime production emissions from producer 1.**

Year	CaO (t)	MgO (t)	EF (t CO <sub>2</sub> /t CaO)	EF (t CO <sub>2</sub> /t MgO)	Emissions CO <sub>2</sub> (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

**Table 4.2.3: Lime production emissions from producer 2.**

Year	CaO (t)	MgO (t)	EF (t CO <sub>2</sub> /t CaO)	EF (t CO <sub>2</sub> /t MgO)	Emissions CO <sub>2</sub> (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

**Table 4.2.4: Lime production emissions from producer 3.**

Year	CaCO <sub>3</sub> (t)	EF (t CO <sub>2</sub> /t CaCO <sub>3</sub> )	Emissions CO <sub>2</sub> (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 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<sub>2</sub> and CaO, CO<sub>2</sub> and MgO or CO<sub>2</sub> and CaCO<sub>3</sub>.

An annual implied emission factor was then calculated from the total CO<sub>2</sub> 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).

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<sub>2</sub> 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<sub>2</sub> emissions of all three producers, total lime production and calculated implied emission factor for the last few years.**

Year	2005	2010	2015	2016	2017	2018	2019	2020
Lime Produced (t)	165125	125117	79507	80060	77591	81214	75777	75638
Total emissions CO <sub>2</sub> (t)	121346	90248	60001	60591	58415	61207	56723	56554
Implied emission factor (kg CO <sub>2</sub> /t of lime)	735	721	755	757	753	754	749	748

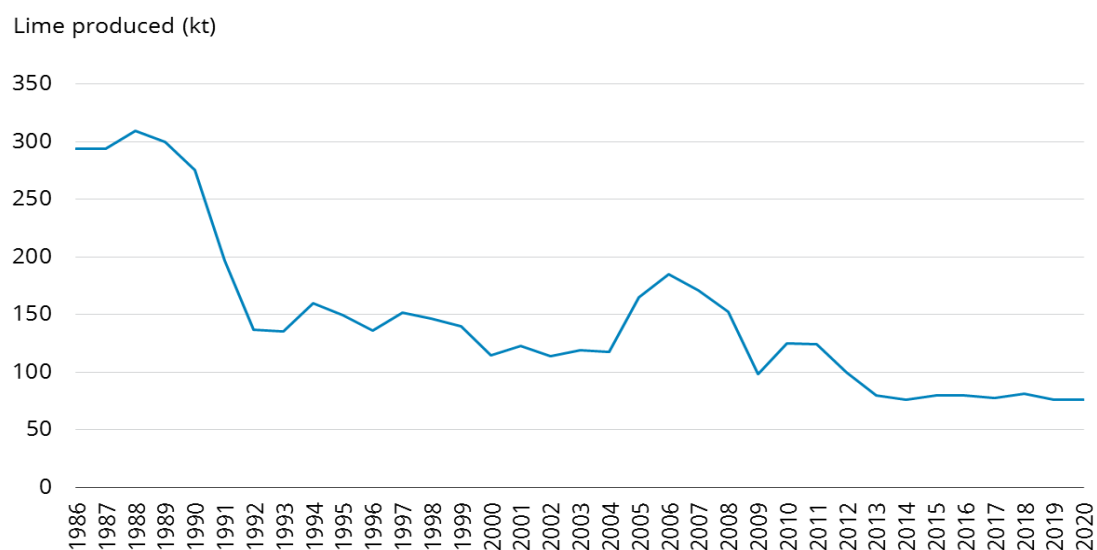
CO<sub>2</sub> emissions for the period 1986-2004 have been calculated using the average implied emission factor for the period 2005–2012 and data on annual production of lime obtained from SORS. The average emission factor for the period 2005–2012 is 728 kg CO<sub>2</sub> /t of lime. Data on implied 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 <sub>2</sub> /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

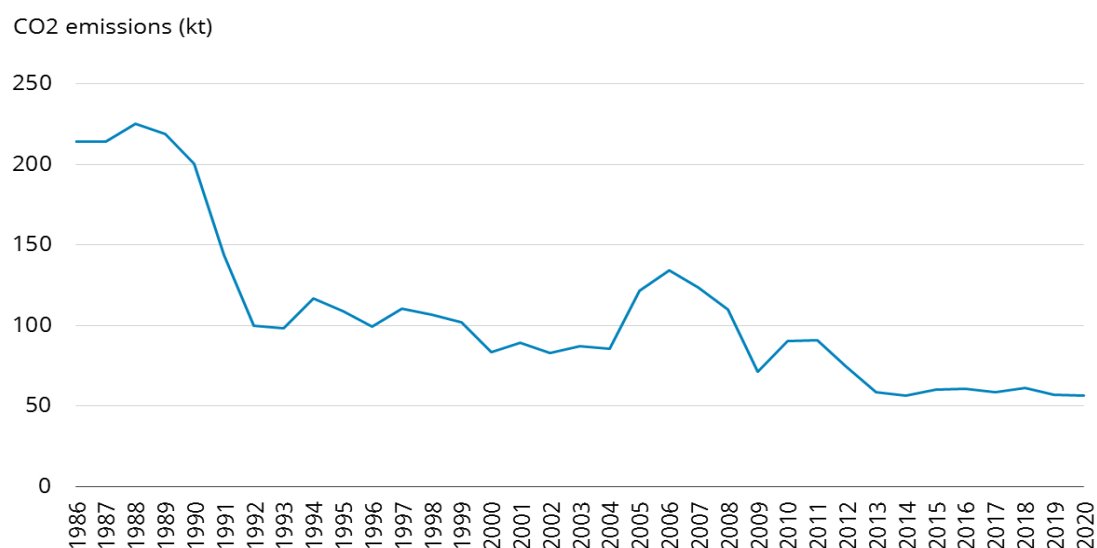
The limestone used for lime production contains mostly CaCO<sub>3</sub>. In the limestone there is also a small amount of dolomite, which, in addition to CaCO<sub>3</sub>, consists also of MgCO<sub>3</sub>. A high-calcium lime is the main type of lime. Quicklime and hydrated lime are the main types of 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<sub>2</sub> emissions.



**Figure 4.2.3: Lime production in kilotons/year.**

The annual amount of lime produced and CO<sub>2</sub> emissions arising from the lime production are shown in Figures 4.2.3 and 4.2.4.



**Figure 4.2.4: CO<sub>2</sub> 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 2020 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 2020 was therefore 1.74%.

#### **4.2.2.1 Category-specific QA/QC and verification**

QC procedures for the three lime plants data collected under the ETS have been performed. In the year 2020 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.

#### **4.2.2.2 Category-specific recalculations**

No recalculations have been performed since the last submission.

#### **4.2.2.3 Category-specific planned improvements**

No improvements are planned for the next submission.

## 4.2.3 Glass Production (CRF 2.A.3)

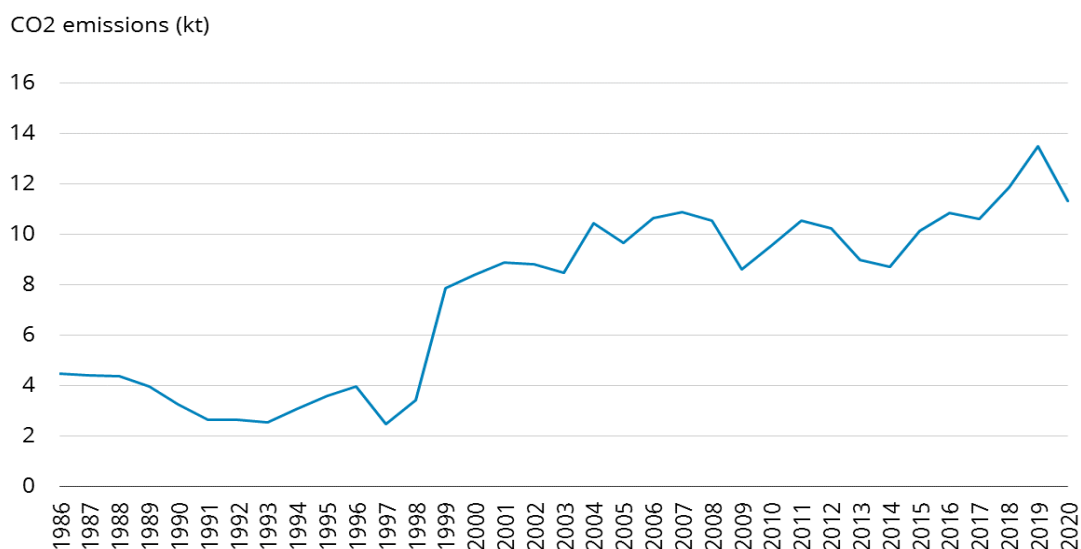
### 4.2.3.1 Category description

This chapter comprises CO<sub>2</sub> 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 (CRF Code: 2A3). There are five glass and glass wool producers in Slovenia.

CO<sub>2</sub> is emitted during the melting process of glass raw materials. The calcination of carbonates at high temperatures yields CO<sub>2</sub>. Major raw materials in glass production which emit CO<sub>2</sub> during the melting process are limestone, dolomite and soda ash.

### 4.2.3.2 Methodological issues

CO<sub>2</sub> emissions from glass production for the period 1999-2020 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<sub>3</sub>), magnesium carbonate (MgCO<sub>3</sub>), soda ash (Na<sub>2</sub>CO<sub>3</sub>), potash (K<sub>2</sub>CO<sub>3</sub>) and barium carbonate (BaCO<sub>3</sub>).



**Figure 4.2.5: CO<sub>2</sub> emissions from glass production.**

Default 2006 IPCC emission factors have been used for the calculation of CO<sub>2</sub> 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<sub>2</sub>/t calcium carbonate, 0.52197 t CO<sub>2</sub>/t magnesium carbonate and 0.41492 t CO<sub>2</sub>/t sodium carbonate.

The emission factors for potassium carbonate and barium carbonate are based on the stoichiometric ratio of CO<sub>2</sub> and K<sub>2</sub>CO<sub>3</sub> and CO<sub>2</sub> and BaCO<sub>3</sub>. They are 0.318 t CO<sub>2</sub>/t potassium carbonate and 0.223 t CO<sub>2</sub>/t barium carbonate.

The calculation of CO<sub>2</sub> 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<sub>2</sub> 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 lower 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<sub>2</sub>. 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 (CRF code: 2A4a), Other Uses of Soda Ash (CRF Code: 2A4b) and Other (CRF Code: 2A4d). CRF Code: 2A4d, Other comprises emissions from mineral wool production.

### 4.2.4.2 Methodological issues

#### Ceramics

Ceramics include the production of bricks and roof tiles, household ceramics, sanitary ware and technical ceramics. Process related CO<sub>2</sub> emissions from ceramics result from the calcination of carbonates in the clay, as well as the addition of carbonate additives.

CO<sub>2</sub> emissions for the period 2005-2020 have been calculated from the use of CaCO<sub>3</sub>, MgCO<sub>3</sub> and BaCO<sub>3</sub> 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<sub>2</sub> emissions from calcium carbonate and magnesium carbonate. They are 0.43971 t CO<sub>2</sub>/t calcium carbonate and 0.52197 t CO<sub>2</sub>/t magnesium carbonate. The emission factor for barium carbonate is based on the stoichiometric ratio of CO<sub>2</sub> and BaCO<sub>3</sub>. It is 0.223 t CO<sub>2</sub>/t barium carbonate.

CO<sub>2</sub> 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.

Estimated emission for 1995 was applied for the period 1986-1994 as well due to a lack of data on carbonate consumption and a statistical parameter which was used for the emission estimation for the period 1995-2004.

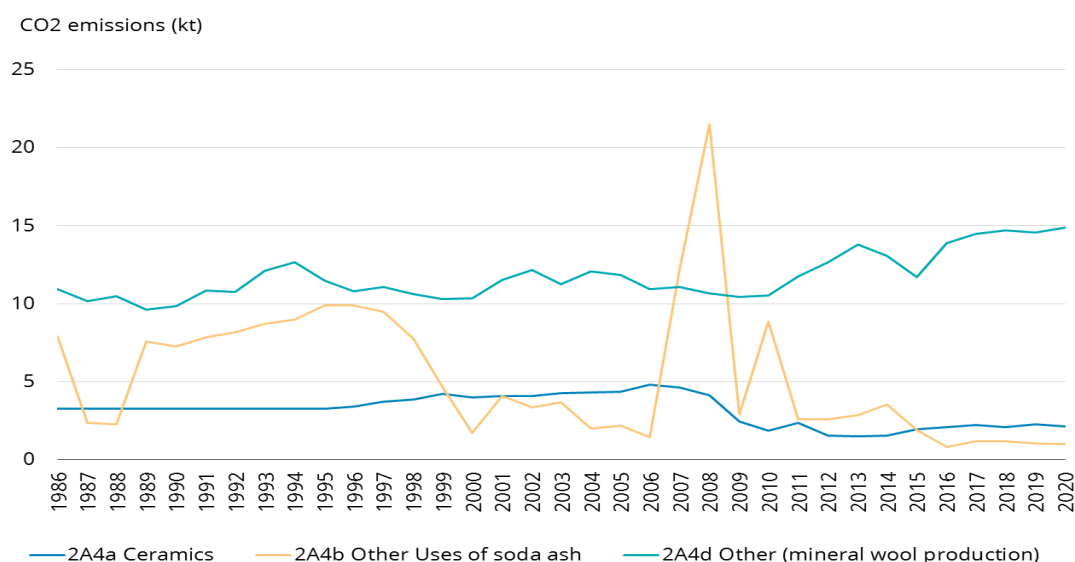
#### Other Uses of Soda Ash

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 (CRF Code: 2A3).

CO<sub>2</sub> emissions for the period 1986-2020 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 1998-2020 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<sub>2</sub> emissions for the whole period (0.41492 t CO<sub>2</sub>/t Na<sub>2</sub>CO<sub>3</sub>).

### Other

This sector comprises CO<sub>2</sub> emissions arising from mineral wool production. Dolomite is used as a raw material in mineral wool production. The activity data have been obtained from the producer of mineral wool used for insulation purposes. The default 2006 IPCC emission factor 0.47732 t CO<sub>2</sub>/t dolomite has been used for the whole period 1986-2020.



**Figure 4.2.6: CO<sub>2</sub> emissions from other process uses of carbonates.**

Figure 4.2.6 shows CO<sub>2</sub> emissions from ceramics, other uses of soda ash and mineral wool production.

### 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 2020 the data on uncertainties from the ETS has been used in combination of uncertainties from 2006 IPCC 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 a survey 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.

#### **4.2.4.5 Category-specific recalculations**

No recalculations were performed since the last submission.

#### **4.2.4.6 Category-specific planned improvements**

Considering UNFCCC ERT's recommendation we will try to estimate CO<sub>2</sub> emissions from ceramics for the period 1990-1994 in another way as they are estimated in the present submission.



## **4.3 CHEMICAL INDUSTRY (CRF 2.B)**

### **4.3.1 Nitric Acid Production (CRF 2.B.2)**

#### **4.3.1.1 Category description**

The production of nitric acid ( $\text{HNO}_3$ ) generates nitrous oxide ( $\text{N}_2\text{O}$ ) as a by-product of the high temperature catalytic oxidation of ammonia ( $\text{NH}_3$ ).  $\text{N}_2\text{O}$  emissions from nitric acid production are reported under Nitric Acid Production (CRF 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  $\text{N}_2\text{O}$  have originated from this sector since 2006.  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$ /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 (CRF 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<sub>2</sub>). The production of carbide can result in emissions of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). 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<sub>2</sub> and CH<sub>4</sub> emissions from carbide production are reported under Carbide Production (CRF 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<sub>2</sub> is released as a by-product. CO<sub>2</sub> emissions had been estimated for the period 1986-1994. From 1995 onwards there has been no production of silicon carbide in Slovenia. CO<sub>2</sub> 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<sub>2</sub>/t petroleum coke had been used for the CO<sub>2</sub> emission calculations.

The petroleum coke used in the process may contain volatile compounds which will form methane. CH<sub>4</sub> 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<sub>4</sub>/t petroleum coke had been used for the CH<sub>4</sub> emission calculations.

#### Calcium carbide production

Calcium carbide (CaC<sub>2</sub>) is produced by heating calcium carbonate and subsequently reducing CaO with carbon (petroleum coke). Both steps lead to emissions of CO<sub>2</sub>. In Slovenia, calcium carbide was not produced from limestone but from lime, hence CO<sub>2</sub> emissions arose only in the reduction with carbon.

CO<sub>2</sub> 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<sub>2</sub> emissions had been calculated from the amount of calcium carbide produced. The data on CaC<sub>2</sub> production was obtained from the carbide producer. The 2006 IPCC

emission factor of 1.09 t CO<sub>2</sub>/t calcium carbide produced had been used for the CO<sub>2</sub> emission calculations.

To avoid double counting of CO<sub>2</sub> 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 (CRF 2.B.6)**

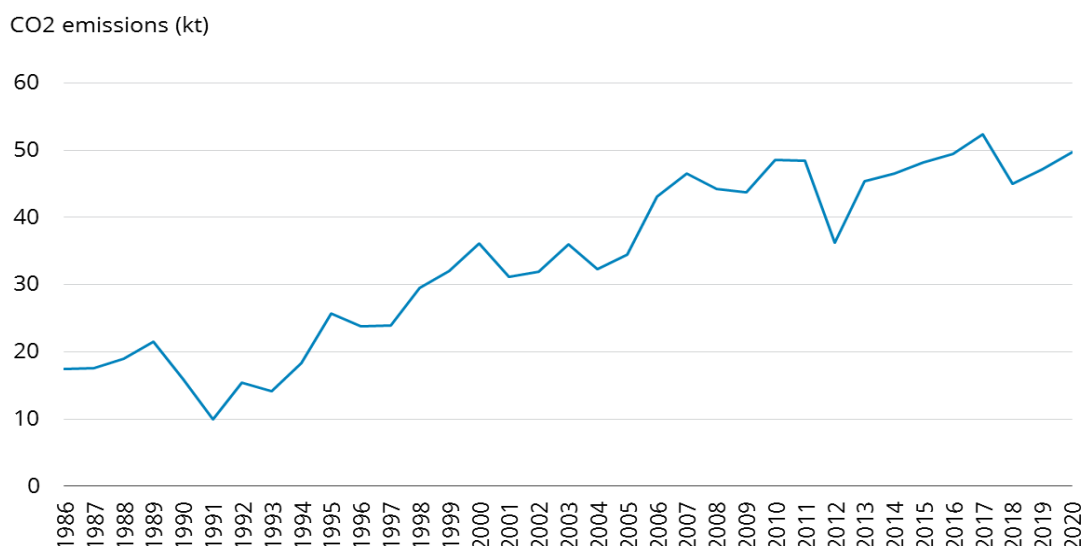
#### **4.3.3.1 Category description**

Titanium dioxide (TiO<sub>2</sub>) 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<sub>2</sub>. The production of TiO<sub>2</sub> is based on the sulphate route process. The CO<sub>2</sub> emissions from titanium dioxide production are reported under Titanium Dioxide Production (CRF 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<sub>2</sub> limestone has been used for the neutralization of sulphuric acid used in sulphate process. The use of limestone is a source of CO<sub>2</sub> emissions.

CO<sub>2</sub> emissions have been estimated for the period 1986-2020. The CO<sub>2</sub> emissions have been calculated from the amount of calcium carbonate consumed. The data on the consumption of CaCO<sub>3</sub> has been provided by the producer. The 2006 IPCC emission factor of 0.43971 t CO<sub>2</sub>/t of calcium carbonate has been used for the CO<sub>2</sub> emission calculations for the whole period (Figure 4.3.1).



**Figure 4.3.1: CO<sub>2</sub> 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 (CRF 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<sub>4</sub> and CO<sub>2</sub> emissions from methanol production are reported under the subcategory Methanol (CRF code: 2B8a).

##### **4.3.4.2 Methodological issues**

CH<sub>4</sub> and CO<sub>2</sub> 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<sub>4</sub> and CO<sub>2</sub> 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<sub>4</sub>/t methanol produced and 0.267 t CO<sub>2</sub>/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 (CRF 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<sub>2</sub> is produced and capture with 70% efficiency and then sold to the other users. However, this CO<sub>2</sub> 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**

Data on non-energy use of natural gas have been obtained from SORS. In addition to the amount use for hydrogen production, a very small amount was used also for the production of organic chemical and some other productions. Due to completeness reason emissions from these source have been also included in this category.

Due to the unavailability of methodology in the 2006 IPCC GL, CO<sub>2</sub> emissions are calculated using the same approach as for combustion emission using the same NCV and CO<sub>2</sub> EF as in the energy sector and are available in the Table 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<sub>2</sub> emission factor amounts to 2.5% in 1986 and 0.5 in 2020.

#### **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.

#### **4.3.5.5 Category-specific recalculations**

No recalculations were performed since the last submission.

#### **4.3.5.6 Category-specific planned improvements**

We will investigate the methodology for determination of CO<sub>2</sub> emissions from steam reforming which is described in the IPCC 2019 Refinement and will recalculate emissions for the next submission, if relevant.

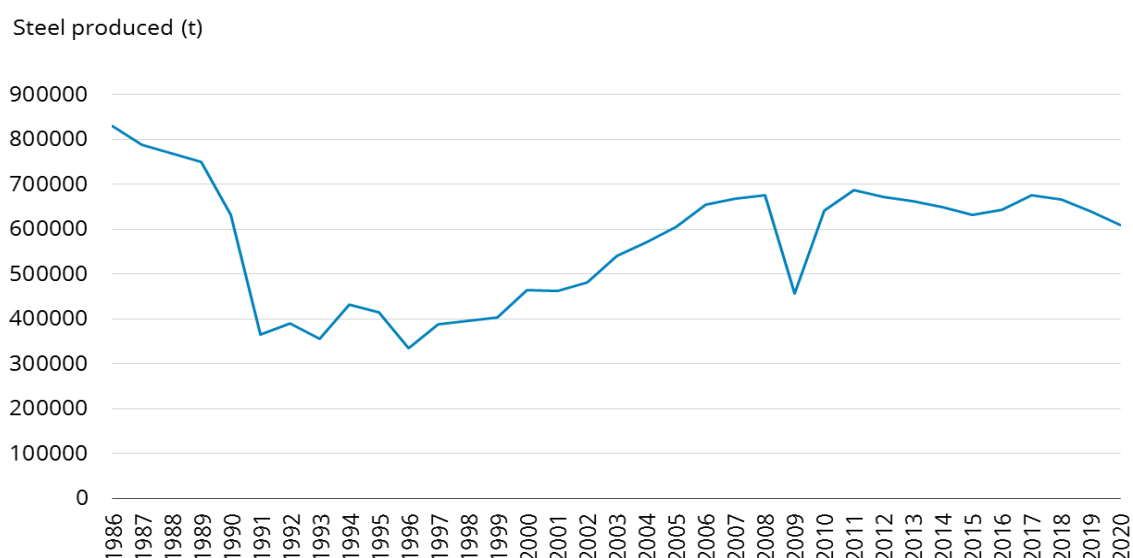
## 4.4 METAL PRODUCTION (CRF 2.C)

### 4.4.1 Iron and Steel Production (CRF 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<sub>2</sub> 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<sub>2</sub>. 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<sub>2</sub> emissions take place as a result of graphite electrode consumption in the EAF. CO<sub>2</sub> emissions originate also in the consumption of limestone and dolomite and carbon containing additives. In Slovenia, there are three steel production plants.

Following the 2018 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<sub>4</sub> emissions from pig iron production were not calculated since 2006 IPCC Guidelines do not provide CH<sub>4</sub> emission factor for this type of production process.

CO<sub>2</sub> emissions from iron and steel production are reported under Iron and Steel Production (CRF code: 2C1). The annual amount of steel produced is shown in Figure 4.4.1.

#### **4.4.1.2 Methodological issues**

CO<sub>2</sub> emissions from iron production were calculated for the years 1986 and 1987. CO<sub>2</sub> 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 calculated from carbon content data obtained from the 2006 IPCC Guidelines. The emission factor applied was 0.146 t CO<sub>2</sub>/t pig iron produced.

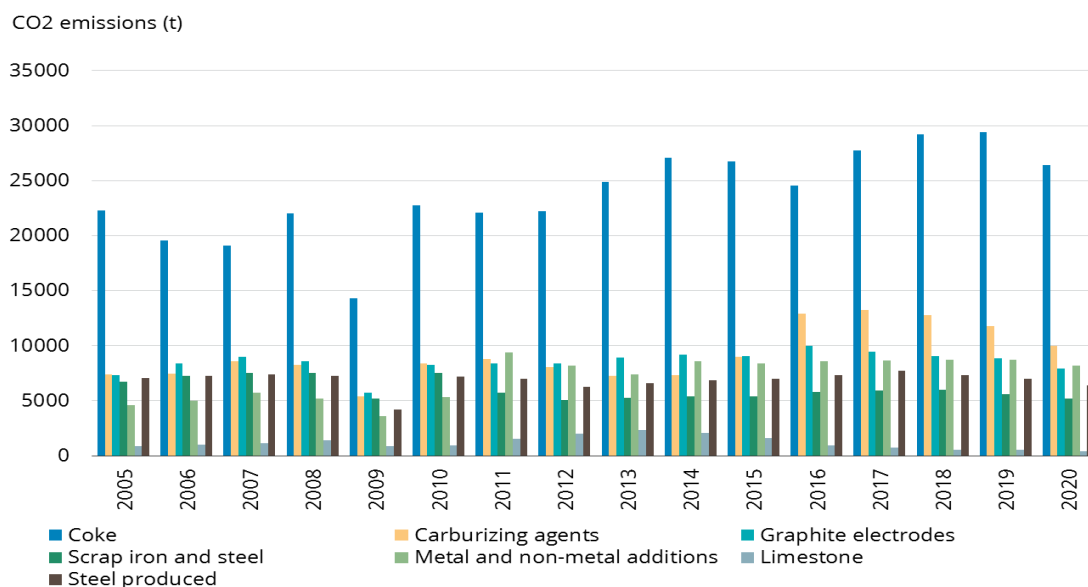
The CO<sub>2</sub> emissions from steel production for the period 2005-2020 have been calculated from the amount and carbon content of input and output materials. In our case, the input materials were mostly graphite electrodes, coke, carburizing agents, scrap iron and steel, metal and non-metal additions, 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<sub>2</sub> emissions contributed by the different input materials and steel produced for 2005-2020.

The calculation of CO<sub>2</sub> 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 - 2020 all coke consumption is included in the



industrial processes sector. The CO<sub>2</sub> 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<sub>2</sub>/t carbon electrodes.



**Figure 4.4.2: CO<sub>2</sub> 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

Considering the 2018 UNFCCC ERT recommendation we will try to recalculate CO<sub>2</sub> emissions from pig iron production for 1986 and 1987 due to potential overestimation.

### 4.4.2 Ferroalloys Production (CRF 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<sub>2</sub> and CH<sub>4</sub> emissions from ferroalloy production are reported under Ferroalloys Production (CRF code: 2C2).

#### 4.4.2.2 Methodological issues

CO<sub>2</sub> emissions had been estimated for the period 1986-2008. From 2009 onwards there was no production of ferroalloys in Slovenia. The CO<sub>2</sub> 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<sub>2</sub> emission calculations. These were 3.3 t CO<sub>2</sub>/t coke, 3.5 t CO<sub>2</sub>/t petroleum coke and 3.4 t CO<sub>2</sub>/t electrodes.

CH<sub>4</sub> emissions had been estimated for the period 1986-2008 as well. The CH<sub>4</sub> 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<sub>4</sub> emission calculations. These were 1.2 kg CH<sub>4</sub>/t Si-metal and 1.1 kg CH<sub>4</sub>/t FeSi 65-75.

The trend in the CO<sub>2</sub> 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 (CRF 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<sub>2</sub> 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<sub>2</sub> emissions. The CO<sub>2</sub> 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 (CRF 2.C.3)

#### 4.4.3.1 Category description

Aluminium is produced in two phases. In the first phase alumina ( $\text{Al}_2\text{O}_3$ ) 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  $\text{CO}_2$ , 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 ( $\text{CF}_4$ ) and hexafluoroethane ( $\text{C}_2\text{F}_6$ ) 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 Söderberg 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.

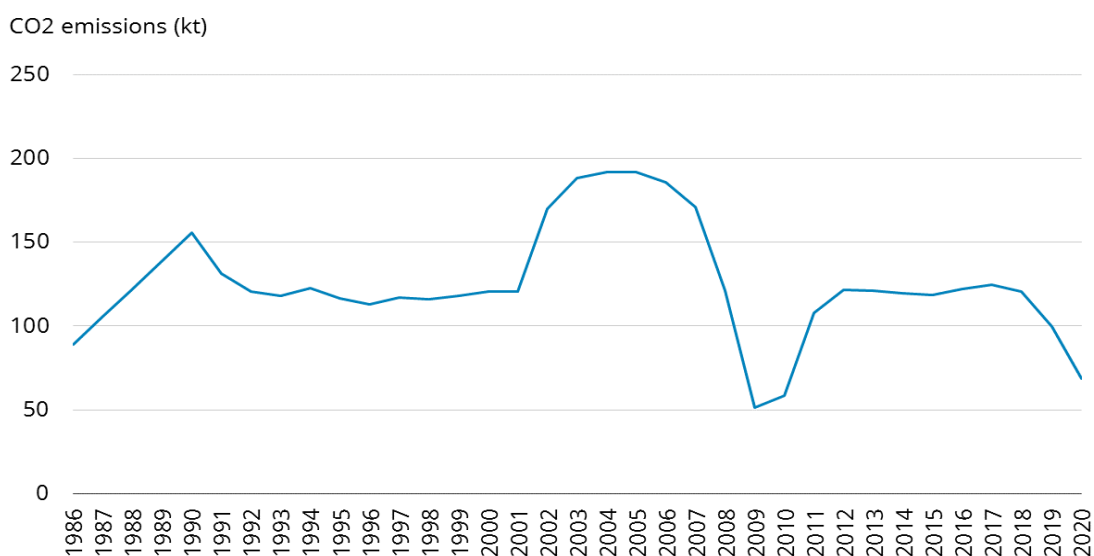
In 2002, upgrading the aluminium production that includes the construction of the second half of the electrolysis unit C with an annual production capacity of 40000 t of aluminium was carried out. Due to high costs for electricity used, the plant had to wind up the production in pot B in the end of 2007. 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 2020, the production of aluminium decreased considerably due to a global pandemic crisis.

The emissions of CO<sub>2</sub>, CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> from aluminium production are reported under Aluminium Production (CRF 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<sub>2</sub> emissions are submitted to the Slovenian Environment Agency by producer expert service on a regular basis.



**Figure 4.4.3: CO<sub>2</sub> emissions from aluminium production.**

CO<sub>2</sub> emissions from primary aluminium production are most precisely estimated from the consumption of anodes. The consumption of anodes in 2020 amounted to 0.377 t/ton

aluminium. The emission factor was 3.63 t CO<sub>2</sub>/ton anodes. The significant decline of CO<sub>2</sub> emissions in 2009 occurred due to lower aluminium production. In 2012, the production of aluminium increased considerably and CO<sub>2</sub> emissions reached pre-crises values. The same trend is observed for the following years. In 2020, the CO<sub>2</sub> emissions decreased considerably due to smaller aluminium production as a result of the unstable situation on markets due to the global pandemic crisis (Figure 4.4.3).

In 2020, electrolysis unit C with point feeding prebaked anode Pechiney technology was in operation.

The 2006 IPCC methodology is used for the CO<sub>2</sub> emission calculation.

$$ECO_2 = (MP \cdot NAC \cdot (100 - S - Ash) / 100) \cdot 44 / 12$$

ECO<sub>2</sub> = CO<sub>2</sub> emissions from prebaked anode consumption (t CO<sub>2</sub>)

MP = aluminium production (t)

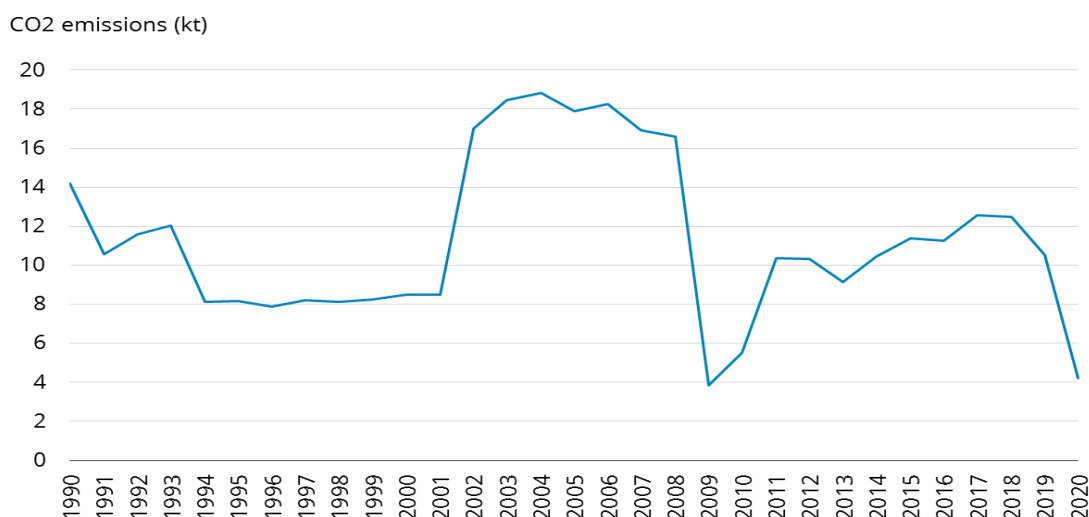
NAC = net prebaked anode consumption per tonne of aluminium (t C/t aluminium)

S = sulphur content in baked anodes (wt %)

Ash = ash content in baked anodes (wt %)

44/12 = CO<sub>2</sub> molecular mass/ carbon atomic mass ratio

This chapter comprises also CO<sub>2</sub> 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 (CRF code: 2C7).



**Figure 4.4.4: CO<sub>2</sub> emissions in the process of anode production.**

Two sources of CO<sub>2</sub> 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<sub>2</sub> 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).

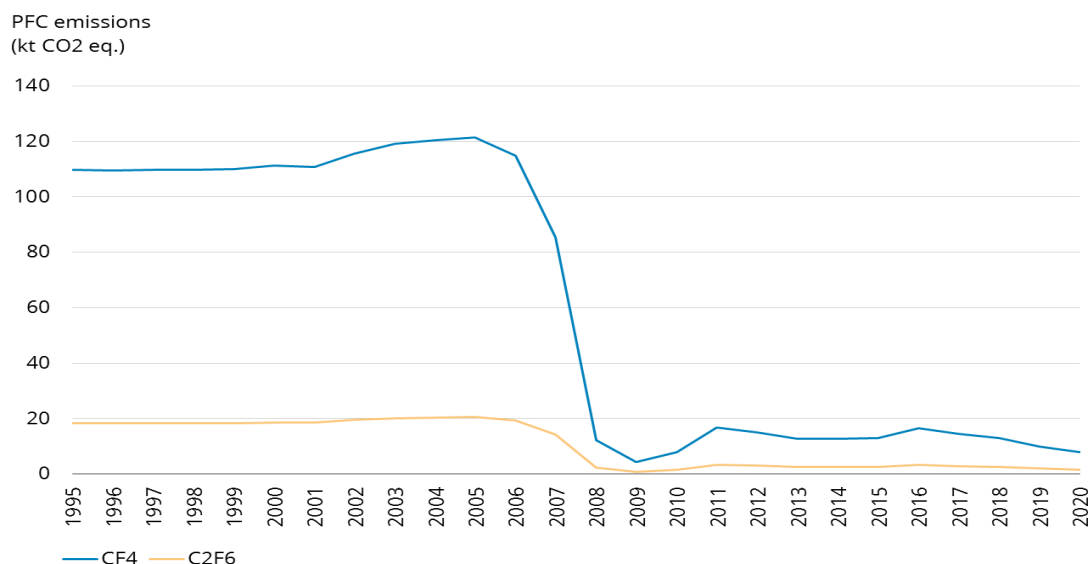
The emission factor for anode burn-off is a plant specific. Data on the amount of anodes, operational parameters and emissions of CO<sub>2</sub> are provided by the producer expert service. The CO<sub>2</sub> implied emission factor for 2020 is 3.18 t CO<sub>2</sub>/t anode burn-off. Figure 4.4.4 shows CO<sub>2</sub> emissions arising from anode burn-off in the process of anode production.

#### PFC emission

Data on emission calculations of tetrafluoromethane (CF<sub>4</sub>) and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>) 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<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emission factors from 1995 to 2020. The CF<sub>4</sub> emission factor has decreased from the base year 1995 till now from 0.2 kg CF<sub>4</sub>/ton Al to 0.02 kg CF<sub>4</sub>/ton Al and C<sub>2</sub>F<sub>6</sub> emission factor from 0.02 kg C<sub>2</sub>F<sub>6</sub>/ton Al in the base year to 0.003 kg C<sub>2</sub>F<sub>6</sub>/ton Al in 2020.

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 - 2020. 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<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> in aluminium production are shown in Figure 4.4.5.

In 2020, electrolysis unit C with point feeding prebaked anode Pechiney technology has been in operation.



**Figure 4.4.5: CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions in aluminium production.**

The 2006 IPCC methodology is used for CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emission calculation.

$$ECF_4 = MP \cdot OVC \cdot AEO/CE$$

$$EC_2F_6 = E_{CF_4} \cdot F_{C_2F_6/CF_4}$$

ECF<sub>4</sub> = emissions of CF<sub>4</sub> from aluminium production (kg CF<sub>4</sub>)

EC<sub>2</sub>F<sub>6</sub> = emissions of C<sub>2</sub>F<sub>6</sub> from aluminium production (kg C<sub>2</sub>F<sub>6</sub>)

OVC = Overvoltage coefficient for CF<sub>4</sub> ((kg CF<sub>4</sub>/tonne Al)/mV)

AEO = anode effect overvoltage (mV)

CE = aluminium production process current efficiency expressed (%)

MP = aluminium production (t)

F<sub>C<sub>2</sub>F<sub>6</sub>/CF<sub>4</sub></sub> = weight fraction of C<sub>2</sub>F<sub>6</sub>/CF<sub>4</sub>, kg C<sub>2</sub>F<sub>6</sub>/kg CF<sub>4</sub>

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<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emission factors.**

Technology	Unit	Emission factors
Electrolysis unit A, Soderberg, HSS	kg CF <sub>4</sub> /t	0.61
	kg C <sub>2</sub> F <sub>6</sub> /t	0.061
Electrolysis unit B, Soderberg, HSS, until 1987	kg CF <sub>4</sub> /t	0.61
	kg C <sub>2</sub> F <sub>6</sub> /t	0.061
Electrolysis unit B, reconstruction to PB, 1988	kg CF <sub>4</sub> /t	0.40
	kg C <sub>2</sub> F <sub>6</sub> /t	0.04
Electrolysis unit C, Pechiney, PFPB, until 2004	kg CF <sub>4</sub> /t	0.022
	kg C <sub>2</sub> F <sub>6</sub> /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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> and PFC emissions are compared with the verified emissions from ETS. Possible inconsistencies were consulted with the producers 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 (CRF 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<sub>2</sub> emissions from lead production are reported under Lead Production (CRF code: 2C5).

#### **4.4.4.2 Methodological issues**

CO<sub>2</sub> emissions have been estimated for the period 1986-2020. The CO<sub>2</sub> 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 2017-2020 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<sub>2</sub> emission calculations. These were 0.25 t CO<sub>2</sub>/t lead produced for primary production (1986-1988) and 0.2 t CO<sub>2</sub>/t lead produced for secondary lead production (1989-2020).

#### **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 (CRF 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<sub>2</sub> emissions from zinc production are reported under Zinc Production (CRF code: 2C6).

**4.4.5.2 Methodological issues**

CO<sub>2</sub> emissions have been estimated for the period 1986-2020. The CO<sub>2</sub> 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 2017-2020 were obtained from the producer. The 2006 IPCC emission factor of 1.72 t CO<sub>2</sub>/t zinc produced has been used for the CO<sub>2</sub> 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 PRODUCTS FROM FUELS AND SOLVENT USE (CRF 2.D)

### 4.5.1 Lubricant use (CRF 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<sub>2</sub> emissions from lubricant use are reported under Lubricant Use (CRF code: 2D1).

#### 4.5.1.2 Methodological issues

CO<sub>2</sub> emissions have been estimated for the period 1986-2020. 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 5.5.1) 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<sub>2</sub> emissions for the whole period 1986-2019 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.5.1) 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<sub>2</sub> 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 (CRF 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<sub>2</sub> emissions from paraffin wax use are reported under Paraffin Wax Use (CRF code: 2D2).

### **4.5.2.2 Methodological issues**

CO<sub>2</sub> emissions for the period 2000-2020 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 (CRF 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<sub>2</sub> emissions from the use of urea-based additives in catalytic converters. The emissions from these sources are reported under the category Other (CRF 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 (diluent 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<sub>2</sub> 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 1990-2020. Detailed information about the methodologies used is described in the Slovenian Informative Inventory Report 2022 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 2022: Informative inventory report \(IIR 2022\) \(europa.eu\)](#)

##### CO<sub>2</sub> emissions

This chapter comprises CO<sub>2</sub> emissions from the use of urea-based additives in catalytic converters in road transport. After treatment systems used to reduce NO<sub>x</sub> 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<sub>2</sub> are formed by the reaction. The CO<sub>2</sub> emissions have been calculated for the period 2006 -2020. The CO<sub>2</sub> emissions have been estimated with COPERT 5 methodology. The methodology is fully incorporated in the computer software program COPERT 5 (version 5.5.1) 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<sub>2</sub> emissions for the period 2006-2019 was performed due to changes in CO<sub>2</sub> 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 5.5.1) 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<sub>2</sub> 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 (CRF 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
<b>Refrigeration and AC equipment</b>		
- 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
<b>Foam blowing</b>		
- hard foam - production	1995-2005	HFC-134a
- hard foam - use	Since 1995	HFC-134a
- soft foam	1995-1998	HFC-134a
<b>Fire extinguishers</b>	Since 1997	HFC-227ea
<b>Aerosols and meter dose inhalers</b>	Since 2001	HFC-134a

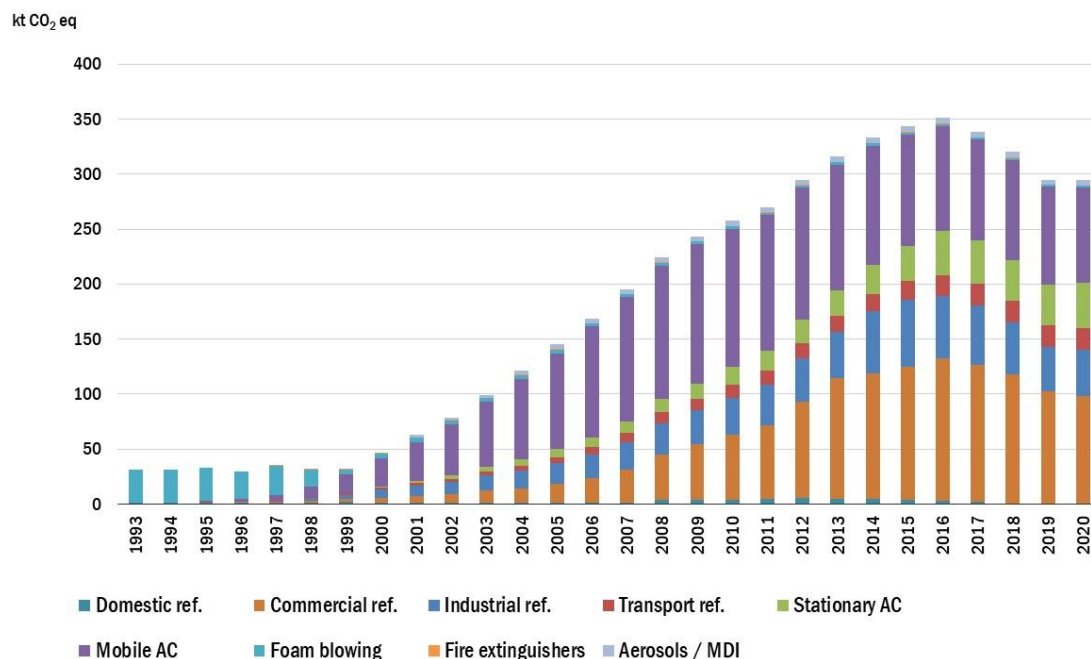
HFCs began to be used in Slovenia in 1993 as a substitute for CFCs, which are ozone-depleting substances. They asserted themselves in particular in those fields where no other, more appropriate alternatives (e.g. hydrocarbons, CO<sub>2</sub> etc.) were available.

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 2020 was Commercial refrigeration with contribution of 33.1%. Mobile Air-Conditioning was the second most important source in 2020, 29.3% 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 2020 was by 31.9% lower than in 2009, 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 1<sup>st</sup> 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<sub>2</sub> 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)

$$E_t = E_{\text{assembly, } t} + E_{\text{operation, } t} + E_{\text{disposal, } t}$$

where:

$$E_{\text{assembly, } t} = E_{\text{charge, } t} * (k/100)$$

$E_{\text{assembly, } t}$  = Emissions during system manufacture/assembly in year t

$E_{\text{charge, } t}$  = The amount of F-gas charged into new systems in year t

k = Production/assembly losses (%)

$$E_{\text{operation, } t} = E_{\text{stock, } t} * (x/100)$$

$E_{\text{operation, } t}$  = Amount of F-gas emitted during system operation in year t

$E_{\text{stock, } t}$  = 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)

$$E_{\text{disposal, } t} = E_{\text{consumption (t-n)}} * (y/100)$$

$E_{\text{disposal, } t}$  = Amount of F-gas emitted at disposal in year t

$E_{\text{consumption (t-n)}}$  = 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 isobutane 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 (isobutane). 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 10 years for medium and large appliances. Product lifetime for industrial refrigerators is 25 years, hence the disposal emissions in 2020 did not exist, yet.

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. We have no evidence on the new location of this vehicles but unofficial information is that they are sold abroad – mostly to the former Yugoslavian republic. In Slovenia there is no centre for decommissioning of spent trucks and buses therefore no transport refrigerators can be legally disposed in the country.

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 – 2019. 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 overestimation. Emissions due to the accidents have been estimated to be between 1.3 and 1.9 kt CO<sub>2</sub> 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.

#### 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 2020, 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 <sub>2</sub> eq)
<b>Domestic refrigeration</b> Range from 2006 IPCC GL	1 0.2 - 1	0.5 0.1 - 0.5	15 12 - 20	70 0 - 70	85 0 - 80	0.2
<b>Commercial refrigeration</b> Stand alone Range from 2006 IPCC GL	3 0.5 - 3	8 1 - 15	12 10 - 15	70 0 - 70	40 0 - 80	97.7
Medium and large Range from 2006 IPCC GL	3 0.5 - 3	25* 10 - 35	15 7 - 15	70 0 - 70	75 50 - 100	
<b>Industrial refrigeration</b> Range from 2006 IPCC GL	3 0.5 - 3	16* 7 - 25	25 15 - 30	NO 0 - 90	NO 50 - 100	42.1
<b>Transport refrigeration</b> Range from 2006 IPCC GL	NO 0.1 - 1	30 15 - 50	NA 6 - 9	NO 0 - 70	NO 0 - 50	20.0
<b>Stationary Air Conditioning</b> Range from 2006 IPCC GL	0.6 0.2 - 1	1 - 10* 1 - 10	15 10 - 20	80 0 - 80	40 0 - 80	41.6
<b>Mobile Air Conditioning</b> Range from 2006 IPCC GL	0.5 0.5	10 10 - 20	15 9 - 16	50 0 - 50	25 0 - 50	86.4

*Note: Since 2015 EFs indicated with \* are not used for calculation any more*

Recovery

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**Hard Foam

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<sub>2</sub> and pentane have been used as blowing agents, while flammable hydrocarbons (propane, butane...) have been used for PU OCF.

Soft Foam

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 evidence of F-gases used in fire extinguishers in our database is incomplete, because not all enterprises are aware of this reporting obligation. Generally used fire extinguishing agents include dust, CO<sub>2</sub>, or water. Halon systems were replaced by HFC.

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 present submission 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 for replacement of gas which was released during the firefighting. For this reason, amount filled in the installations in particular year is the same as emitted amount from the use.

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. The EF from the 1<sup>st</sup> 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.

### 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. 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 CRF category have been compared with the emissions from neighbouring countries

#### 4.6.5 Category-specific recalculations

##### 2.F.1 Product uses as a substitute for ODS/ Refrigeration and air-conditioning, HFC

For the period 2015 to 2019 an error in the calculation have been corrected: emissions from the heat pump disposal have not been included in the previous submission by mistake.

##### 2.F.4 Product uses as a substitute for ODS/ Aerosol, HFC 134a

Data on HFC used in the MDIs in 2019 has been updated and corresponding emissions of HFC 134a in 2019 have been recalculated.

#### 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.

In the next submission the incorrect data on number of transport refrigerators in 2018 will be corrected and emissions will be recalculated.

## 4.7 Other Product Manufacture and Use (CRF 2.G)

### 4.7.1 Electrical equipment (CRF 2.G.1)

#### 4.7.1.1 Category description

SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> in equipment.

**Table 4.7.1: SF<sub>6</sub> emissions in high-voltage equipment.**

Emissions from	Units	1986	1990	1995	2000	2005	2010	2015	2020
manufacturing	kg	0.1	0.0	0.9	1.4	2.6	2.3	1.2	0.8
stock	kg	428.4	431.1	481.2	657.1	786.7	746.6	725.8	697.7
disposal	kg	-	-	-	-	-	-	0.3	-
<b>Total SF<sub>6</sub> emissions</b>	<b>kg</b>	<b>428.5</b>	<b>431.1</b>	<b>482.1</b>	<b>658.5</b>	<b>789.3</b>	<b>748.9</b>	<b>727.2</b>	<b>698.5</b>
<b>Total SF<sub>6</sub> emissions</b>	<b>Gg CO<sub>2</sub> eq</b>	<b>9.8</b>	<b>9.8</b>	<b>11.0</b>	<b>15.0</b>	<b>18.0</b>	<b>17.1</b>	<b>16.6</b>	<b>15.9</b>

#### 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<sub>6</sub> 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 from 2006 IPCC GL, where  $\text{Total } E_{\text{emissions}} = \sum E_{\text{manufacturing},t} + \sum E_{\text{installation},t} + \sum E_{\text{use},t} + \sum E_{\text{recycling},t}$

Manufacturing emissions do not exist 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<sub>6</sub> used to fill the new equipment.

The emissions due to the use of the equipment are determined by the amount of SF<sub>6</sub> used to maintain the equipment. SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> is fully recovered from the retiring equipment and it is their estimate that a leakage is less than 0.1%. Experts justify such a low factor with an extremely high gas price.

When calculating SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> and PFCs from other product use (CRF 2.G.2)**

### **4.7.2.1 Category description**

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<sub>6</sub> for soundproof windows in Slovenia. According to the Regulation on certain fluorinated greenhouse gasses, placing of double glazed windows filled with SF<sub>6</sub> 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>

### **4.7.2.2 Methodological issues**

The amount of SF<sub>6</sub> 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 emissions calculation 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**

No recalculations have been performed for this category.

### **4.7.2.6 Source-specific planned improvements**

No improvements are planned for the next submission.

### 4.7.3 N<sub>2</sub>O from Product Uses (CRF 2.G.3)

#### 4.7.3.1 Category description

Evaporative emissions of nitrous oxide (N<sub>2</sub>O) 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 CRF code 2G3a: N<sub>2</sub>O from Medical Applications, since the largest application of N<sub>2</sub>O in Slovenia arising from the use in health service.

N<sub>2</sub>O emissions from CRF code 2G3b: Other are reported as IE. CRF code 2G3b covers the use of N<sub>2</sub>O as a propellant in aerosol products in the food industry. The emissions from that category are included under CRF code 2G3a.

#### 4.7.3.2 Methodological issues

N<sub>2</sub>O emissions have been estimated for the period 1986-2020. N<sub>2</sub>O emissions have been calculated from the amount of nitrous oxide used. Data on N<sub>2</sub>O consumption for the period 1999-2020 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<sub>2</sub>O /t have been used for the emission calculations. Figure 4.7.1 shows N<sub>2</sub>O emissions arising product uses.

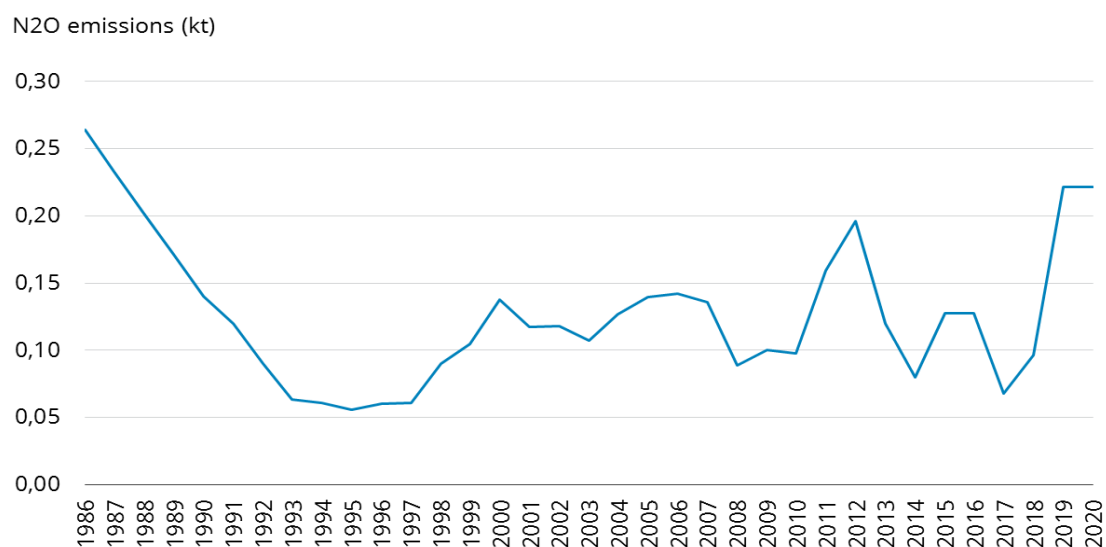


Figure 4.7.1: N<sub>2</sub>O emissions from product uses.

#### **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**

Emissions of N<sub>2</sub>O have been recalculated for the year 2019 due to new activity data obtained by the Statistical Office of the Republic of Slovenia.

#### **4.7.3.6 Category-specific planned improvements**

No improvements are planned for this category.

## 5 AGRICULTURE (CRF 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<sub>4</sub> emissions from livestock and manure management, N<sub>2</sub>O emissions from manure management (direct and indirect emissions) and from managed agricultural soils (direct and indirect emissions) as well as CO<sub>2</sub> 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 2020 in the Agriculture sector.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Method	EF	Key cat	Method	EF	Key cat	Method	EF	Key cat
<b>3.A Enteric Fermentation</b>	NA	NA	NA	T1, T2	CS, D	L, T	NA	NA	NA
<b>3.B Manure Management</b>	NA	NA	NA	T1, T2	CS, D	L	T1, T2	CS, D	L
<b>3.D.1 Direct Emissions</b>	NA	NA	NA	NA	NA	NA	T1	D	L, T
<b>3.D.2 Indirect Emissions</b>	NA	NA	NA	NA	NA	NA	T1	D	L
<b>3.G Liming</b>	T1	D	-	NA	NA	NA	NA	NA	NA
<b>3.H Urea application</b>	T1	D	-	NA	NA	NA	NA	NA	NA
<b>3.I Other C-cont. fertilizers</b>	T1	D	-	NA	NA	NA	NA	NA	NA

In Agriculture as the second most important sector, emissions in 2020 amounted to 1,724 Gg CO<sub>2</sub> eq, which represents 10.9% of all GHG emissions. Agriculture represents the main source of methane and N<sub>2</sub>O emissions, namely 61.9% of all methane emissions and 67.5% of all N<sub>2</sub>O emissions. In the agricultural sector, CH<sub>4</sub> emissions accounted for 68% of emissions and N<sub>2</sub>O emissions accounted for 30.2% of emissions, while CO<sub>2</sub> emissions accounted for 1.8% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2020, emissions were 11% below the emissions in the base year.

The most important sub-sector represents emissions from enteric fermentation, which contributes 54.6% of all emissions from agriculture, followed by emissions from agricultural soils, with 25.6%; the rest is contributed by emissions of methane and N<sub>2</sub>O from animal manure (18.0%) while CO<sub>2</sub> emissions due to the liming and application of urea and other C-containing fertilizers represent only 1.8 % of emissions in this sector (Figure 5.1.1.)

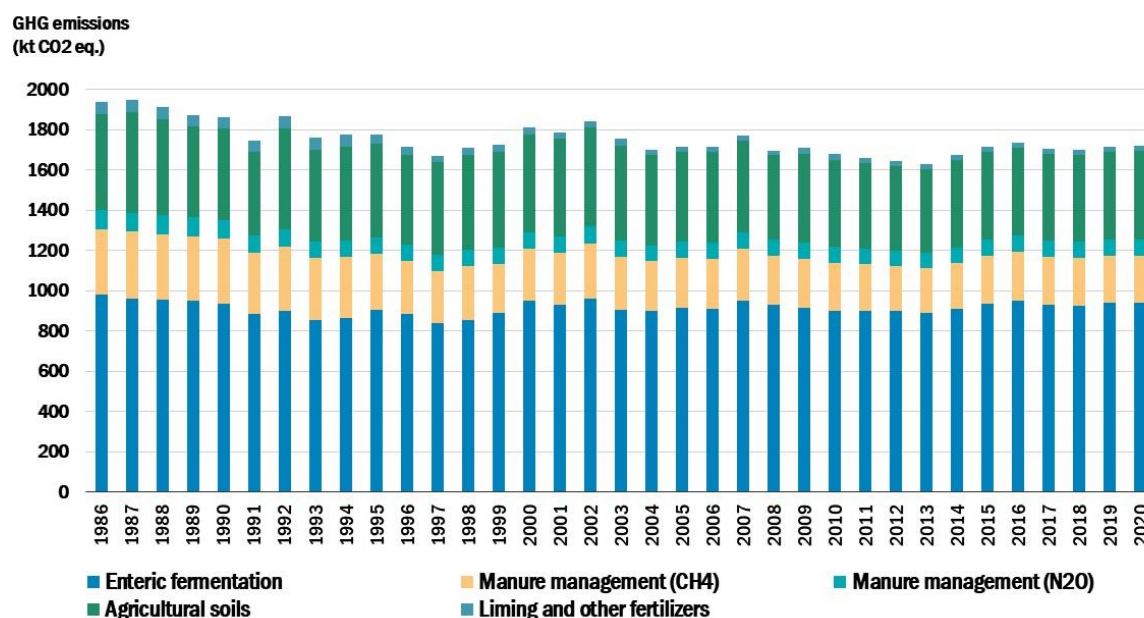


Figure 5.1.1: GHG emissions from agriculture activities in Gg CO<sub>2</sub> eq.



## 5.2 Enteric Fermentation (CRF 3.A)

### 5.2.1 Category description

CH<sub>4</sub> 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.

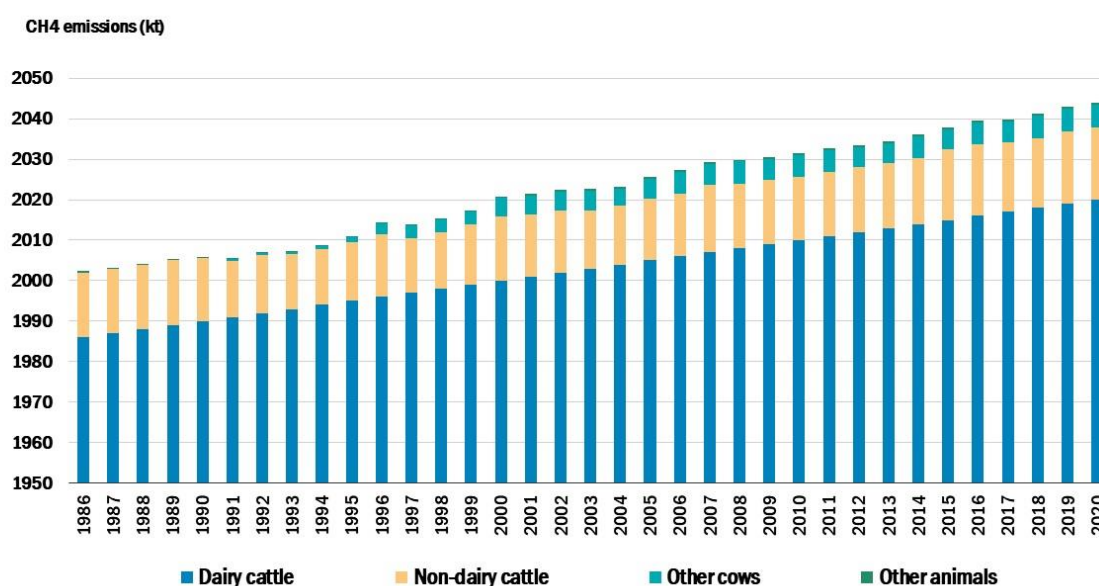


Figure 5.2.1: CH<sub>4</sub> emissions from enteric fermentation in Gg.

CH<sub>4</sub> 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 33.5% of total CH<sub>4</sub> emissions from enteric fermentation, other cows 15.5%, while non-dairy cattle represent about 47.2% of total CH<sub>4</sub> from enteric fermentation. Jointly, cattle are responsible for 96.2% of total CH<sub>4</sub> emissions from enteric fermentation in 2020 (Figure 5.2.1).

The contribution of all other animals to methane emissions from enteric fermentation, e.g. sheep, swine, horses, goats and rabbits, listed here according to the importance of their contribution, is less than 4%. No methodology for calculating CH<sub>4</sub> 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 (2006) was used to assess the of CH<sub>4</sub> 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., 2021 and Žabjek et al., 2021 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	<p><b>YOUNG CATTLE – under 1 year</b>  calves for slaughter- young bulls  calves for slaughter - young heifers  calves for fattening - young bulls  calves for fattening - young heifers</p> <p><b>YOUNG CATTLE – 1 -2 years</b>  breeding heifers in calf  other breeding heifers  heifers for fattening  bulls, oxen</p> <p><b>CATTLE – over 2 years</b>  breeding heifers in calf  other breeding heifers  heifers for fattening  bulls for breeding  bulls and oxen for fattening</p>

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.

2006 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 (CRF 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 (2006) methodology was used taking into account the local production practices.

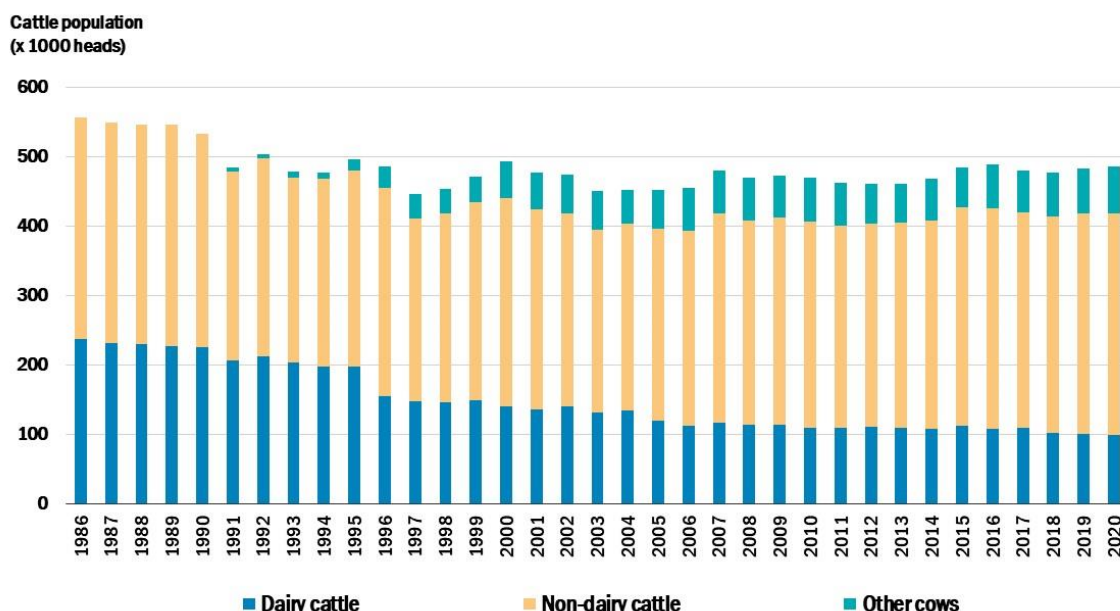


Figure 5.2.2: Number of cattle, dairy, non-dairy, and other cows in thousands.

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 relation  $W = 418.8 + 0.0313 \times M$  was used for the estimation of body weight ( $W$ , in kg).  $M$  in the equation is milk production in standard lactation (kg in 305 days). 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.  $0.386 \text{ MJ d}^{-1} \text{ kg}^{-1}$ , IPCC, 2006). 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 (2006). 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 Spiekens (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

$$dOM = 24.12 + \text{net energy for lactation} \times 7.9.$$

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 (2006).

Emission factor was calculated from data on gross energy intake (GE) and methane conversion rate ( $Y_m$ ) according to IPCC (2006):

$$\text{Emissions (kg/animal/year)} = \text{GE (MJ/year)} \times Y_m \div 55.65 \text{ MJ/ kg of methane}$$

For methane conversion rate ( $Y_m$ ) the value of 0.065 was used, as recommended by IPCC (2006). EFs and milk yield are presented on the 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
<b>Milk yield</b>	2818	2763	2770	2796	2774	3252	2836	2800	3015
<b>EF</b>	92.1	91.6	91.7	91.9	91.7	96.5	92.8	92.7	95.0
	1995	1996	1997	1998	1999	2000	2001	2002	2003
<b>Milk yield</b>	3168	3833	3975	4092	4252	4625	4807	5198	5063
<b>EF</b>	96.7	103.2	104.8	106.0	107.8	111.5	113.4	117.0	115.8
	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Milk yield</b>	4855	5479	5709	5727	5763	5530	5519	5515	5592
<b>EF</b>	113.9	119.6	121.1	121.5	122.0	119.8	119.8	119.8	120.7
	2013	2014	2015	2016	2017	2018	2019	2020	
<b>Milk yield</b>	5435	5716	5598	6024	5954	6123	6178	6356	
<b>EF</b>	119.4	121.8	120.3	124.2	123.8	125.4	125.7	127.3	

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 95 to 125 kg of methane per year. Average milk production per cow was more than doubled during the period 1986 – 2020. 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 2020, the CS EF (127.3 kg/head/year) was comparable to the updated EF for dairy cattle for Western Europe from IPCC 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.

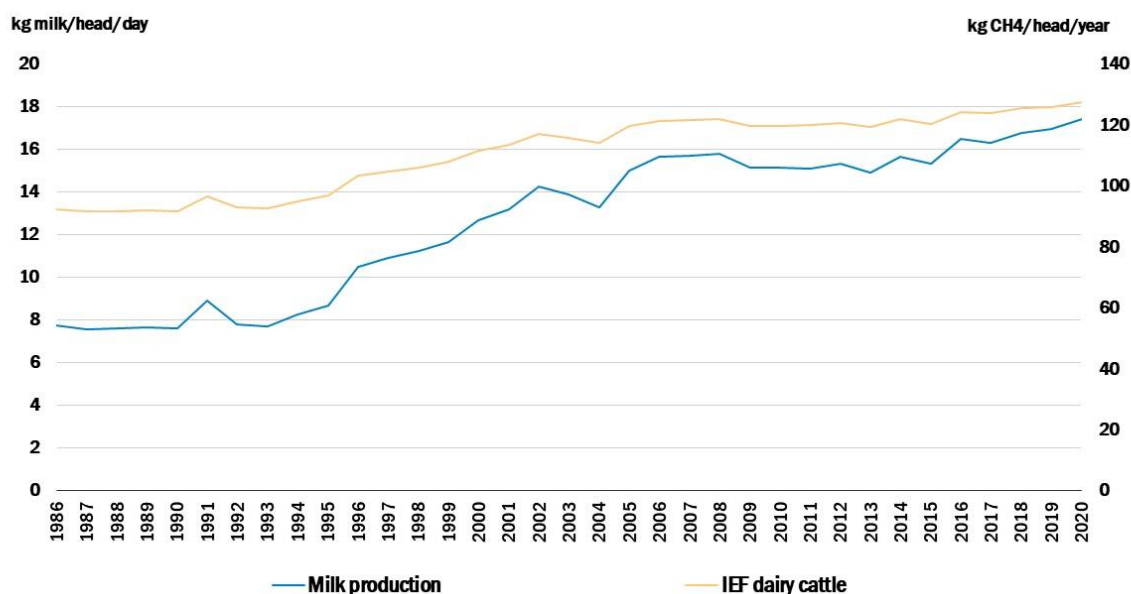


Figure 5.2.3: Milk production per cow in kg milk/head/day and IEF in kg CH<sub>4</sub>/head/year.

### 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 86.1 to 86.8 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 (2006) 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  $\frac{3}{4}$  of young bovine animals up to 1 year were considered.

In the first step, net energy requirements for the maintenance (NE<sub>m</sub>), activity (NE<sub>a</sub>), growth (NE<sub>g</sub>) and pregnancy (NE<sub>p</sub>) 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  $0.322 \text{ MJ d}^{-1} \text{ kg}^{-1}$  (IPCC, 2006). It was increased by 15% in case of intact males (i.e.  $0.335 \text{ MJ d}^{-1} \text{ kg}^{-1}$ , IPCC, 2006). 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. They were calculated on the basis of data on slaughter date and carcass weight from slaughter houses and on the basis of birth dates of individual animals which were recorded in the Central database CATTLE (Verbič and Jeretina, 2009, unpublished). Average daily gains between 1986 and 2005 were estimated by interpolation. For the period 2005-2015, average daily gains on a yearly basis were used for calculations. Requirements for growth were calculated according to equation given by IPCC (2006), 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, 2006). In order to express the requirements for pregnancy on a yearly basis (365 days) the obtained values were multiplied by the factor  $(365/\text{age at first calving})$ .

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 (2006).

Emission factor was calculated from data on gross energy intake (GE) and methane conversion rate ( $Y_m$ ) according to IPCC (2006):

$$\text{Emissions (kg/animal/year)} = GE \text{ (MJ/year)} \times Y_m \div 55.65 \text{ MJ/kg of methane}$$

For methane conversion rate ( $Y_m$ ) the value of 0.065 was used, as recommended by IPCC (2006).

**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
<b>Cattle for fattening</b>	57.2	57.3	57.4	57.6	57.7	57.8	58.0	58.1	58.3
<b>Heifers</b>	49.5	49.4	49.5	49.5	49.5	50.3	49.6	49.6	50.0
<b>Other cows</b>	NA	NA	NA	NA	NA	86.7	86.7	86.8	86.7
<b>Breeding bulls</b>	72.0	72.0	72.0	72.0	72.0	72.1	72.2	72.2	72.3
	1995	1996	1997	1998	1999	2000	2001	2002	2003
<b>Cattle for fattening</b>	58.4	58.6	58.7	58.9	59.0	59.2	59.3	59.4	59.6
<b>Heifers</b>	50.3	51.5	51.8	52.0	52.3	53.0	53.3	54.0	53.9
<b>Other cows</b>	86.7	86.7	86.7	86.6	86.6	86.7	86.7	86.7	86.6
<b>Breeding bulls</b>	72.3	72.4	72.5	72.5	72.6	72.7	72.7	72.7	72.7
	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Cattle for fattening</b>	59.7	59.8	59.3	60.0	59.8	59.6	59.6	59.8	59.8
<b>Heifers</b>	53.6	54.6	55.1	55.1	55.2	54.9	54.8	54.9	54.9
<b>Other cows</b>	86.5	86.5	86.5	86.4	86.4	86.4	86.4	86.4	86.4
<b>Breeding bulls</b>	72.7	72.7	72.7	72.7	72.7	72.8	72.8	72.8	72.8
	2013	2014	2015	2016	2017	2018	2019	2020	
<b>Cattle for fattening</b>	59.7	58.6	59.7	59.7	59.8	60.1	60.1	60.0	
<b>Heifers</b>	54.7	55.2	54.9	55.6	55.4	55.6	55.7	56.1	
<b>Other cows</b>	86.3	86.2	86.2	86.1	86.2	86.2	86.2	86.1	
<b>Breeding bulls</b>	72.8	72.8	72.8	72.8	72.8	72.8	72.8	72.8	

### Breeding bulls

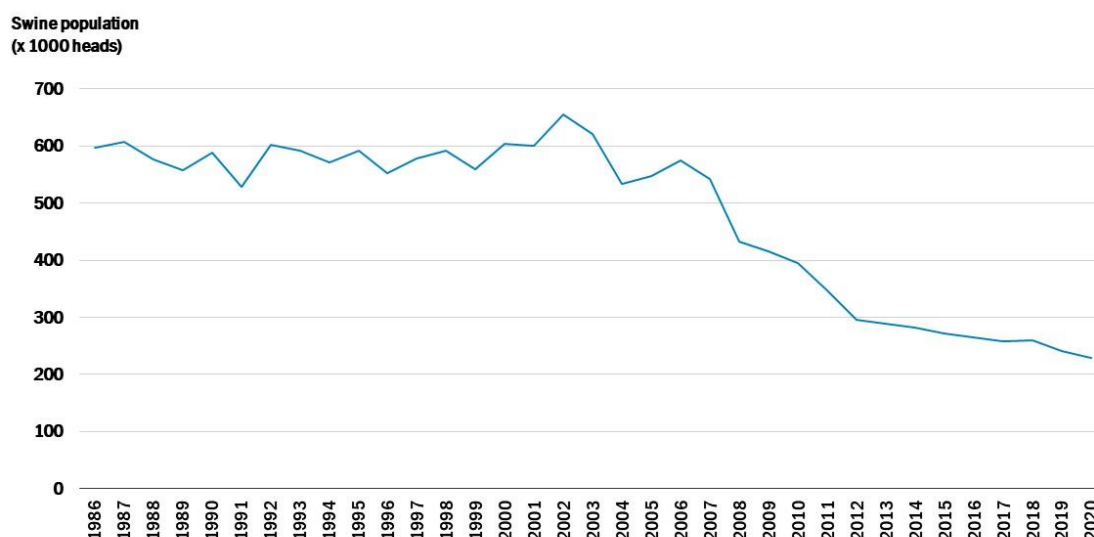
Emissions for breeding bulls were estimated by the use of same principles as for young cattle. The body weight of 700 kg and no daily gain were taken into account. It was estimated that energy digestibility of the diet has to be 60.6%. The value was derived on the basis of requirements and expected dry matter intake as summarized by Kirchgeßner et al. (2008).

The country specific CH<sub>4</sub> 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 NIR, are available in the Annex 3 to the NIR and in the CRF tables.

### **5.2.2.2 Swine (CRF 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 (CRF 3.A.2.) and Goats (CRF 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 5.2.4) 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.

### 5.2.2.4 Horses (CRF 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. 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 (CRF 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 and 2010) or the Farm Structure Surveys (2003, 2005, 2007, 2013 and 2016). For the years in between, the values were estimated by interpolation. The 2020 agricultural census data are not yet available. Therefore, the last available figure (2016) was used for the years starting in 2017. Methane emissions have been estimated by applying emission factor used in the Italian GHG inventory, i.e. 0.08 kg per animal per year.

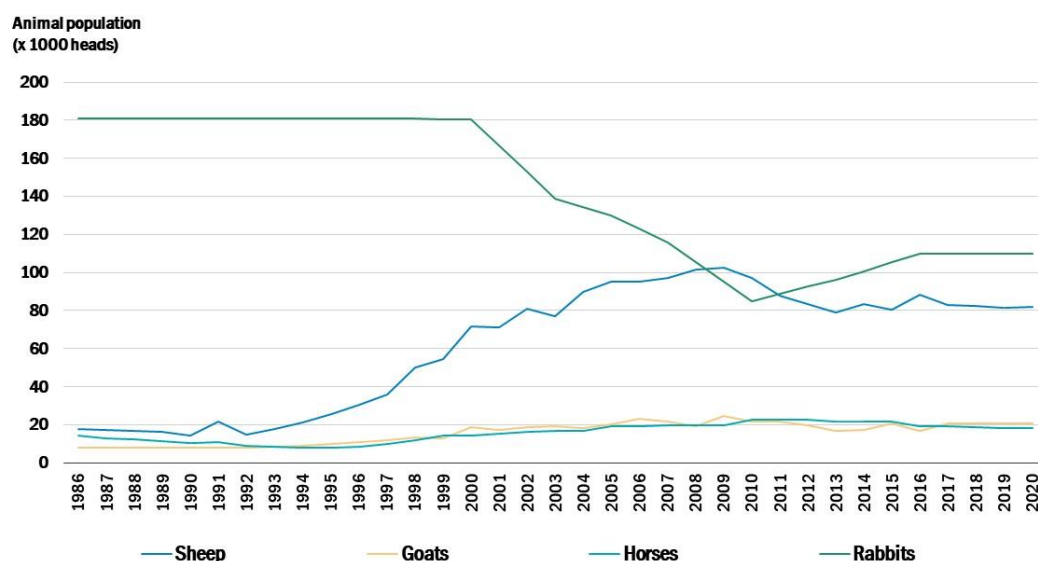


Figure 5.2.5: Number of sheep, goats, horses and rabbits in thousands.

### 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 based on expert judgement.

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 counties and all outliers have to be justified.

### **5.2.5 Category-specific recalculations**

The 2017-2019 horse number data has been updated based on the recently released Census of Agriculture 2020 data. No additional recalculations have been made since the last submission.

### **5.2.6 Category-specific planned improvements**

No major improvements are planned. It is planned to update the data on the number of rabbits for the period after 2016.

## 5.3 CH<sub>4</sub> Emissions from Manure Management (3.B)

### 5.3.1 Source category description

In storing solid and/or liquid manure, both methane and N<sub>2</sub>O are emitted. Emissions depend largely on the type of manure storage. Methane arises in significantly larger amounts when manure is managed as slurry, while N<sub>2</sub>O prevails in storage of solid manure.

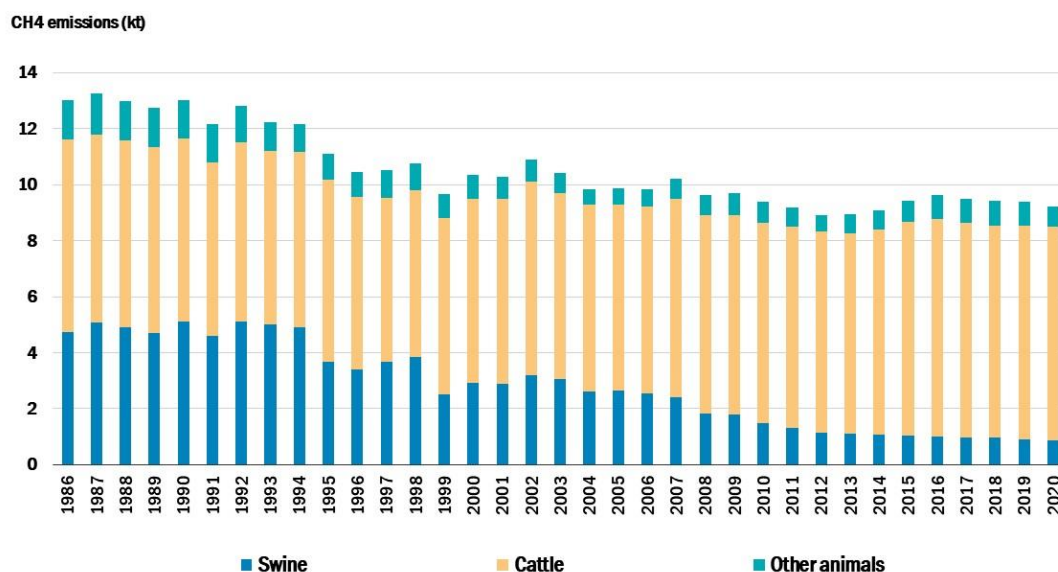
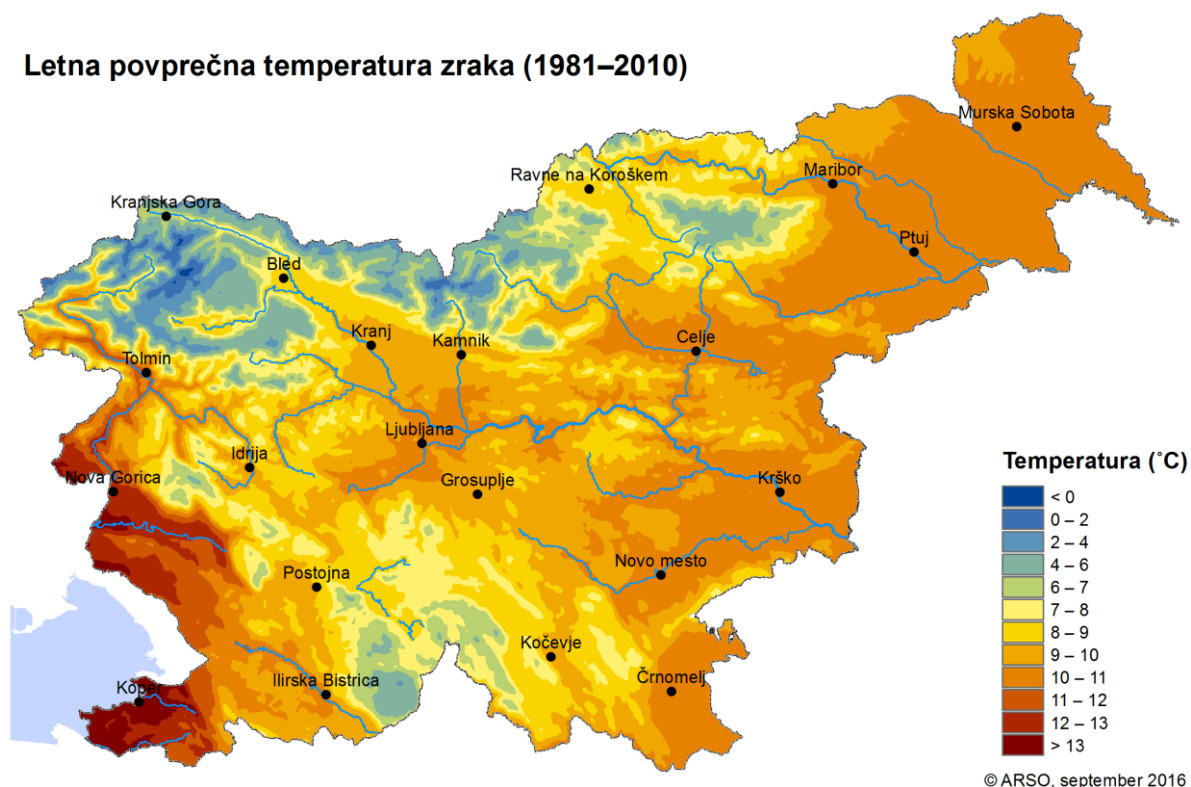


Figure 5.3.1: CH<sub>4</sub> emissions from manure management in Gg.

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<sup>3</sup> 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.

### Letna povprečna temperatura zraka (1981–2010)



© ARSO, september 2016

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/>

## 5.3.2 Methodological issues

### 5.3.2.1 Cattle (CRF 3.B.1)

Annual quantities of volatile solids excreted via faeces 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). It results in about 11 % higher emission factors than in previous reports (until 2014). 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).

$$VS(\text{kg/day}) = \left[ GE \times \left( 1 - \frac{DE\%}{100} + (UE \times GE) \right) \right] \times \left[ \frac{1 - ASH}{18.45} \right]$$

In dairy cows the estimated amount of VS ranged between 1651 and 1930 kg per year and animal. For other cows, heifers and beef cattle the corresponding values were from 1517 to 1542, from 820 to 878 and from 813 to 845 kg per year and animal.

The annual emitted amount of methane ( $E_{\text{MANURE}}$ ) was estimated according to the equation:

$$E_{\text{MANURE}} = VS (\text{kg/day}) \times 365 \text{ days/year} \times B_0 (\text{m}^3/\text{kg VS}) \times 0.67 \text{ kg/m}^3 \times \text{MCF}$$

For methane producing capacity of manure ( $B_0$ ) the value of 0.24 m<sup>3</sup>/kg VS was considered for dairy cows and the value 0.17 m<sup>3</sup>/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, 0.00 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, anaerobic digesters and grazing, respectively.

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, and 2016. 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. Due to fact that there are no historical data on agricultural production methods it was decided to preserve the consistency of time series and to retain estimates based on farm structure. No new data on manure management methods were published by SORS recently. Therefore, we were not able to respect the recommendation of 2016 review to include the latest SORS information on manure management systems into the calculation procedure.

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 2011-2020. Generally, biogas is produced from livestock manure which is generated within the farm. The data on



retention time in animal housing or stores are not available. We assume that managers are interested in achieving the shortest possible times and therefore the MCF value was set to 0.

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.

**Table 5.3.1: CH<sub>4</sub> 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
Cattle for fattening	7.5	7.5	7.4	7.4	7.4	7.5	7.6	7.6	7.7
Heifers	7.3	7.3	7.3	7.3	7.3	7.4	7.5	7.5	7.7
Other cows	NA	NA	NA	NA	NA	13.9	14.0	14.2	14.3
Breeding bulls	11.8	11.8	11.8	11.8	11.8	12.0	12.1	12.3	12.4
	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
Cattle for fattening	7.8	7.9	8.0	8.0	8.1	8.2	8.4	8.5	8.7
Heifers	7.8	8.0	8.1	8.2	8.3	8.5	8.7	9.0	9.2
Other cows	14.5	14.7	14.8	14.9	15.1	15.3	15.6	16.0	16.3
Breeding bulls	12.6	12.7	12.9	13.0	13.2	13.4	13.7	14.0	14.3
	2004	2005	2006	2007	2008	2009	2010	2011	2012
Dairy cows	26.5	27.2	27.8	28.5	29.0	29.2	29.7	29.8	30.0
Cattle for fattening	8.7	8.8	9.0	9.1	9.3	9.5	9.7	9.7	9.7
Heifers	9.2	9.4	9.6	9.8	10	10.1	10.3	10.3	10.3
Other cows	16.4	16.5	16.8	17.1	17.4	17.7	18.0	18.0	18.1
Breeding bulls	14.4	14.5	14.8	15.1	15.4	15.6	15.9	16.0	16.0
	2013	2014	2015	2016	2017	2018	2019	2020	
Dairy cows	29.9	30.5	30.7	31.5	31.5	31.7	31.7	31.9	
Cattle for fattening	9.7	9.9	10.0	10.1	10.1	10.0	10.0	10.0	
Heifers	10.3	10.5	10.6	10.8	10.8	10.8	10.8	10.9	
Other cows	18.1	18.2	18.5	18.7	18.7	18.7	18.7	18.6	
Breeding bulls	16.0	16.2	16.4	16.6	16.6	16.6	16.6	16.6	

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. For the years up to 2016, when the last data for farm size and structure are available, extrapolated values based on 2000-2010 period were used. For the period 2017-2020 the estimate for 2016 was used. It has been estimated that the fraction of grazing animals and the fraction of liquid manure management systems have increased while the fraction of bovine animals in straw based systems has decreased.

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.

### 5.3.2.2 Swine (CRF 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.

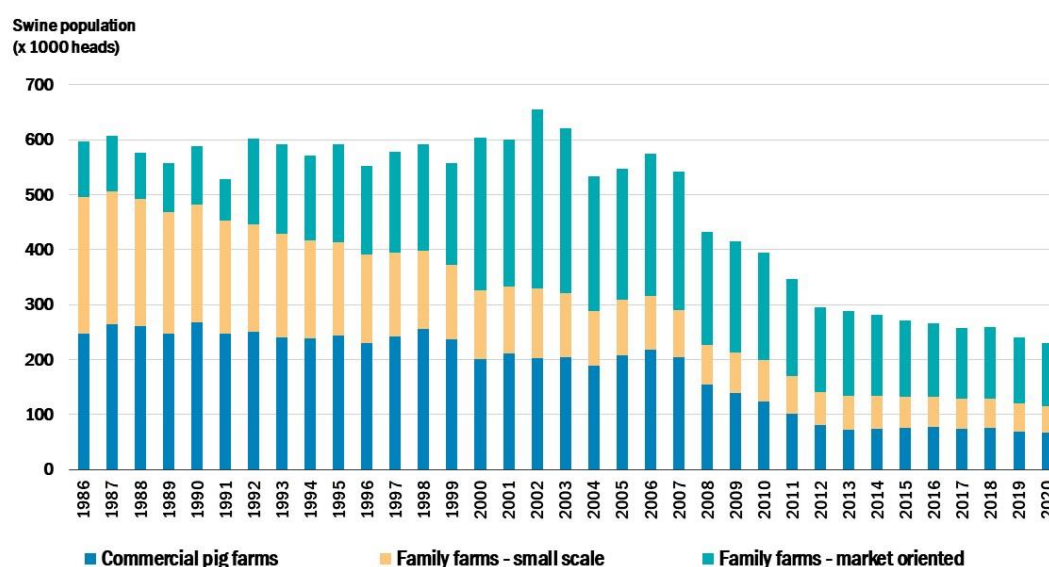


Figure 5.3.3: Number of swine in thousands.

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 and 2016 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) 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 2017, 2018, 2019 and 2020). 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 and 2016. 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.

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 2010-2020 only 0.6 to 1.5 % 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 2010-2020 is given in the Table 5.3.2 below.

**Table 5.3.2: Proportion of pigs which are kept on organic farms during the period 2010-2020 (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					
Total population of pigs	259,125	240,138	229,483					
Number of pigs on organic farms	3,203	3,252	2,992					
Proportion of pigs on organic farms (%)	1.24	1.35	1.30					

## Emission factors

Annual emissions of methane ( $E_{\text{M MANURE}}$ ) 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<sup>3</sup>/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, and 0.00 were used for liquid manure storage, solid manure storage in heaps, solid manure in deep bedding systems, uncovered anaerobic lagoons and anaerobic digesters, respectively. The following estimates and assumptions have been taken into account.

### 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.

**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		
Slurry	55.4	56.0	55.3	54.5	53.8	53.8	53.8	53.8	53.8		
Farmyard manure	22.0	22.9	22.8	22.6	22.4	22.4	22.4	22.4	22.4		
Separation (solid fraction)	10.9	10.1	10.6	11.1	11.6	11.6	11.6	11.6	11.6		
Anaerobic lagoons	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	12.2	12.2	12.2	12.2		

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 0.277. 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 0.146 until 2005 and further to 0.052 in 2020. 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 zero. However, in the CRF tables we have used notation key NE and we are planning to estimate MCF from anaerobic digesters in the near future.

#### 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 2020.

#### 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.

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<sub>4</sub> EFs for manure management in pig production (in kg/head/year)**

	1986	1987	1988	1989	1990	1991	1992	1993	1994
CH <sub>4</sub> 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 <sub>4</sub> EFs	6.2	6.2	6.3	6.5	4.5	4.8	4.8	4.9	4.9
	2004	2005	2006	2007	2008	2009	2010	2011	2012
CH <sub>4</sub> EFs	4.9	4.9	4.4	4.4	4.3	4.3	3.8	3.8	3.9
	2013	2014	2015	2016	2017	2018	2019	2020	
CH <sub>4</sub> EFs	3.9	3.8	3.8	3.7	3.8	3.7	3.7	3.7	

### 5.3.2.3 Poultry (CRF 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<sup>3</sup>/kg VS was considered for layers and the value 0.36 m<sup>3</sup>/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. 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).

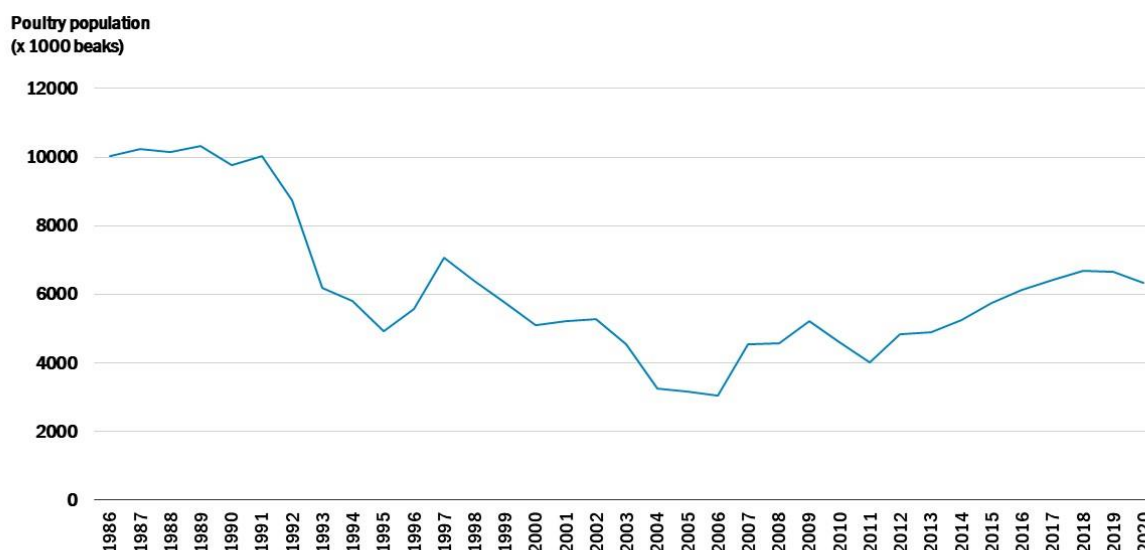


Figure 5.3.4: Number of poultry in thousands.

#### **5.3.2.4 Sheep (CRF 3.B.2), Goats, (CRF 3.B.4), and Horses (CRF 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<sup>3</sup>/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 (expert estimate). 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 (CRF 3.B.4)**

For rabbits IPCC default emissions factor 0.08 kg/head/year was applied. It was considered that rabbits are not grazed and that only the solid manure system has been 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 2020.

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.

#### Verification of the average temperature used for selection of MCF

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<sub>4</sub> 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**

The 2017-2019 horse number data has been updated based on the recently released Census of Agriculture 2020 data and corresponding emissions have been recalculated.

### **5.3.6 Category-specific planned improvements**

In accordance with Regulation (EU) 2018/1091 of the European Parliament and of the Council of 18 July 2018, the SORS has collected the data on housing and manure management in 2020. The data have not been published yet. Slovenia will make a comparison between the collected data and the estimates based on the farm structure data currently used for the allocation of manure management systems. The data for will be available before the next NIR submission. It is also planned to update the data on the number of rabbits for the period after 2016.

## **5.4 N<sub>2</sub>O Emissions from Manure Management (CRF 3.B)**

### **5.4.1 Source category description**

This category considers N<sub>2</sub>O 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<sub>2</sub>O evolves during storage of animal waste. Animal excreta are also source of indirect N<sub>2</sub>O emissions. They are associated with volatilization of ammonia (NH<sub>3</sub>) and nitric oxide (NO<sub>x</sub>) from animal houses and manure stores. Volatilised N is deposited to soils and water surfaces where it causes indirect N<sub>2</sub>O 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<sub>2</sub>O emissions from managed soils".

On the Figure 5.4.1 the nitrogen excretions from the different manure management system in the period 1986-2020 are presented. In the past a solid storage was a main type of MMS used while in the recent years the liquid systems prevailed.



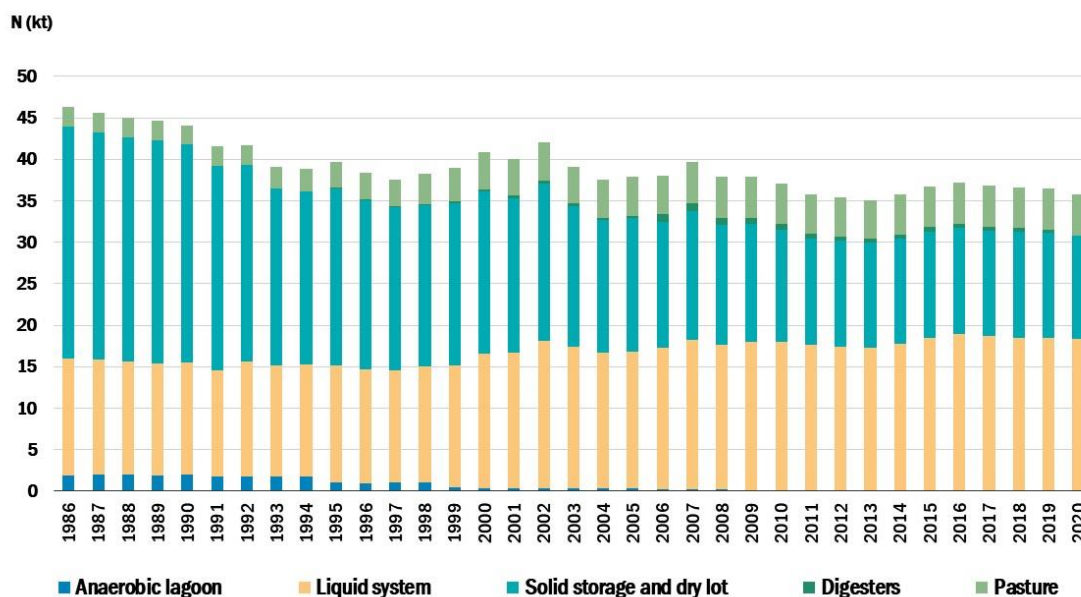


Figure 5.4.1: Nitrogen excretion per different MMS in kilotons.

## 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<sub>2</sub>O 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. In dairy cows the nitrogen excretion has been linked to productivity, i.e. milk production (M). The equation proposed by Menzi et al. (1997) was used:

$$\text{N excretion (kg/year)} = 52.5 + 0.0105 \times M \text{ (kg/year)}$$

**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	81-119	Menzi et al. (1997) taken into account milk production
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 <sup>a</sup>	36	EMEP/CORINAIR (2002)
Fattening pigs	14	EMEP/CORINAIR (2002)
Small ruminants		
Sheep <sup>b</sup>	15.5	EMEP/EEA (2019), based on information from IPCC (2006)
Goats <sup>c</sup>	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 <sup>d</sup>	8.1	IPCC (2006)

<sup>a</sup> Sows and pregnant gilts; the value includes N excretion in piglets and boars

<sup>b</sup> Adult sheep (including breeding female sheep and other adult sheep, like rams and barren sheep); the excretion value includes N excretion in lambs

<sup>c</sup> Adult goats (including breeding female goats and other adult goats, like he goats and barren goats); the excretion value includes N excretion in kids

<sup>d</sup> 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
<b>Nex</b>	82.1	81.5	81.6	81.8	81.6	86.6	82,3	81.9	84.1	85.8
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
<b>Nex</b>	92.7	94.2	95.5	97.1	101.1	103.0	107.1	105.7	103.5	110.0
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<b>Nex</b>	112.4	112.6	113.0	110.6	110.4	110.4	111.2	109.6	112.5	111.3
	2016	2017	2018	2019	2020					
<b>Nex</b>	115.8	115.0	116.8	117.4	119.2					

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.

**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
<i>Of which gilts not yet covered</i>	2,2294	36	-80,258
<b>Total</b>	<b>257,241</b>	<b>12.20</b>	<b>3,138,448</b>

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 1986-2020 is available in the Annex 3 to the NIR.

### **Emissions from animal housing, manure stores and due to fertilization with animal manures in cattle production (CRF 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<sub>2</sub>O, 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<sub>4</sub> 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<sub>3</sub>, N<sub>2</sub>O, NO and N<sub>2</sub> emissions in cattle production (Sources for emission factors: Menzi et al., 1997, EMEP/EEA, 2019).

**Table 5.4.4: Emission factors and basic information on manure management systems in cattle production.**

		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	0.825***	0.60
<b>Basic information</b>				
Proportion of covered manure stores	/	0.00	0.90	0.50
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
<b>Emission factors (kg NH<sub>3</sub>-N/kg TAN)</b>				
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
<b>Emission factors (kg N<sub>2</sub>O-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	/	0.020	0.000	Slurry: 0.010 Anaer. dig.: 0.000
<b>Emission factors (kg NO-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	/	0.010	0.0001	Slurry: 0.0001 Anaer. dig.: 0.0000

		Tied housing system		Loose housing system
	Grazing	Farmyard* manure	Liquid* fraction (urine)	Slurry and anaerobic digesters
<b>Emission factors (kg N<sub>2</sub>-N/kg TAN)</b>				
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.

### Emissions from animal housing, manure stores and due to fertilization with animal manures in pig production (CRF 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<sub>4</sub> 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.

**Table 5.4.5: Emission factors and basic information on manure management systems for the calculation of NH<sub>3</sub>, N<sub>2</sub>O, NO and N<sub>2</sub> emissions in pig production (Sources for emission factors: EMEP/EEA 2019, EPA, 2004)**

	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
<b>Basic information</b>				
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	0.32

	Farmyard manure and solid*	Slurry	Anaerobic lagoon	Anaerobic fermenter
Immobilization of TAN during storage (proportion of TAN)	0.0067	0.000	0.000	0.000
<b>Emission factors (kg NH<sub>3</sub>-N/kg N)</b>				
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	0.0266**
Emissions from covered manure stores (proportion of TAN entering the stores)	/	0.022	/	0.0266**
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
<b>Emission factors (kg N<sub>2</sub>O-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	0.01	0.000	0.000	0.000
<b>Emission factors (kg NO-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	0.01	0.0001	0.0001	0.0000
<b>Emission factors (kg N<sub>2</sub>-N/kg TAN)</b>				
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

### Emissions from animal housing, manure stores and due to fertilization with animal manures in poultry production (CRF 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<sub>4</sub> 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<sub>3</sub>, N<sub>2</sub>O, NO and N<sub>2</sub> 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
<b>Basic information</b>						
Proportion of manure incorporation	0.20	0.20	0.20	0.20	0.20	0.20
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
<b>Emission factors (kg NH<sub>3</sub>-N/kg N)</b>						
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
<b>Emission factors (kg N<sub>2</sub>O-N/kg TAN)</b>						
Emissions from manure stores (proportion of TAN entering the stores)	0.002	0.000**	0.002	0.002	0.002	0.002
<b>Emission factors (kg NO-N/kg TAN)</b>						
Emissions from manure stores (proportion of TAN entering the stores)	0.010	0.0001	0.010	0.010	0.010	0.010
<b>Emission factors (kg N<sub>2</sub>-N/kg TAN)</b>						
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 (CRF 3.B.2 and CRF 3.B.4)

Nitrous oxide emissions in goats, sheep, horses and rabbits were estimated using the information presented in Table 5.4.7. Grazing and farmyard manure management system are typical for these species. The proportions of grazing animals were estimated by the means of expert opinion. The description and estimates are given in chapter dealing with CH<sub>4</sub> emissions (5.2.2.)

**Table 5.4.7: Emission factors and basic information on manure management systems for the calculation of NH<sub>3</sub>, N<sub>2</sub>O, NO and N<sub>2</sub> 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 <sup>a</sup>
<b>Basic information</b>				
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
<b>Emission factors (kg NH<sub>3</sub>-N/kg N)</b>				
From animal houses (proportion of excreted TAN)	0.22	0.22	0.22	0.22 <sup>a</sup>
During grazing (proportion of excreted TAN)	0.09	0.09	0.35	NA
Emissions from manure stores (proportion of TAN entering the stores)	0.320	0.280	0.350	0.28 <sup>a</sup>
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
<b>Emission factors (kg N<sub>2</sub>O-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	0.020	0.020	0.020	0.020 <sup>b</sup>
<b>Emission factors (kg NO-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	0.010	0.010	0.010	0.010
<b>Emission factors (kg N<sub>2</sub>-N/kg TAN)</b>				
Emissions from manure stores (proportion of TAN entering the stores)	0.30	0.30	0.30	0.030

<sup>a</sup> There are no emission factors in EMEP/EEA emission inventory guidebook; values for sheep were used

<sup>b</sup> There are no emission factors in EMEP/EEA emission inventory guidebook; value for horses were used



#### 5.4.2.2 Indirect N<sub>2</sub>O emissions from manure management (CRF 3.B.5)

Indirect N<sub>2</sub>O emissions from manure management are associated with volatilization of ammonia (NH<sub>3</sub>) and nitric oxide (NO<sub>x</sub>). The amount of N which is lost in the form of above mentioned compounds was estimated simultaneously with direct N<sub>2</sub>O emissions using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). Emission factor 0.01 kg N<sub>2</sub>O-N per kg of volatilised N (NH<sub>3</sub>-N and NO<sub>x</sub>-N) was used, as suggested by IPCC (2006).

We have assumed that indirect N<sub>2</sub>O 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 field 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%.

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**

Emission factors for ammonia from the tied dairy cow housing system were updated. This affected the amount of N entering the manure stores. As a result, nitrous oxide emissions from livestock manure storage and nitrous oxide emissions due to livestock manure application (3.D. Agricultural Soils) were slightly increased. The overall impact on emissions was small. The recalculations were performed for the entire reporting period.

Following the recommendations of TERT, the percentage of total ammonia-N in the liquid fraction formed in the farmyard manure system was increased. This impacted nitrous oxide emissions from manure storage and from the application of animal manures (3.D. Agricultural Soils). The overall impact of the recalculations on emissions was small. The recalculations were performed for the entire reporting period.

Estimates of indirect nitrous oxide emissions have been revised. In previous reports, we inadvertently omitted ammonia emissions from cattle barns that installed anaerobic digesters. On the other hand, we included ammonia and nitric oxide emissions from anaerobic digesters at pigs that are not part of the agricultural sector. The overall impact of the recalculations on emissions was small.

Data on the number of horses and resulting N excretion for 2017-2019 have been updated based on recently released Census of Agriculture 2020 data.

### **5.4.6 Category-specific planned improvements**

The SORS has collected the data on housing and manure management in 2020. The data have not been published yet. Slovenia will make a comparison between the collected data and the estimates based on the farm structure data currently used for the allocation of manure management systems. It is also planned to update the data on the number of rabbits for the period after 2016.

## 5.5 N<sub>2</sub>O Emissions from Agricultural Soils (CRF 3.D)

### 5.5.1 Overview of category

Two sources of N<sub>2</sub>O are distinguished in the IPCC methodology: direct N<sub>2</sub>O emissions from managed soils and indirect emissions from managed soils.

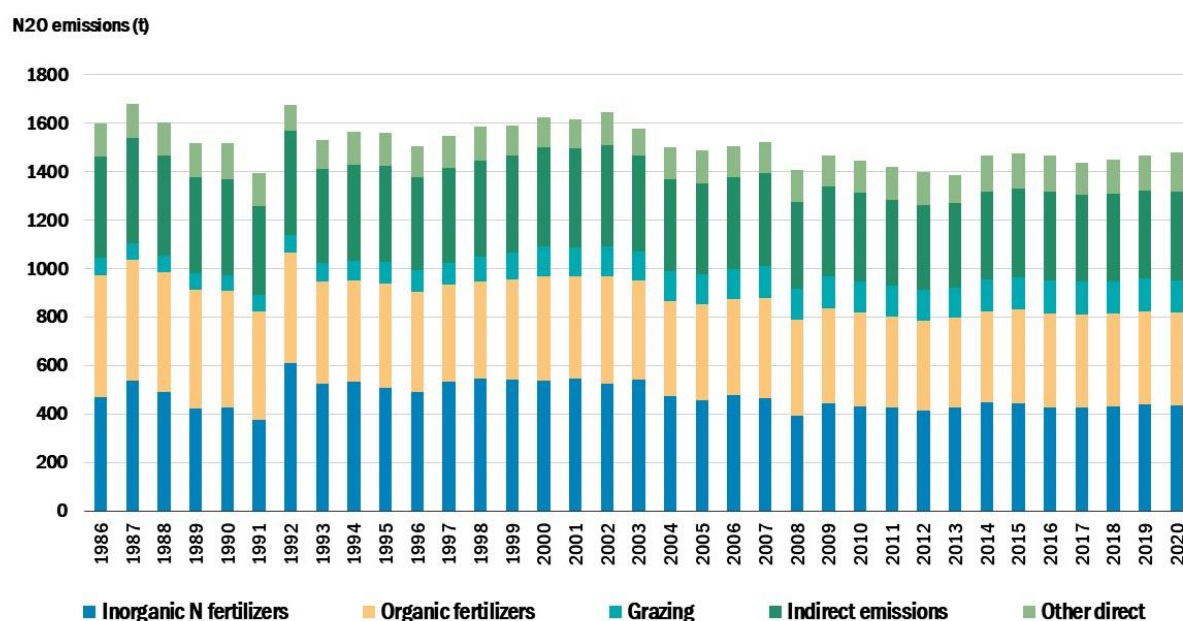


Figure 5.5.1: N<sub>2</sub>O emissions from agricultural soil in Gg.

### 5.5.2 Direct N<sub>2</sub>O Emissions from Managed Soils (CRF 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):

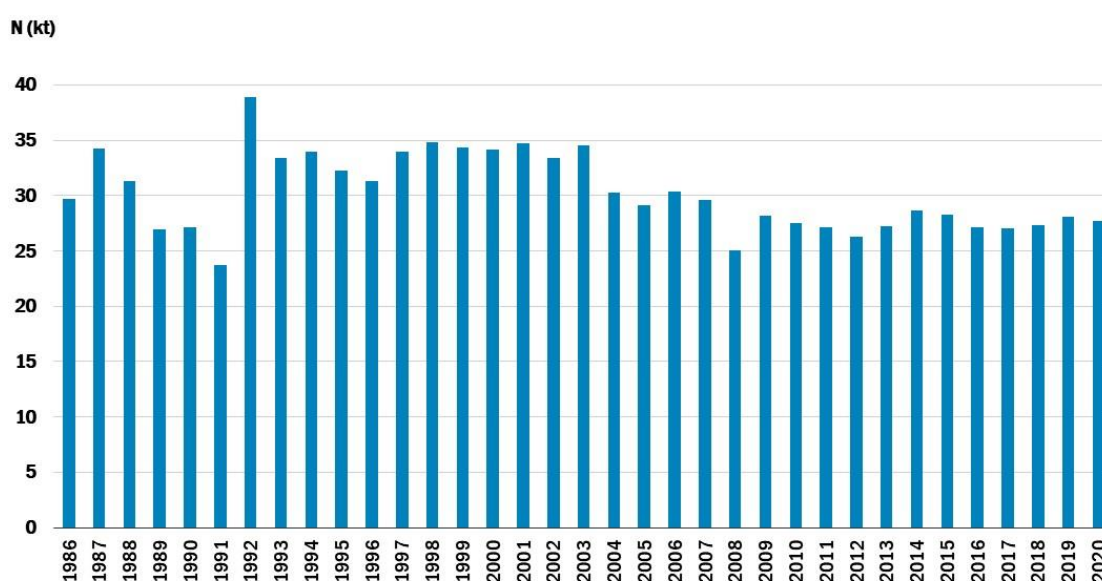
- mineral (inorganic) fertilizers;
- organic fertilizers, including animal manures, urban composts, digestates and sewage sludge;
- urine and dung deposited by grazing animals;
- crop residues;
- mineralization of soil organic matter which is associated with land use change or management of mineral soils;
- management of organic soils.

### 5.5.2.2 Methodological issues

#### Inorganic N fertilizers (CRF 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<sub>2</sub>O-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  $\text{NH}_3$  and  $\text{NO}_x$  volatilization after application to soil, which was required by IPCC (1996) methodology.

### **Organic N fertilizers (CRF 3.D.a.2)**

#### **a. Animal manure applied to soils (CRF 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 ( $\text{N}_2\text{O}$  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 ( $\text{NH}_3$ ,  $\text{NO}_x$ ,  $\text{N}_2\text{O}$  and  $\text{N}_2$ ) 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  $\text{N}_2\text{O}$ -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 (CRF 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  $\text{N}_2\text{O}$ -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 (CRF 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 2014-2020 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 2015-2020 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<sub>2</sub>O-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 (CRF 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<sub>2</sub>O 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<sub>2</sub>O-N per kg of deposited N was used for cattle and 0.01 kg N<sub>2</sub>O-N per kg of deposited N for sheep, goats and horses.

### **Crop residues (CRF 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<sub>DM</sub>) 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<sub>BG-BIO</sub>). 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<sub>2</sub>O emissions. In Slovenia crop residues from cereals are mainly used for bedding. In assessment of N<sub>2</sub>O 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<sub>2</sub>O-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 <sub>DM</sub> ) (t) AG <sub>DM</sub> = Crop (t, in DM) : slope + intercept		N conc. in above ground residues (N <sub>AG</sub> )	Ratio of below-ground residues to above-ground biomass (R <sub>BG-BIO</sub> )	N conc. in below-ground residues (N <sub>BG</sub> )
		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 <sup>1</sup>	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 <sup>2</sup>	1.09 <sup>2</sup>	0.88 <sup>2</sup>	0.005 <sup>3</sup>	0.24 <sup>1</sup>	0.011 <sup>3</sup>
Buckwheat	0.88 <sup>2</sup>	1.09 <sup>2</sup>	0.88 <sup>2</sup>	0.006 <sup>1</sup>	0.24 <sup>1</sup>	0.009 <sup>1</sup>
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 <sup>4</sup>	0.20	0.014
Fodder beet	0.22	0.10	1.06	0.025 <sup>4</sup>	0.20	0.014
Other fodder roots	0.22	0.10	1.06	0.025 <sup>4</sup>	0.20	0.014
Industrial crops						
Rapeseed	0.88 <sup>2</sup>	1.09 <sup>2</sup>	0.88 <sup>2</sup>	0.006 <sup>2</sup>	0.24 <sup>1</sup>	0.009 <sup>2</sup>
Sunflower seed	0.88 <sup>2</sup>	1.09 <sup>2</sup>	0.88 <sup>2</sup>	0.006 <sup>2</sup>	0.24 <sup>1</sup>	0.009 <sup>2</sup>
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 <sup>4</sup>	0.30	0	0.015	0.54	0.012
Leguminous plants	0.88 <sup>4</sup>	0.30	0	0.025	0.80	0.016
Grasslands						
Temporary grassland	0.88 <sup>4</sup>	0.30	0	0.015	0.80	0.012
Permanent grassland	0.88 <sup>4</sup>	0.30	0	0.015	0.80	0.012

<sup>1</sup> Value for wheat; <sup>2</sup> Value for grains; <sup>3</sup> Value for rye; <sup>4</sup> National estimate.

### Mineralization/immobilization associated with loss/gain of soil organic matter (CRF 3.D.a.5)

For estimation of indirect N<sub>2</sub>O 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<sub>2</sub>O-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 (CRF 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<sub>2</sub>O 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<sub>2</sub>O-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<sub>2</sub>O emissions are presented in Table 5.5.2.

**Table 5.5.2: Area of cultivated organic soil (in ha) and N<sub>2</sub>O emissions (in tons)**

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
<b>Area</b>	2096	2096	2096	2096	2096	2096	2096	2096	2096	2096	2096
<b>N<sub>2</sub>O</b>	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
<b>Area</b>	2096	2096	2096	2096	2116	2136	2156	2177	2197	2197	2217
<b>N<sub>2</sub>O</b>	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
<b>Area</b>	2254	2251	2266	2277	2343	2347	2347	2352	2497	2498	2498
<b>N<sub>2</sub>O</b>	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							
<b>Area</b>	2501	2489	2354	2356							
<b>N<sub>2</sub>O</b>	31.4	31.3	29.6	29.6							



### 5.5.3 Indirect N<sub>2</sub>O Emissions from Managed Soils (CRF 3.D.b)

#### 5.5.3.1 Category description

Indirect N<sub>2</sub>O 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<sub>3</sub>) and nitric oxide (NO<sub>x</sub>) 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<sub>3</sub>) and nitric oxide (NO<sub>x</sub>) from animal houses and manure stores are reported under the category "3B Manure management".

Indirect N<sub>2</sub>O 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<sub>x</sub>). 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<sub>2</sub>O. Emissions are attributed to the place of origin of ammonia and NO<sub>x</sub>, not to the place where N is re-deposited, causing N<sub>2</sub>O 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<sub>x</sub> 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<sub>3</sub>-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 and 2020 it was taken into account that low emission application techniques are used on 8.8, 11.8, 14.7 17.6 and 20.6% 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<sub>2</sub>O emissions were used. In addition, data for urea consumption for the period 1994-2020 were obtained from SORS (personal communication, data not officially published). 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 fertilizers 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). From 2002 the data for CAN consumption are also available (SORS, personal communication, data not published in national statistics).  $\text{NO}_x$  emissions were calculated by the use of a uniform emission factor, i.e. 0.040 kg  $\text{NO}_2$  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  $\text{N}_2\text{O}$ -N/kg  $\text{NH}_3$  and  $\text{NO}_x$ -N (IPCC, 2006) has been considered.

b. Animal manure applied to soils (CRF 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  $\text{NH}_3$  losses were done simultaneously with direct  $\text{N}_2\text{O}$  emissions from manure management using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). For emissions of  $\text{NO}_x$ , emission factor 0.040 kg  $\text{NO}_2$  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  $\text{N}_2\text{O}$ -N per kg of volatilised N ( $\text{NH}_3$ -N and  $\text{NO}_x$ -N) was used to assess  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  emissions as for direct ones. An emission factor 0.13 kg of ammonia nitrogen per kg of total nitrogen applied by sewage sludge was used (EMEP/EEA, 2019). For emissions of  $\text{NO}_x$ , emission factor 0.040 kg  $\text{NO}_2$  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  $\text{N}_2\text{O}$ -N per kg of volatilised N ( $\text{NH}_3$ -N and  $\text{NO}_x$ -N) was used to assess  $\text{N}_2\text{O}$  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  $\text{NO}_x$  default emission factors, as suggested by EMEP/EEA emission inventory guidebook (2019) were used (0.08 kg  $\text{NH}_3$  and 0.04 kg  $\text{NO}_2$  per kg of N applied to soils). In the second stage, emission factor 0.01 kg  $\text{N}_2\text{O}$ -N per kg of volatilised N ( $\text{NH}_3$ -N and  $\text{NO}_x$ -N) was used to assess  $\text{N}_2\text{O}$  emissions, as suggested by IPCC (2006).

e. Urine and dung deposited by grazing animals

Estimates on the amount of  $\text{NH}_3$ -N which is volatilized from grazing areas due to N deposited by grazing animals were done simultaneously with direct  $\text{N}_2\text{O}$  emissions using EMEP/EEA

(2019) methodology (Chapter 5.4.2.1). For emissions of  $\text{NO}_x$ , emission factor 0.040 kg  $\text{NO}_2$  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  $\text{N}_2\text{O-N}$  per kg of volatilised N ( $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$ ) was used to assess  $\text{N}_2\text{O}$  emissions, as suggested by IPCC (2006).

### **Nitrogen leaching and run-off (CRF 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. Mineral fertilizers applied to soils**

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  $\text{N}_2\text{O-N}$  is emitted (IPCC, 2006).

#### **b. Animal manure applied to soils**

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  $\text{NH}_3\text{-N}$ ,  $\text{N}_2\text{O-N}$  and  $\text{N}_2$  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  $\text{N}_2\text{O-N/kg}$  of leached/run-off N) (IPCC, 2006).

#### **c. Sewage sludge applied to soils**

Emissions of  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O-N}$  per kg of leached/run-off N (IPCC, 2006).

#### **d. Other organic fertilizers applied to soils**

Emissions of  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O-N}$  per kg of leached/run-off N (IPCC, 2006).

e. Urine and dung deposited by grazing animals

Emissions of N<sub>2</sub>O 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<sub>2</sub>O-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<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O-N per kg of leached/run-off N was used to calculate N<sub>2</sub>O emissions (IPCC, 2006).

g. Mineralization of soil organic matter which is associated with land use change or management of mineral soils

Emissions of N<sub>2</sub>O 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<sub>2</sub>O-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

An error was found in estimating the amount of N in livestock manure, which is the basis for estimating nitrous oxide emissions due to manure application. The error was due to incorrect accounting for N losses with nitrous oxide during storage of farmyard manure. In the case of liquid manure the calculations were in order. The recalculations were performed for the entire reporting period. The effect of the error on emissions was small.

Emission factors for ammonia from the tied dairy cow housing system were updated. This affected the amount of N in animal manures. As a result, nitrous oxide emissions due to livestock manure application were slightly increased. The recalculations were performed for the entire reporting period.

Following the recommendations of TERT, the percentage of total ammonia-N in the liquid fraction formed in the farmyard manure system was increased. This impacted nitrous oxide from the application of animal manures. The recalculations were performed for the entire reporting period.

Estimates of indirect nitrous oxide emissions from animal houses and manure storage facilities have been revised. In previous reports, we inadvertently omitted ammonia emissions from cattle barns that installed anaerobic digesters. On the other hand, we included ammonia and nitric oxide emissions from anaerobic digesters at pigs that are not part of the agricultural sector. The recalculations affected the amount of N in animal manure and the resulting direct and indirect nitrous oxide emissions from agricultural soils. The overall impact of the recalculations on emissions was small.

Data on the number of horses and resulting N in animal manures for 2017-2019 have been updated based on recently released Census of Agriculture 2020 data.

Based on new information on C stocks in agricultural soils, C emissions/sinks from cropland were updated. This also impacted the nitrous oxide emissions associated with loss/gain of soil organic matter. The impact of the recalculations on emissions ranged from +0.078% of total greenhouse gas emissions from agriculture at the beginning of the reporting period to +0.107% of total emissions at the end of the reporting period.

### 5.5.3.6 Category-specific planned improvements

The revision of manure management system data is planned. It will affect direct and indirect nitrous oxide emissions via the amount of nitrogen in animal manure. It is also planned to update the data on the number of rabbits and the resulting N in manure for the period after 2016.

## 5.6 Liming (CRF 3.G)

### 5.6.1 Category description

Emissions from liming of arable land are not a key source of CO<sub>2</sub> 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 below 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).

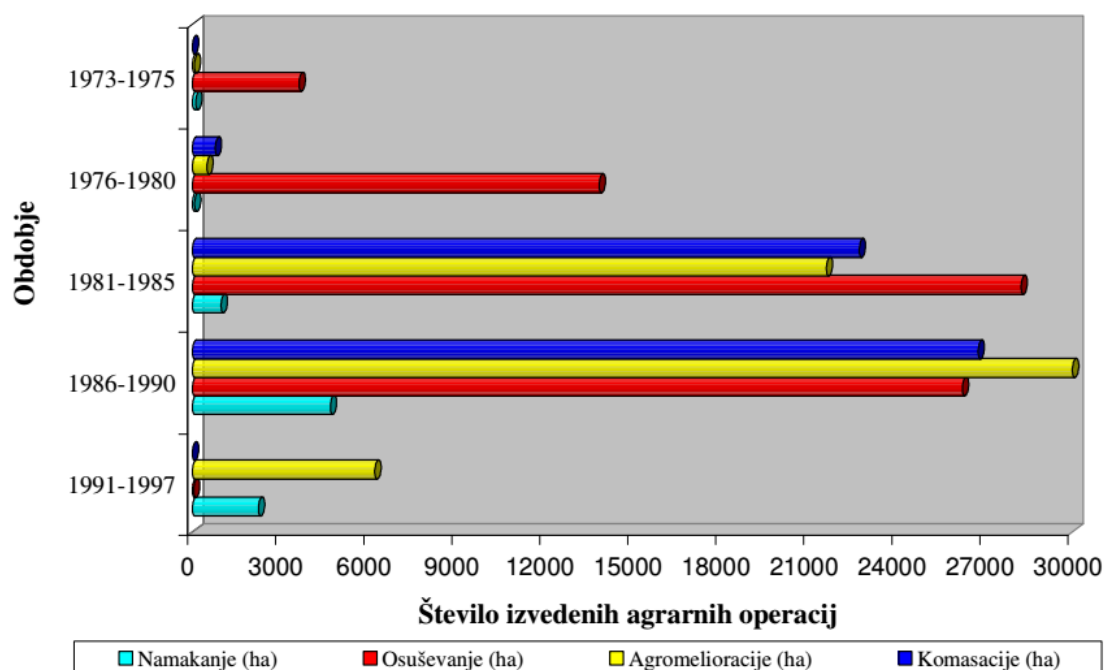


Figure 5.6.1: Area in hectares of different agricultural operations (irrigation-blue, drainage-red, agromelioration-yellow, land consolidation-blue), source: Miličić, 2007

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.

$$CO_2 - C \text{ Emissions} = (M_{\text{Limestone}} \bullet EF_{\text{Limestone}}) + (M_{\text{Dolomite}} \bullet EF_{\text{Dolomite}})$$

$CO_2 - C \text{ Emissions}$  – annual C emissions from lime application [ $t \text{ C yr}^{-1}$ ]

$M$  – annual amount of calcic limestone or dolomite [ $t \text{ yr}^{-1}$ ]

$EF$  – 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 (CRF 3.H)**

### **5.7.1 Category description**

Adding urea to soils during fertilisation leads to a loss of CO<sub>2</sub>. This source category is included because the CO<sub>2</sub> 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 (CRF 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<sub>2</sub>.

### **5.8.2 Methodological issues**

CO<sub>2</sub> 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<sub>3</sub>, 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<sub>2</sub> (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<sub>2</sub> 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 (CRF sector 4)

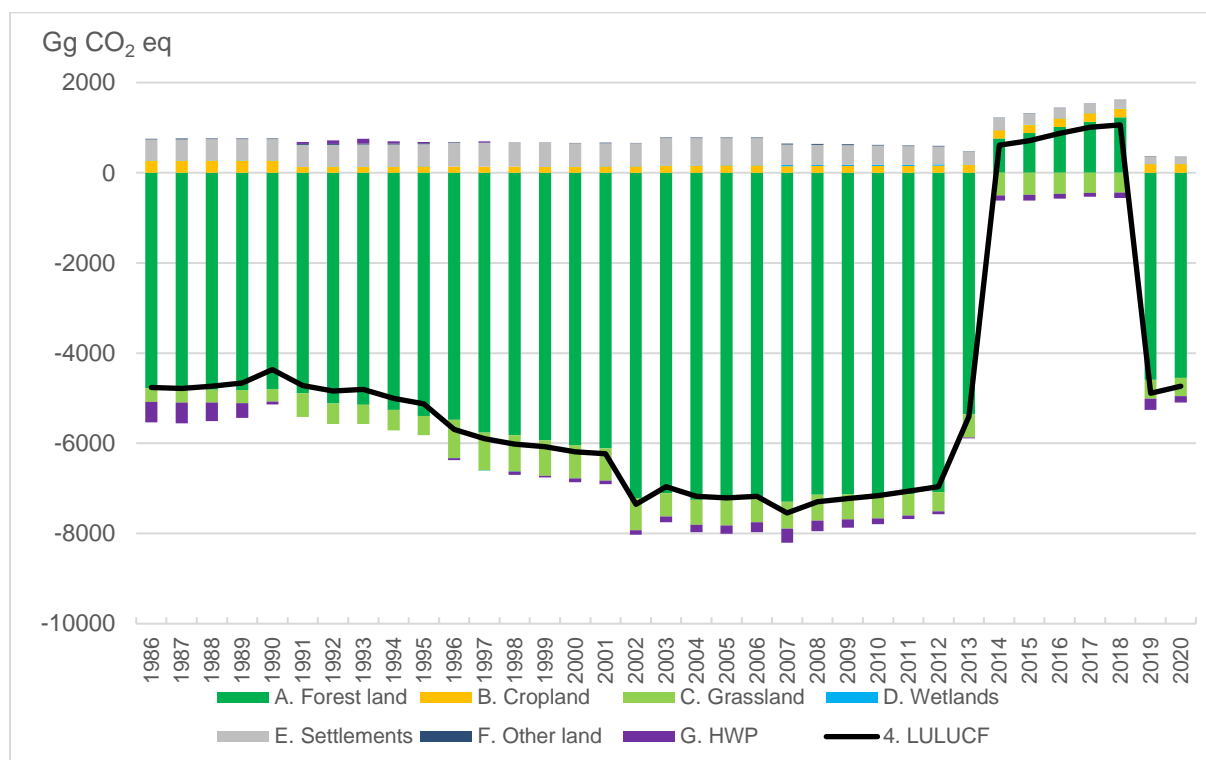
### 6.1 Overview of sector

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<sub>2</sub>O emissions from drainage of organic soils, direct and indirect N<sub>2</sub>O 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<sub>2</sub> 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<sub>2</sub>O emissions from N fertilization and CO<sub>2</sub> 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 2020 in the LULUCF sector**

		CO <sub>2</sub>		
		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 <sub>4</sub>		
		Method	EF	Key category
A. Forest land	1. Forest land remaining Forest land	D, T1	D	-
		N <sub>2</sub> O		
		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 2020, the LULUCF sector acted as a CO<sub>2</sub> sink of -4,735.80 Gg CO<sub>2</sub> eq as total emissions from this sector were higher than total removals (Figure 6.1.1).



**Figure 6.1.1: Net emissions and removals in the LULUCF sector in 1986-20 by land-use category, Gg CO<sub>2</sub> eq**

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.

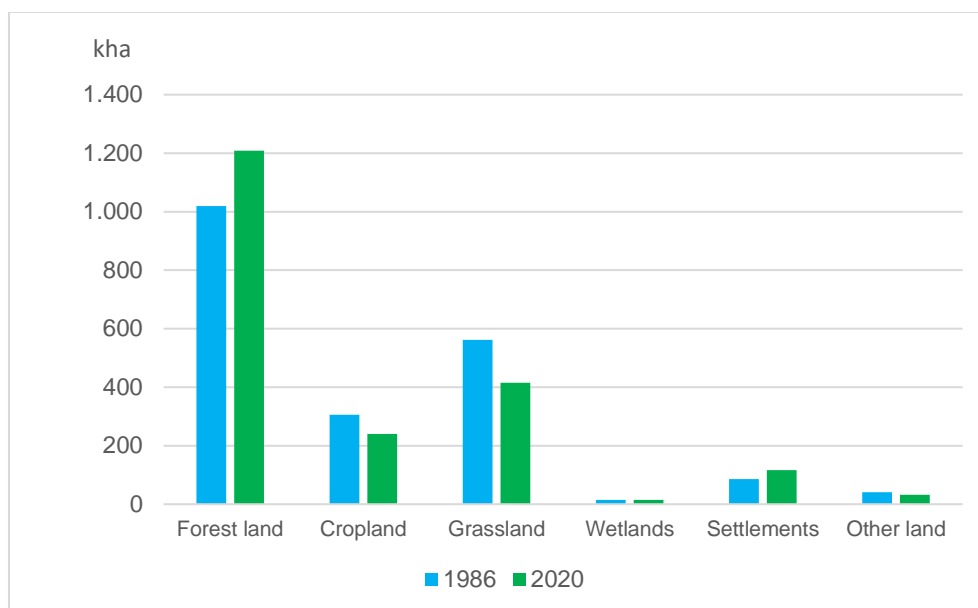
Country-specific emission factors and carbon stock values for forest land and, in some cases, for cropland and grassland are derived from surveys and measurements and have been used wherever possible. For other land use categories, IPCC default values or expert judgements are used.

The areas and shares of land use in 2020 are shown in Table 6.1.2, while the comparison of area by land use category between 1986 and 2020 is shown in Figure 6.1.2.

**Table 6.1.2: Area by categories of land use in the year 2020**

Category	Area, kha	Share, %
Forest land	1208.53	59.61
Cropland	240.40	11.86
Grassland	415.06	20.47
Wetlands	14.35	0.71
Settlements	116.81	5.76
Other land	32.15	1.59
Sum	2027.30	100.00

Table 6.1.3 summarizes CO<sub>2</sub> emissions and removals as a result of carbon losses and gains for the period 1986-2020. Total net emissions of CO<sub>2</sub> from the LULUCF sector were -4,765 Gg CO<sub>2</sub> eq in the base year (1986) and -4,735 Gg CO<sub>2</sub> eq in 2020. 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 recent 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 2020**

Emission trends showed that the largest change from the base year (1986) was for Settlements 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<sub>2</sub> 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 <sub>2</sub> equivalent								
Change to 1986 (%)	-1	-5	-28	34	18	-68	-71	-69
2020	-4736	-4547	193	-403	2	151	4	-142
2019	-4888	-4589	190	-419	2	169	4	-253
2018	1062	1230	193	-437	2	188	4	-126
2017	1010	1128	191	-444	2	207	4	-86
2016	874	1017	189	-470	2	226	4	-102
2015	713	880	188	-486	3	244	4	-129
2014	612	759	185	-503	2	268	5	-113
2013	-5407	-5355	176	-512	2	291	5	-25
2012	-6960	-7083	156	-423	27	397	20	-64
2011	-7060	-7129	150	-474	26	411	20	-75
2010	-7158	-7142	153	-521	26	424	20	-129
2009	-7227	-7136	150	-549	25	435	20	-183
2008	-7297	-7143	148	-575	25	446	19	-228
2007	-7545	-7293	146	-599	24	457	19	-311
2006	-7173	-7188	162	-563	7	599	16	-219
2005	-7209	-7258	162	-564	6	601	16	-185
2004	-7174	-7251	159	-554	6	602	16	-164
2003	-6960	-7105	156	-520	6	603	16	-129
2002	-7354	-7225	140	-705	1	513	8	-98
2001	-6228	-6112	141	-717	1	515	8	-78
2000	-6186	-6037	138	-743	0	518	9	-85
1999	-6077	-5936	138	-782	0	520	9	-40
1998	-6020	-5820	137	-811	0	523	9	-71
1997	-5894	-5765	135	-837	-1	525	10	24
1996	-5690	-5481	135	-852	-1	528	10	-43
1995	-5121	-5397	140	-420	1	490	22	28
1994	-5006	-5257	138	-456	1	488	21	45
1993	-4806	-5143	136	-427	1	486	21	106
1992	-4842	-5114	136	-460	1	484	20	77
1991	-4718	-4887	137	-525	1	482	20	40
1990	-4364	-4796	272	-276	2	471	15	-67
1989	-4661	-4821	273	-287	2	471	15	-329
1988	-4736	-4810	272	-284	2	470	15	-416
1987	-4783	-4790	271	-305	2	470	15	-460
1986	-4765	-4776	270	-302	2	470	14	-457

\*Total LULUCF emissions and removals include also indirect N<sub>2</sub>O 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**

### **6.2.1 Land use and land-use change**

In the NIR 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 associated 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 NIR 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.

### 6.2.2 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 percent, 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. Forest infrastructure that is not valued as a separate area is an integral part of forest. All Forest land is assumed managed.

### 6.2.3 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...), 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.

### 6.2.4 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.

### 6.2.5 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 used 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.

### 6.2.6 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.



## 6.2.7 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<sup>2</sup>), 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 satellite 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 orthophotos are available for this period. Two baselines 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 <sub>1986</sub>
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 <sub>1990</sub>	1024295	246952	58457	348291	211844	14815	87002	35645	2027300

**Table 6.3.2: Land-use change matrix for the period 1990-1995 in hectares**

<b>1990-1995</b>	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total <sub>1990</sub>
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
Total <sub>1995</sub>	1101795	234316	54457	345091	150280	14915	92102	34346	2027300

**Table 6.3.3: Land-use change matrix for the period 1995-2002 in hectares**

<b>1995-2002</b>	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total <sub>1995</sub>
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
Total <sub>2002</sub>	1210350	219050	57550	316150	75050	14050	103150	31950	2027300

**Table 6.3.4: Land-use change matrix for the period 2002-2006 in hectares**

<b>2002-2006</b>	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total <sub>2002</sub>
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
Total <sub>2006</sub>	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 <sub>2006</sub>
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 <sub>2012</sub>	1206450	209050	52950	312450	84850	14350	115050	32150	2027300

**Table 6.3.6: Land-use change matrix for the period 2012-2017 in hectares**

2012-2017	FL	CL_a	CL_w	GL_a	GL_w	WL	SL	OL	Total <sub>2012</sub>
FL	1204750	100	200	1000	100		300		1206450
CL_a		194750	1500	12100	400		300		209050
CL_w		500	45850	3200	3300		100		52950
GL_a		4000	500	293950	13600	100	300		312450
GL_w	3000	400	700	4800	75750	100	100		84850
WL				100		14150	100		14350
SL					100		114950		115050
OL								32150	32150
Total <sub>2017</sub>	1207750	199750	48750	315150	93250	14350	116150	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 (Miličič 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). In order to be consistent with KP reporting, the most recent data on forest area and deforestation were used for activity-based reporting within KP Articles 3.3 and 3.4.

Land-use areas for each land use were calculated using following equation:

$$Area_{LU, year of inventory} = Area_{LU, previous inventory year} + Area_{land converted to LU} \quad (\text{Equation 1})$$

$Area_{LU, year of inventory}$  - area of selected land use category in year of inventory [ha]

$Area_{LU, previous inventory year}$  - area of selected land use category in previous year [ha]

$Area_{land converted to LU}$  - 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 6.3.7: Standard error (%) of an area estimate for the land-use categories**

Land-use category	Standard error, %		
	2002-2006	2006-2012	2012-2017
Forest land remaining forest land	0.6	0.6	0.6
Land converted to forest land	21.8	14.6	18.2
Cropland remaining cropland	1.8	1.8	2.0
Land converted to cropland	12.6	14.6	10.1
Grassland remaining grassland	1.5	1.5	1.5
Land converted to grassland	8.6	8.1	7.0
Wetlands remaining wetlands	8.6	8.5	8.5
Land converted to wetlands	100.0	44.7	70.7
Settlements remaining settlements	3.0	3.0	2.9
Land converted to settlements	12.2	12.6	28.9
Other land remaining other land	5.6	5.6	5.5
Land converted to other land	70.7	70.7	NA

**Table 6.3.8: Areas per LULUCF land-use categories from 1986 to 2020 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							
2020	2027.3	1208.53	240.40	415.06	14.35	116.81	32.15
2019	2027.3	1208.27	243.10	412.84	14.35	116.59	32.15
2018	2027.3	1208.01	245.80	410.62	14.35	116.37	32.15
2017	2027.3	1207.75	248.50	408.40	14.35	116.15	32.15
2016	2027.3	1207.49	251.20	406.18	14.35	115.93	32.15
2015	2027.3	1207.23	253.90	403.96	14.35	115.71	32.15
2014	2027.3	1206.97	256.60	401.74	14.35	115.49	32.15
2013	2027.3	1206.71	259.30	399.52	14.35	115.27	32.15
2012	2027.3	1206.45	262.00	397.30	14.35	115.05	32.15
2011	2027.3	1206.50	263.53	396.80	14.27	114.07	32.13
2010	2027.3	1206.55	265.07	396.30	14.18	113.08	32.12
2009	2027.3	1206.60	266.60	395.80	14.10	112.10	32.10
2008	2027.3	1206.65	268.13	395.30	14.02	111.12	32.08
2007	2027.3	1206.70	269.67	394.80	13.93	110.13	32.07
2006	2027.3	1206.75	271.20	394.30	13.85	109.15	32.05
2005	2027.3	1207.65	272.55	393.53	13.90	107.65	32.02
2004	2027.3	1208.55	273.90	392.75	13.95	106.15	32.00
2003	2027.3	1209.45	275.25	391.98	14.00	104.65	31.98
2002	2027.3	1210.35	276.60	391.20	14.05	103.15	31.95
2001	2027.3	1194.84	278.34	406.08	14.17	101.57	32.29
2000	2027.3	1179.33	280.08	420.96	14.30	99.99	32.63
1999	2027.3	1163.83	281.82	435.84	14.42	98.42	32.98
1998	2027.3	1148.32	283.56	450.73	14.54	96.84	33.32
1997	2027.3	1132.81	285.29	465.61	14.67	95.26	33.66
1996	2027.3	1117.30	287.03	480.49	14.79	93.68	34.00
1995	2027.3	1101.79	288.77	495.37	14.91	92.10	34.35
1994	2027.3	1086.29	292.10	508.32	14.89	91.08	34.61
1993	2027.3	1070.79	295.43	521.28	14.87	90.06	34.87
1992	2027.3	1055.29	298.75	534.23	14.85	89.04	35.13
1991	2027.3	1039.79	302.08	547.18	14.83	88.02	35.39
1990	2027.3	1024.29	305.41	560.13	14.81	87.00	35.65
1989	2027.3	1022.94	305.46	560.63	14.79	86.60	36.87
1988	2027.3	1021.59	305.51	561.13	14.76	86.20	38.10
1987	2027.3	1020.24	305.56	561.63	14.74	85.80	39.32
1986	2027.3	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 6.3.9, 6.3.10, and 6.3.11. The values of SOC stocks were estimated for the depth of 0-30 cm of the mineral part of soil. Note that wetlands, settlements and other land were not subject of this monitoring.

**Table 6.3.9: Average carbon stocks in living biomass**

Land use	Above-ground biomass [t C ha <sup>-1</sup> ]	Below-ground biomass [t C ha <sup>-1</sup> ]	Living biomass [t C ha <sup>-1</sup> ]
Forest land*	*79.20	22.09	101.29
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 year 2018

**Table 6.3.10: Average carbon stocks in dead organic matter**

Land use	Dead wood [t C ha <sup>-1</sup> ]	Litter [t C ha <sup>-1</sup> ]	Dead organic matter [t C ha <sup>-1</sup> ]
Forest land	5.89	10.41	16.30
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

**Table 6.3.11: Average soil organic carbon stocks**

Land use	Mineral soil [t C ha <sup>-1</sup> ]	n
Cropland annual	86.00 ± 5.29	183
Cropland perennial	77.80 ± 12.76	88

Grassland annual	94.86 ± 4.31	141
Grassland perennial	101.53 ± 25.43	53
Wetlands	113.68 ± 18.55	11
Settlements	32.12	EJ
Other land	33.18	EJ

Soil monitoring in wetlands was carried out in 2012 as part of the inventory on non-forest land, where the average SOC stock was estimated for the depth of 0-40 cm of the mineral part of soil. The values of SOC stock for settlements and other land were estimated by expert judgment (EJ). On basis of data on green areas in urban land for municipality Ljubljana the estimate of expert judgment for SOC stock in settlements equals to the half a value of SOC stock in the category grassland annual. The SOC stock in other land was estimated on basis of SOC values of grassland annual and perennial grassland, which were attributed to the share of grass and shrub cover. The SOC stock in other land was calculated as the weighted average, where the areas of national land use class 5000 and 6000 were used as weights.



## 6.4 Forest Land (4A)

### 6.4.1 Source category description

Forest land category includes CO<sub>2</sub> 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<sub>2</sub> emissions from biomass burning are reported.

The forest area in Slovenia in 2020 was 1208.53 kha, which is 59.6 % 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 – 2020) 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								
2020	1208.53	1164.19	43.74	NO	43.64	NO	NO	0.10
2019	1208.27	1148.20	60.07	NO	59.97	NO	NO	0.10
2018	1208.01	1132.22	75.79	NO	75.69	NO	NO	0.10
2017	1207.75	1116.24	91.51	NO	91.41	NO	NO	0.10
2016	1207.49	1100.26	107.23	NO	107.13	NO	NO	0.10
2015	1207.23	1084.27	122.96	NO	122.86	NO	NO	0.10
2014	1206.97	1068.17	138.80	NO	138.70	NO	NO	0.10
2013	1206.71	1052.07	154.64	NO	154.54	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	40.50	NO	NO	NO
1987	1020.24	979.74	40.50	NO	40.50	NO	NO	NO
1986	1018.89	978.39	40.50	NO	40.50	NO	NO	NO

Table 6.4.2: Emissions/removals from Forest land (1986 – 2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>								
2020	-4555.03	-4277.39	-277.64	NO	-275.57	NO	NO	-2.06
2019	-4597.11	-4218.67	-378.44	NO	-376.38	NO	NO	-2.06
2018	1228.24	1702.65	-474.41	NO	-472.35	NO	NO	-2.06
2017	1109.31	1678.62	-569.31	NO	-567.25	NO	NO	-2.05
2016	991.43	1654.58	-663.15	NO	-661.10	NO	NO	-2.05
2015	874.62	1630.55	-755.93	NO	-753.88	NO	NO	-2.05
2014	757.85	1606.34	-848.48	NO	-846.44	NO	NO	-2.04
2013	-5360.03	-4420.06	-939.97	NO	-937.93	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	-232.90	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 1986-2018 were from -4,830.51 Gg CO<sub>2</sub> to 221.31 Gg CO<sub>2</sub> with a maximum value in 2007.

Forest land remaining forest land (CO<sub>2</sub>) and land converted to forest land (CO<sub>2</sub>) were identified as key source categories according to level and trend. Concerning the CH<sub>4</sub> or N<sub>2</sub>O 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<sup>2</sup>). 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 1986-2018, annual removals and emissions ranged between -4577.07 Gg CO<sub>2</sub> and 634.92 Gg CO<sub>2</sub>. The maximum value of removals in this subcategory was in 2012. As of 2014, the category acts as a net source of emissions. In recent years, forests have been significantly affected by 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 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.

#### 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.

$$C = (V_j \times D_j \times BEF_j) \times (1 + R_j) \times CF \quad \text{(Equation 2)}$$

*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 stem from the ground to a top diameter of 6.99 cm, and may also include branches to a minimum diameter of 6.99 cm. The methodology for volume estimation is described in detail in Kušar et al. (2010).

### 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.

$$y = a + \frac{b}{x} \quad \text{(Equation 3)}$$

*y* – biomass expansion factor (dimensionless)

*x* – mean growing stock

*a, b* – coefficient of the non-linear regression model

### 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.

### 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<sup>3</sup> for beech and 0.394 t/m<sup>3</sup> 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 Forestry Institute were used for the calculations.

For calculations the equation 2.5 from 2006 Guidelines was used:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{t_2 - t_1} \quad \text{(Equation 4)}$$

$\Delta C$  – annual carbon stock change in living biomass [t C yr<sup>-1</sup>]

$C_t$  – 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 were used to apply stock-difference method. The FECS, which can be understood as a national forest inventory, was conducted on concentric permanent fixed plots of a sampling grid with density 4 km × 4 km (see detailed description in Annex 3). The volume of above-ground biomass was 283.2 m<sup>3</sup>/ha in 2000, 313.69 m<sup>3</sup>/ha in 2007, 333.94 m<sup>3</sup>/ha in 2012 and 329.63 m<sup>3</sup>/ha in 2018.

**Table 6.4.3: Average growing stock volume**

Year	Above-ground biomass [m <sup>3</sup> ha <sup>-1</sup> ]	n
2007	313.69 ± 13.39	724
2012	333.94 ± 13.65	760
2018	329.63 ± 13.69	759

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.

$$y_0 = x_0 * \left( \frac{1}{(n - m + 1)} * \sum_{i=m}^n \frac{y_i}{x_i} \right) \quad \text{(Equation 5)}$$

$y_0$  – 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  $n$

### **Carbon stock changes in dead organic matter**

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.

$$\Delta C_{FF_{DOM}} = \Delta C_{FF_{DW}} + \Delta C_{FF_{LT}} \quad \text{(Equation 6)}$$

$\Delta C_{FF_{DOM}}$  – annual change in carbon stocks in dead organic matter [t C yr<sup>-1</sup>]

$\Delta C_{FF_{DW}}$  – change in carbon stocks in dead wood [t C yr<sup>-1</sup>]

$\Delta C_{FF_{LT}}$  – change in carbon stocks in litter [t C yr<sup>-1</sup>]

## 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).

$$\Delta C_{FF}(DW) = \left[ A * \frac{(DW_{t2} - DW_{t1})}{T} \right] * CF \quad \text{(Equation 7)}$$

$\Delta C_{FF}(DW)$  – annual change in carbon stocks in dead wood [t yr<sup>-1</sup>]

$A$  – 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 9.56 t d.m./ha (19.75 m<sup>3</sup>/ha), 9.57 t d.m./ha (19.76 m<sup>3</sup>/ha), and 11.57 t d.m./ha (23.77 m<sup>3</sup>/ha), respectively. Dead wood accounted for 5.9 % of growing stock in 2012 and 7.2 % in 2018.

## 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, fomic, 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 6.4.4) 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<sub>l</sub>, O<sub>f</sub> and O<sub>h</sub> 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:

$$C_{pool} = \sum_{i=1}^k (\%C_{org,i} \cdot M_{105^{\circ}C,i} / 100) \quad \text{(Equation 8)}$$

$C_{pool}$  - carbon stock [t ha<sup>-1</sup>]

$C_{org}$  - the organic carbon content and clay content (both in %)

$M_{105^{\circ}C,i}$  - quantity of dry soil in sub horizon  $i$  [t ha<sup>-1</sup>]

$k$  - number of soil horizon in soil profile

**Table 6.4.4: Average carbon stock in forest litter**

Layer	Average carbon stock [t ha <sup>-1</sup> ]	n
O <sub>l</sub> horizon	1.44 ± 0.15	143
O <sub>fh</sub> horizon	8.85 ± 1.42	145
Litter (O <sub>l</sub> + O <sub>fh</sub> )	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 and Simončič, 2011) 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 6.4.5) 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:

$$C_{pool} = \sum_{i=1}^k (\%C_{org,i} \cdot d_i \cdot \rho_i \cdot 100) \quad \text{(Equation 9)}$$

$C_{pool}$  - carbon stock [Gg ha<sup>-1</sup>]

$d_i$  - thickness [m] of soil horizon  $i$

$\rho_i$  - soil bulk density [g cm<sup>-3</sup>]

$k$  - number of sub horizon in soil profile

Since bulk density measurements were not available, soil bulk density [g/cm<sup>3</sup>] 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).

$$\rho_i = \left\{ \begin{array}{l} 1 / (0,625 + 0,05 \cdot \% C_{org} + 0,0015 \cdot \% clay) \rightarrow \text{if } \% C_{org} \leq 5\% \\ 1,55 - 0,0814 \cdot \% C_{org} \rightarrow \text{if } 5\% < \% C_{org} \leq 15\% \\ 0,725 - 0,337 \cdot \log_{10} \% C_{org} \rightarrow \text{if } \% C_{org} \geq 15\% \end{array} \right\} \quad \text{(Equation 10)}$$

$\rho_i$  - soil bulk density [g cm<sup>-3</sup>]

$C_{org}$  - the organic carbon content and clay content (both in %)

**Table 6.4.5: Average soil organic carbon stock of forest land**

Layer	Average carbon stock [t C ha <sup>-1</sup> ]	n
M <sub>10</sub> horizon	35.25 ± 2.06	141
M <sub>40</sub> 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 and Simončič, 2011) 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 ( $\varnothing = 7$  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 ( $p = 0.052$ ).

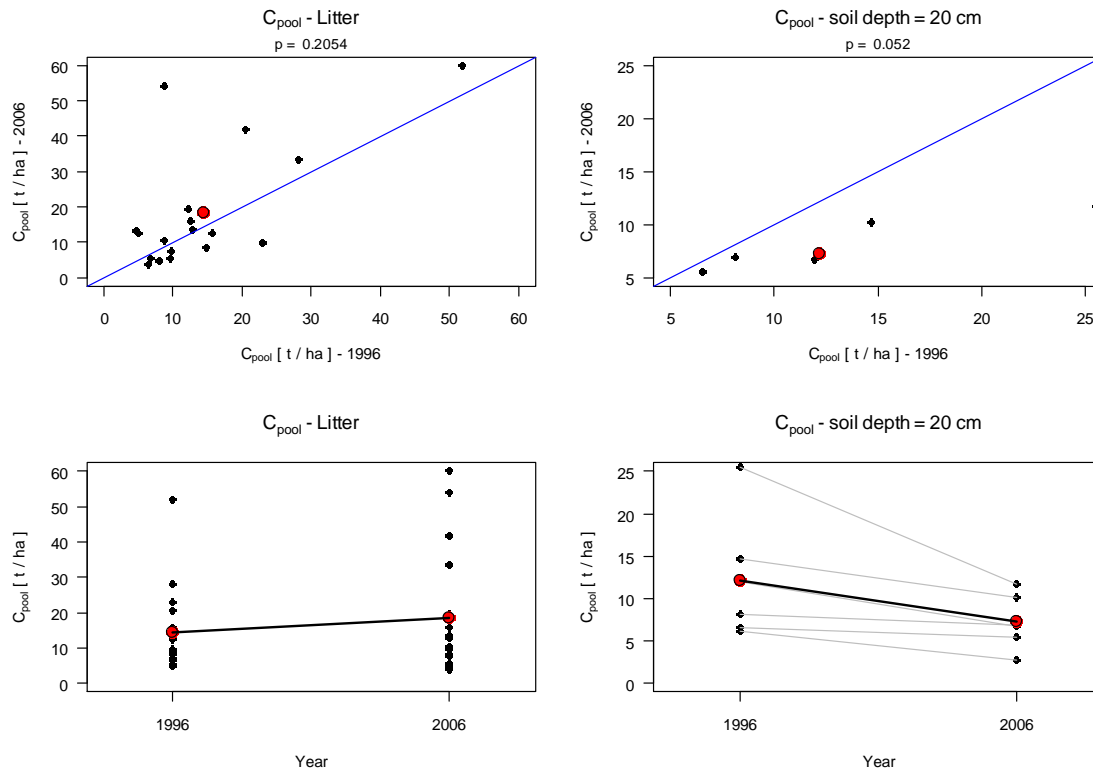


Figure 6.4.1: Carbon stock in forest soils and litter (1996-2006)

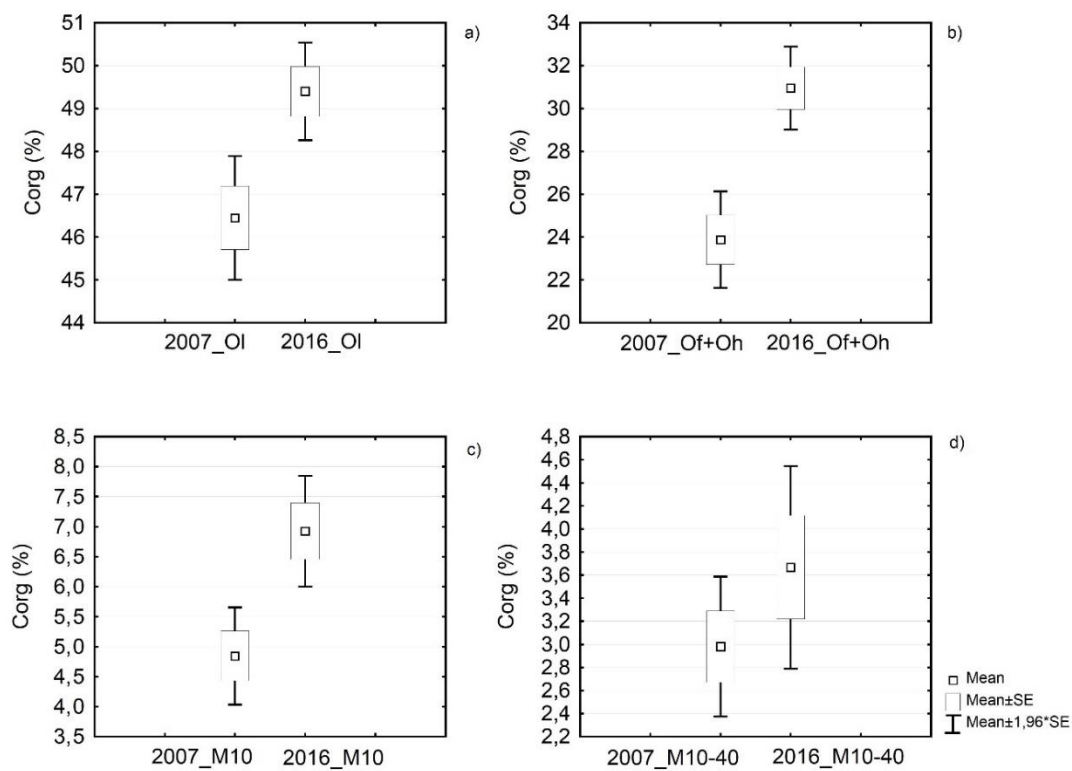


Figure 6.4.2: Carbon stock in forest soils and litter (2007-2016)

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, fumiic 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<sub>2</sub> greenhouse gas emission

##### **N<sub>2</sub>O 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 CRF tables 4(I) and 4(II).

There is a legal act (Regulation on the protection of waters against pollution caused by nitrates from agricultural sources, 2009) that prohibits fertilization of forest land. Article 11 of the Regulation also prohibits fertilization on overgrown agricultural land and on infertile land and inland waters.

##### **Emissions from wildfires**

It should be noted that emissions from forest fires (wildfires) refer to the entire forest area (i.e. 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 half a percent in 2003, which was the most problematic year in the following period. For the calculations, Tier 2 (estimation of burned area at the country level) and estimation of GHGs directly released from fires were used. Equation 2.27 (IPCC 2006) was used for the calculations of emissions from forest fires.

$$L_{fire}[tGHG] = A * M_B * C_f * G_{ef} * 10^{-3} \quad \text{(Equation 11)}$$

*A* – area burnt [ha]

*M<sub>B</sub>* – mass of fuel available for combustion [kg d.m. ha<sup>-1</sup>]

*C<sub>f</sub>* – combustion factor (dimensionless)

*G<sub>ef</sub>* – emission factor (g kg<sup>-1</sup> dry matter burnt)

Default emission factors were used for all GHGs (IPCC 2006, Table 2.5). The values of the emission factors of extra tropical forest were adopted.

The mass of available fuel (*M<sub>B</sub>*) was calculated from the average growing stock in the part of the country where most wildfires occur (i.e. Karst region, see map: [Forest Fire Hazard Map](#)) and the average carbon stocks in dead organic matter (i.e. dead wood and litter) in Slovenia. 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 6.4.6: Emission factors used from Table 2.5 (IPCC 2006)**

Gas		Emission factor ( $G_{ef}$ )
		[g / kg d.m.]
CO <sub>2</sub>	carbon dioxide	1,569
CO	carbon oxide	107
CH <sub>4</sub>	methane	4.7
NO <sub>x</sub>	nitrogen oxide	3.0
N <sub>2</sub> O	nitrous oxide	0.26
NMHC	non methane hydrocarbons	10

According to national statistics, about 70% of forest fires occur in the Karst region. The database of forest fires is in the domain of Slovenia Forest Service (since 1994), which describes and records forest fires through information such as location, type of fire, area burned, type of vegetation burned, etc. The data is available for the forest management unit – OE Sežana: [Forest Management Plan OE Sežana](#), whose area corresponds approximately to that of Forest Fire Hazard Map. Average growing stocks from forest management plans were applied.

Note that wildfires are not covered by the national forest inventory (FECS) because the applied grid size 4 km × 4 km is too large, so there is no double counting of CO<sub>2</sub> emissions from wildfires in forest land remaining forest land.

**Table 6.4.7: Productive forest land affected by wildfires and resulting GHG emissions 1986-2020**

Year	Area (ha)	CO <sub>2</sub> (kt)	CO (kt)	CH <sub>4</sub> (kt)	NO <sub>x</sub> (kt)	N <sub>2</sub> O (kt)	NMVOC (kt)
2020	73.38	7.17	0.49	0.02	0.01	0.00	0.05
2019	72.75	7.01	0.48	0.02	0.01	0.00	0.05
2018	15.15	1.44	0.10	0.00	0.00	0.00	0.01
2017	176.47	16.64	1.14	0.05	0.03	0.00	0.11
2016	237.41	22.39	1.53	0.07	0.04	0.00	0.14
2015	47.98	4.48	0.31	0.01	0.01	0.00	0.03
2014	13.03	1.22	0.08	0.00	0.00	0.00	0.01
2013	48.36	4.42	0.30	0.01	0.01	0.00	0.03
2012	606.53	53.30	3.64	0.16	0.10	0.01	0.34
2011	159.08	14.12	0.96	0.04	0.03	0.00	0.09
2010	52.06	4.62	0.32	0.01	0.01	0.00	0.03
2009	114.73	10.19	0.70	0.03	0.02	0.00	0.07
2008	46.69	4.10	0.28	0.01	0.01	0.00	0.03
2007	98.61	8.76	0.60	0.03	0.02	0.00	0.06
2006	1022.81	85.16	5.81	0.26	0.16	0.01	0.54
2005	142.23	11.59	0.79	0.04	0.02	0.00	0.07
2004	76.87	6.12	0.42	0.02	0.01	0.00	0.04
2003	1592.84	124.74	8.51	0.37	0.24	0.02	0.80
2002	77.47	5.96	0.41	0.02	0.01	0.00	0.04
2001	240.36	18.17	1.24	0.05	0.04	0.00	0.12
2000	124.14	9.22	0.63	0.03	0.02	0.00	0.06
1999	321.10	23.26	1.59	0.07	0.04	0.00	0.15

Year	Area (ha)	CO <sub>2</sub> (kt)	CO (kt)	CH <sub>4</sub> (kt)	NO <sub>x</sub> (kt)	N <sub>2</sub> O (kt)	NM VOC (kt)
1998	725.10	51.28	3.50	0.15	0.10	0.01	0.33
1997	383.33	26.45	1.80	0.08	0.05	0.00	0.17
1996	243.75	16.40	1.12	0.05	0.03	0.00	0.11
1995	148.88	9.76	0.67	0.03	0.02	0.00	0.06
1994	835.47	53.34	3.64	0.16	0.10	0.01	0.34
1993	1196.92	74.35	5.07	0.22	0.14	0.01	0.47
1992	344.97	20.84	1.42	0.06	0.04	0.00	0.13
1991	559.51	32.83	2.24	0.10	0.06	0.01	0.21
1990	615.77	35.07	2.39	0.11	0.07	0.01	0.22
1989	120.00	6.74	0.46	0.02	0.01	0.00	0.04
1988	181.75	10.05	0.69	0.03	0.02	0.00	0.06
1987	393.00	21.41	1.46	0.06	0.04	0.00	0.14
1986	515.00	27.63	1.88	0.08	0.05	0.01	0.18

Data for the period up to 2004 for the Sežana forest management unit are aggregated and available only for decades (1980, 1990, 2000) as the duration of the inventory cycle is 10 years. 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.

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 6.2.1 and chapter 6.3.2. 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 2002-2012 is between 0.53 and 16.3 kha according to land use change matrices (Table 6.3.1.-Table 6.3.5). As described in chapter 6.2.1 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.

$$\Delta C_B = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L \quad (\text{Equation 12})$$

$\Delta C_B$  – annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr<sup>-1</sup>

$\Delta C_G$  – annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr<sup>-1</sup>

$\Delta C_{\text{CONVERSION}}$  – initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr<sup>-1</sup>

$\Delta C_L$  – 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<sup>-1</sup>

$$\Delta C_{\text{CONVERSION}} = \sum [(B_{\text{AFTER}} - B_{\text{BEFORE}}) \times \Delta A] \times CF \quad (\text{Equation 13})$$

$\Delta C_{\text{CONVERSION}}$  – initial change in biomass carbon stocks on land converted to another land category, tonnes C yr<sup>-1</sup>

$B_{\text{AFTER}}$  – biomass stocks on land type  $i$  immediately after the conversion, tonnes d.m. ha<sup>-1</sup>

$B_{\text{BEFORE}}$  – biomass stocks on land type  $i$  before the conversion, tonnes d.m. ha<sup>-1</sup>

$\Delta A$  – annual area of land use converted to forest land, ha yr<sup>-1</sup>

$CF$  – carbon fraction of dry matter, tonne C (tonnes d.m.)<sup>-1</sup>

### **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.

$$\Delta C_{\text{DOM}} = \frac{(C_n - C_o) \cdot A_{on}}{T_{on}} \quad (\text{Equation 14})$$

$\Delta C_{\text{DOM}}$  – annual change in carbon stocks in dead wood or litter, tonnes C yr<sup>-1</sup>

$C_o$  – dead wood/litter stock, under the old land-use category, tonnes C ha<sup>-1</sup>

$C_n$  – dead wood/litter stock, under the new land-use category, tonnes C ha<sup>-1</sup>

$A_{on}$  – 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 average carbon stocks in mineral soils of forest land and grassland.

$$\Delta C_{\text{Mineral}} = \frac{(SOC_0 - SOC_{(0-T)})}{D} \quad \text{(Equation 15)}$$

$\Delta C_{\text{Mineral}}$  - annual change in carbon stocks in mineral soils, tonnes C yr<sup>-1</sup>

$SOC_0$  – average carbon stock in forest soils, tonnes C ha<sup>-1</sup>

$SOC_{0-T}$  average carbon stock in grassland soils, tonnes C ha<sup>-1</sup>

$D$  – transition period (default = 20 years)

Country-specific value for forest soil ( $SOC_{\text{FL}} = 103.31 \text{ t C ha}^{-1}$ ) was estimated from forest soil monitoring (Table 6.4.5). Country-specific values for annual and perennial grassland soil ( $SOC_{\text{GL}_a} = 94.86 \text{ t C ha}^{-1}$ ,  $SOC_{\text{GL}_w} = 101.53 \text{ t C ha}^{-1}$ ) were estimated from agricultural soil monitoring (Table 6.3.11).

### 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<sub>2</sub> 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 CRF 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 wood growing stock (carbon stock) and dead wood stock as basis for KP/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 6.4.8.

**Table 6.4.8: 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

For 2019, recalculations were made in forest land remaining forest land as the projected growing stock for 2020 was taken into account according to the Global Forest Resources Assessment 2020. In 2020, the first panel of the new NFI (grid 2 x 2 km) was established and about 760 plots were monitored for the first time. The latter are therefore not comparable to

the old plots on the 4 x 4 km grid. The new plots will be re-surveyed after 5 years, when the NFI will provide first results on increment, harvest and mortality.

For the period 1986-2019, recalculations in forest land remaining forest land were made because there was an incorrect reference to the mass of available fuel in the estimate of emissions from biomass burning. The reference in the Excel spreadsheet was linked to soil organic carbon and not litter and deadwood, resulting in overestimated emissions.

The recalculation of land converted to forest land was made for the period 1986-2019 based on improved emission factors for soil organic carbon (SOC) for cropland, grassland and settlements.

.

#### **6.4.8 Source specific planned improvements**

In subsequent years, Slovenia will continue monitoring and data collection as part of the national forest inventory. The sample plots of the second panel were monitored in 2021. In addition, Slovenia plans to improve estimates of GHG emissions from biomass burning, as the Slovenia Forest Service, which has been collecting data since 1995, has provided new and detailed data on forest fires.

## **6.5 Cropland (4B)**

### **6.5.1 Source category description**

The cropland category includes CO<sub>2</sub> 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 % of the country's land area in 2020. 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 28% (i.e. from 261.82 to 188.08 Gg CO<sub>2</sub>) between 1986 and 2020. Cropland remaining Cropland and Land converted to Cropland are key categories according to trend analysis.

Table 6.5.1: Activity data for Cropland (1986 – 2020) 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									
2020	240.40	2.36	217.09	23.31	1.45	21.63	NO	0.23	NO
2019	243.10	2.35	219.54	23.56	1.48	21.84	NO	0.24	NO
2018	245.80	2.49	221.99	23.81	1.50	22.05	NO	0.26	NO
2017	248.50	2.50	224.44	24.06	1.53	22.26	NO	0.27	NO
2016	251.20	2.50	226.88	24.32	1.55	22.48	NO	0.29	NO
2015	253.90	2.50	229.33	24.57	1.58	22.69	NO	0.30	NO
2014	256.60	2.50	232.31	24.29	1.64	22.23	NO	0.42	NO
2013	259.30	2.35	235.37	23.93	1.76	21.63	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 – 2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>								
2020	188.08	86.19	101.89	27.96	73.67	NA	0.26	NA
2019	185.38	84.85	100.53	27.78	72.63	NA	0.12	NA
2018	187.71	88.54	99.17	27.60	71.59	NA	-0.02	NA
2017	185.83	87.72	98.12	27.73	70.55	NA	-0.16	NA
2016	183.43	86.36	97.07	27.85	69.51	NA	-0.30	NA
2015	182.75	86.74	96.01	27.98	68.47	NA	-0.44	NA
2014	179.39	85.73	93.67	28.21	67.09	NA	-1.63	NA
2013	171.05	79.93	91.12	28.57	65.37	NA	-2.81	NA
2012	150.58	77.38	73.19	30.84	46.19	NA	-3.84	NA
2011	144.92	73.95	70.97	30.58	45.68	NA	-5.28	NA
2010	147.43	78.67	68.76	30.31	45.16	NA	-6.72	NA
2009	144.73	77.21	67.52	29.99	46.48	NA	-8.95	NA
2008	142.19	75.91	66.28	29.67	47.80	NA	-11.18	NA
2007	140.13	75.08	65.05	29.34	49.11	NA	-13.41	NA
2006	156.20	74.36	81.84	41.39	55.40	NA	-14.95	NA
2005	155.72	75.09	80.63	40.78	56.53	NA	-16.68	NA
2004	152.44	73.01	79.43	40.18	57.66	NA	-18.41	NA
2003	149.54	71.30	78.23	39.58	58.79	NA	-20.14	NA
2002	133.53	68.33	65.20	33.76	53.68	NA	-22.23	NA
2001	134.59	70.21	64.38	33.28	55.16	NA	-24.07	NA
2000	131.55	67.92	63.63	32.90	56.64	NA	-25.90	NA
1999	131.43	68.53	62.89	32.51	58.12	NA	-27.74	NA
1998	130.78	68.63	62.15	32.12	59.60	NA	-29.57	NA
1997	128.84	67.43	61.41	31.74	61.08	NA	-31.41	NA
1996	128.11	67.45	60.66	31.35	62.55	NA	-33.24	NA
1995	133.37	67.55	65.82	42.28	55.01	NA	-31.47	NA
1994	130.71	64.48	66.23	41.65	56.84	NA	-32.26	NA
1993	129.29	62.65	66.63	41.02	58.67	NA	-33.05	NA
1992	128.36	61.32	67.04	40.39	60.50	NA	-33.84	NA
1991	129.58	62.13	67.44	39.75	62.33	NA	-34.63	NA
1990	264.66	65.06	199.60	33.02	199.28	NA	-32.70	NA
1989	265.42	66.29	199.13	32.55	199.28	NA	-32.70	NA
1988	264.57	65.91	198.66	32.08	199.28	NA	-32.70	NA
1987	263.24	65.05	198.20	31.61	199.28	NA	-32.70	NA
1986	261.82	64.09	197.73	31.14	199.28	NA	-32.70	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**

The annual emissions from cropland remaining cropland ranged from 64.09 Gg CO<sub>2</sub> in 1986 to 82.92 Gg CO<sub>2</sub> in 2019.

**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 1986-2020 in ha**

Year	Intensive orchards	Extensive orchards	Vineyards	Olive groves	Other perennial crops	Total area
2020	2275	15849	14181	1820	1365	35490
2019	2296	15993	14310	1837	1377	35812
2018	2316	16137	14438	1853	1390	36134
2017	2337	16280	14566	1869	1402	36455
2016	2357	16423	14694	1886	1414	36775
2015	2378	16566	14823	1902	1427	37096
2014	2422	16870	15094	1937	1453	37776
2013	2469	17202	15391	1975	1482	38519
2012	2509	17481	15641	2007	1506	39145
2011	2388	19255	15250	1463	1232	39588
2010	2415	19473	15423	1480	1246	40037
2009	2426	19562	15493	1487	1252	40220
2008	2437	19651	15564	1494	1258	40403
2007	2448	19742	15636	1500	1263	40589
2006	2459	19831	15706	1507	1269	40773
2005	2518	19531	16937	1373	763	41123
2004	2537	19682	17068	1384	769	41441
2003	2559	19849	17212	1396	775	41791
2002	2580	20015	17357	1407	782	42141
2001	2559	19852	17215	1396	775	41798
2000	2538	19689	17074	1384	769	41455
1999	2517	19526	16933	1373	763	41112
1998	2496	19364	16792	1362	756	40770
1997	2475	19201	16651	1350	750	40427
1996	2454	19038	16510	1339	744	40084
1995	2433	18875	16368	1327	737	39741
1994	2466	19132	16591	1345	747	40281
1993	2499	19388	16813	1363	757	40821
1992	2532	19645	17036	1381	767	41361
1991	2565	19901	17258	1399	777	41901
1990	2598	20158	17481	1417	787	42441
1989	2575	19980	17326	1405	780	42066
1988	2553	19801	17172	1392	773	41691
1987	2530	19623	17017	1380	767	41316
1986	2507	19445	16863	1367	760	40941

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 NIR. According to this approach, the annual change in biomass was calculated using the Equation 16.

$$\Delta C = A_0 \times G_i - (A_{0-T} \times 1/R \times C_B) \quad \text{(Equation 16)}$$

$\Delta C$  – annual change in biomass

$G$  – biomass accumulation rate

$i$  – perennial crop type

$R$  – rotation period

$C_B$  – biomass 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 <sup>-1</sup> )	Above- and below-ground carbon stock (t C ha <sup>-1</sup> )	Biomass accumulation rate (t C ha <sup>-1</sup> yr <sup>-1</sup> )	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<sup>-1</sup> 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<sup>-1</sup>). This value was used to estimate emissions and removals from land conversion to cropland and vice versa.

### Perennial Cropland converted to annual Cropland

The average annual land-use change from perennial Cropland to annual Cropland from 1986 to 2012 was 85 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.

$$\Delta C_B = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L \quad (\text{Equation 17})$$

$\Delta C_B$  – annual change in carbon stocks in biomass on land converted to annual cropland, in t C yr<sup>-1</sup>

$\Delta C_G$  – annual increase in carbon stocks in biomass due to growth on land converted to annual cropland, in tonnes C yr<sup>-1</sup>

$\Delta C_{\text{CONVERSION}}$  – initial change in carbon stocks in biomass on land converted to annual cropland, in t C yr<sup>-1</sup>

$\Delta C_L$  – annual decrease in biomass carbon stocks due to losses on land converted to annual cropland, in t C yr<sup>-1</sup>

$$\Delta C_{\text{CONVERSION}} = \sum [(B_{\text{AFTER}} - B_{\text{BEFORE}}) \times \Delta A] \times CF \quad (\text{Equation 18})$$

$\Delta C_{\text{CONVERSION}}$  – initial change in biomass carbon stocks on land converted to annual cropland, t C yr<sup>-1</sup>

$B_{\text{AFTER}}$  – biomass stocks immediately after the conversion, t d.m. ha<sup>-1</sup>

$B_{\text{BEFORE}}$  – biomass stocks before the conversion, t d.m. ha<sup>-1</sup>

$\Delta A$  – annual area of land converted to annual cropland, ha yr<sup>-1</sup>

$CF$  – carbon fraction of dry matter, t C (t d.m.)<sup>-1</sup>

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 ( $C_{\text{BEFORE}} = 15.77 \text{ t C ha}^{-1}$ ) 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 1986 to 2012 was 161 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 ( $\Delta C_G = 0.789 \text{ t C ha}^{-1} \text{ yr}^{-1}$ ) 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 ( $C_{\text{BEFORE}} = 2.76 \text{ t C ha}^{-1}$ ) 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 method 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<sup>-1</sup>) was calculated as a weighted average based on the estimates for vineyards, intensive orchards and olive groves.

### **Carbon stock changes in soils**

#### **Mineral soils**

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 occurred since 2007. Therefore, emissions and removals from arable mineral soils are reported only from 2007.

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 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. The input data are available since 2007, so it was technically not possible to make a proper stratification, as the data for land use, management and input were not available. Second, after 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.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i} (SOC_{REF_{c,s,i}} \bullet F_{LU_{c,s,i}} \bullet F_{MG_{c,s,i}} \bullet F_{I_{c,s,i}} \bullet A_{c,s,i})$$

(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 2,356 ha in 2020. 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.

$$\Delta C = \sum (A * EF) \quad \text{(Equation 20)}$$

$A$  – land area of organic soils

$EF$  – emission factor for climate type ( $10\ t\ ha^{-1}$ )

### 6.5.4.2 Land converted to Cropland

The average annual area converted from other land uses to cropland during 1986-2012 is 1,251 ha; 640 ha to annual cropland and 611 ha to perennial cropland according to 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.

In 2002-2012, the average annual area converted from forest land to cropland is 392 ha (to annual cropland: 23 ha; to perennial cropland: 369 ha). The average annual area converted from grassland to cropland is 2,463 ha (to annual cropland: 2,177 ha; to perennial cropland: 286 ha).

### Carbon stock changes in living biomass

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.

$$\Delta C_B = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L \quad (\text{Equation 21})$$

$\Delta C_B$  – annual change in carbon stocks in biomass on land converted to cropland, in t C yr<sup>-1</sup>

$\Delta C_G$  – annual increase in carbon stocks in biomass due to growth on land converted to cropland, in tonnes C yr<sup>-1</sup>

$\Delta C_{\text{CONVERSION}}$  – initial change in carbon stocks in biomass on land converted to cropland, in t C yr<sup>-1</sup>

$\Delta C_L$  – annual decrease in biomass carbon stocks due to loss on land converted to cropland, in t C yr<sup>-1</sup>

$$\Delta C_{\text{CONVERSION}} = \sum [(B_{\text{AFTER}} - B_{\text{BEFORE}}) \times \Delta A] \times CF \quad (\text{Equation 22})$$

$\Delta C_{\text{CONVERSION}}$  – initial change in biomass carbon stocks on land converted to cropland, t C yr<sup>-1</sup>

$B_{\text{AFTER}}$  – biomass stocks immediately after the conversion, t d.m. ha<sup>-1</sup>

$B_{\text{BEFORE}}$  – biomass stocks before the conversion, t d.m. ha<sup>-1</sup>

$\Delta A$  – annual area of land converted to cropland, ha yr<sup>-1</sup>

$CF$  – carbon fraction of dry matter, t C (t d.m.)<sup>-1</sup>

A country specific value for the annual accumulation rate of perennial crop ( $\Delta C_G = 0.789$  t C ha<sup>-1</sup>) was used. The growing stock of forest land ( $C_{\text{BEFORE}}$ ) is presented in the subsection 6.4.4.1. The country-specific value for biomass carbon stock of annual grassland is 1.89 t C ha<sup>-1</sup> and for biomass carbon stock of perennial grassland is 48.15 t C ha<sup>-1</sup> (i.e. above- and below-ground biomass).

### **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:

$$\Delta C_{LC_{\text{DOM}}} = \Delta C_{LC_{\text{DW}}} + \Delta C_{LC_{\text{LT}}} \quad (\text{Equation 23})$$

$\Delta C_{LC_{\text{DOM}}}$  – annual change in carbon stocks in dead organic matter [t C yr<sup>-1</sup>]

$\Delta C_{LC_{\text{DW}}}$  – change in carbon stocks in dead wood [t C yr<sup>-1</sup>]

$\Delta C_{LC_{\text{LT}}}$  – change in carbon stocks in litter [t C yr<sup>-1</sup>]

For calculations of annual change in carbon stocks in dead wood the following equation was used:

$$\Delta C_{LC_{\text{DW}}} = \text{annual area of converted land} \times \Delta C_{\text{conversion}} \quad (\text{Equation 24})$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is 0

$C_{\text{before}}$  – carbon stock in dead wood [t C ha<sup>-1</sup>]

Values for carbon stock in dead wood ( $C_{\text{before}}$ ) 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:

$$\Delta C_{LC_{LT}} = \text{annual area of converted land} * \Delta C_{\text{conversion}} \quad (\text{Equation 25})$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is 0

$C_{\text{before}}$  – carbon stock in litter [ $\text{t C ha}^{-1}$ ]

The value for carbon stock in litter ( $C_{\text{before}} = 10.41 \text{ t C ha}^{-1}$ ) 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.

$$\Delta C_{LC_{\text{mineral}}} = \frac{[SOC_0 - SOC_{0-T}]}{T} \quad (\text{Equation 26})$$

$\Delta C_{LC_{\text{mineral}}}$  – annual change in carbon stock in mineral soils [ $\text{t C yr}^{-1}$ ]

$SOC_0$  – soil organic carbon stock in the inventory year [ $\text{t C ha}^{-1}$ ]

$SOC_{0-T}$  – soil organic carbon stock  $T$  years prior to the inventory [ $\text{t C ha}^{-1}$ ]

$T$  – 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:  $SOC_{CL_{\text{annual}}} = 86.00 \text{ t ha}^{-1}$ ; perennial cropland:  $SOC_{CL_{\text{perennial}}} = 77.80 \text{ t ha}^{-1}$ ) are presented in Table 6.3.11.

#### **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.

**N<sub>2</sub>O emissions from N mineralization/immobilization**

For calculations of N<sub>2</sub>O emissions 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<sub>2</sub>O 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 (CRF sector 3).

$$N_2O - N_{Direct} = N_2O_{Ninputs} - N$$

(Equation 27)

$$N_2O_{Ninputs} - N = EF_1 * F_{SOM}$$

$N_2O - N_{Direct}$  – annual direct N<sub>2</sub>O–N emissions produced from managed soils (kg N<sub>2</sub>O–N yr<sup>-1</sup>)

$F_{SOM}$  – 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<sup>-1</sup>)

$EF_1$  – IPCC default emission factor used to estimate direct N<sub>2</sub>O emissions from managed soils [kg N<sub>2</sub>O–N (kg N)<sup>-1</sup>]. The default value is 0.01 kg N<sub>2</sub>O–N (kg N)<sup>-1</sup>

According to 2006 Guidelines conversion of N<sub>2</sub>O–N emissions to N<sub>2</sub>O emissions for reporting purposes is performed by using the following equation: N<sub>2</sub>O = N<sub>2</sub>O–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:

$$F_{SOM} = \sum_{LU} \left[ \left( \Delta C_{Mineral, LU} * \frac{1}{R} \right) * 1000 \right] \quad \text{(Equation 28)}$$

$F_{SOM}$  – 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<sup>-1</sup>)

$\Delta C_{Mineral, LU}$  – 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<sub>2</sub>O–N/kg N) was used.

**Indirect N<sub>2</sub>O emissions from N leaching and run-off**

For estimation of indirect N<sub>2</sub>O 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 (CRF sector 3).

### 6.5.5 Uncertainties and time-series consistency

Uncertainties were analysed as uncertainty in activity data (Table 6.3.7) 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

The recalculation of land converted to cropland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

### 6.5.8 Source-specific planned improvements

No major improvements are planned for this category for the next annual submission.

## **6.6 Grassland (4C)**

### **6.6.1 Source category description**

Grassland category includes CO<sub>2</sub> 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 20.5% of country total area in 2020.

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 -302.91 to -404.43 Gg CO<sub>2</sub> between 1986 and 2020. Grassland remaining grassland (CO<sub>2</sub>) was identified as key source category according to the level and trend. Land converted to grassland (CO<sub>2</sub>) was identified as key source category according to trend.



Table 6.6.1: Activity data for Grassland in 1986 – 2020 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									
2020	415.06	1.18	346.94	68.12	8.62	57.13	0.35	1.10	0.92
2019	412.84	1.15	345.22	67.62	8.83	55.94	0.37	1.15	1.33
2018	410.62	1.09	343.49	67.13	9.03	54.76	0.39	1.21	1.74
2017	408.40	0.95	341.76	66.64	9.24	53.57	0.41	1.26	2.15
2016	406.18	0.95	340.03	66.15	9.45	52.39	0.44	1.31	2.56
2015	403.96	0.94	338.31	65.65	9.66	51.20	0.46	1.36	2.97
2014	401.74	0.99	334.70	67.04	10.02	50.95	0.46	2.34	3.27
2013	399.52	0.82	331.09	68.43	10.38	50.69	0.46	3.32	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 – 2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>								
2020	-404.43	-358.72	-45.71	79.41	-99.64	0.81	-13.74	-12.55
2019	-419.85	-373.72	-46.14	78.45	-92.41	0.64	-14.19	-18.63
2018	-437.78	-389.13	-48.65	77.41	-87.08	0.46	-14.65	-24.79
2017	-445.13	-402.69	-42.44	77.53	-74.88	0.31	-15.11	-30.31
2016	-471.30	-420.22	-51.08	76.84	-75.23	0.09	-15.56	-37.22
2015	-486.73	-435.50	-51.23	76.62	-68.41	-0.09	-16.02	-43.33
2014	-504.37	-439.34	-65.02	76.36	-67.34	-0.20	-27.16	-46.69
2013	-512.67	-441.35	-71.32	76.47	-60.45	-0.26	-38.30	-48.79
2012	-424.59	-422.92	-1.67	186.32	-85.39	-1.48	-48.64	-52.48
2011	-475.37	-444.73	-30.64	183.21	-95.91	-1.55	-59.50	-56.89
2010	-522.00	-465.42	-56.58	180.43	-104.45	-1.61	-70.32	-60.62
2009	-550.50	-462.80	-87.70	177.84	-105.48	-1.69	-84.31	-74.06
2008	-576.05	-459.55	-116.50	175.44	-105.38	-1.77	-98.27	-86.52
2007	-600.35	-456.17	-144.17	173.08	-104.99	-1.85	-112.23	-98.18
2006	-564.48	-495.90	-68.58	257.18	-91.85	-0.39	-124.27	-109.25
2005	-565.31	-460.49	-104.82	252.67	-93.20	-0.39	-137.66	-126.24
2004	-555.08	-423.54	-131.54	248.94	-91.01	-0.39	-150.85	-138.23
2003	-520.83	-383.82	-137.01	246.60	-82.37	-0.39	-163.68	-137.19
2002	-706.09	-397.91	-308.18	137.19	-109.27	0.71	-178.68	-158.14
2001	-718.20	-401.93	-316.27	135.42	-104.33	0.77	-192.41	-155.72
2000	-743.86	-407.04	-336.82	133.57	-103.30	0.83	-206.26	-161.67
1999	-782.71	-413.03	-369.67	131.37	-105.47	0.89	-220.20	-176.26
1998	-812.03	-418.33	-393.70	129.44	-105.16	0.94	-234.06	-184.86
1997	-838.43	-423.44	-414.99	127.58	-104.13	1.00	-247.91	-191.54
1996	-853.20	-427.86	-425.34	126.00	-100.61	1.06	-261.68	-190.11
1995	-420.99	-78.83	-342.16	169.00	-60.04	-0.30	-250.17	-200.67
1994	-457.42	-102.24	-355.18	166.49	-54.04	-0.31	-253.77	-213.55
1993	-428.11	-115.46	-312.65	165.50	-36.14	-0.33	-253.12	-188.55
1992	-461.21	-138.53	-322.68	163.03	-29.73	-0.34	-256.58	-199.06
1991	-525.69	-166.16	-359.53	159.88	-28.65	-0.36	-261.94	-228.46
1990	-277.03	194.77	-471.79	100.44	-80.94	-0.07	-257.72	-233.50
1989	-287.43	185.93	-473.36	98.87	-80.94	-0.07	-257.72	-233.50
1988	-284.72	180.25	-464.98	97.49	-79.99	-0.07	-256.79	-225.63
1987	-305.62	168.88	-474.50	95.78	-80.75	-0.07	-257.53	-231.93
1986	-302.91	163.21	-466.12	94.40	-79.80	-0.07	-256.60	-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**

##### **Carbon stock changes in living biomass**

##### **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<sup>-1</sup> year<sup>-1</sup> 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 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.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \quad \text{(Equation 29)}$$

$\Delta C_B$  – annual change in carbon stocks in biomass on land converted to annual grassland, in t C yr<sup>-1</sup>

$\Delta C_G$  – annual increase in carbon stocks in biomass due to growth on land converted to annual grassland, in tonnes C yr<sup>-1</sup>

$\Delta C_{CONVERSION}$  – initial change in carbon stocks in biomass on land converted to annual grassland, in t C yr<sup>-1</sup>

$\Delta C_L$  – annual decrease in biomass carbon stocks due to loss on land converted to annual grassland, in t C yr<sup>-1</sup>

$$\Delta C_{CONVERSION} = \sum [(B_{AFTER} - B_{BEFORE}) \times \Delta A] \times CF \quad \text{(Equation 30)}$$

$\Delta C_{CONVERSION}$  – initial change in biomass carbon stocks on land converted to annual grassland, t C yr<sup>-1</sup>

$B_{AFTER}$  – biomass stocks immediately after the conversion, t d.m. ha<sup>-1</sup>

$B_{BEFORE}$  – biomass stocks before the conversion, t d.m. ha<sup>-1</sup>

$\Delta A$  – annual area of land converted to annual grassland, ha yr<sup>-1</sup>

$CF$  – carbon fraction of dry matter, t C (t d.m.)<sup>-1</sup>

Country-specific carbon stock in perennial above-ground biomass of 35.02 t C ha<sup>-1</sup> was calculated 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<sup>-1</sup>, 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.

**Carbon stock changes in dead organic matter**

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.

**Carbon stock changes in soils**

For calculations of carbon stock changes in soils in grassland remaining grassland, the equation 2.24 (IPCC 2006) was used.

$$\Delta C_{GGsoils} = \Delta C_{GGmineral} - L_{GGorganic} + \Delta C_{inorganic} \quad \text{(Equation 31)}$$

$\Delta C_{GGsoils}$  - annual change in carbon stocks in soil [t C yr<sup>-1</sup>]

$\Delta C_{GGmineral}$  - annual change in carbon stocks in mineral soils [t C yr<sup>-1</sup>]

$L_{GGorganic}$  - annual loss of carbon from drained organic soils [t C yr<sup>-1</sup>]

$\Delta C_{GGinorganic}$  - annual change in inorganic carbon stocks from soils [t C yr<sup>-1</sup>]

**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<sup>-1</sup>) 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<sub>REF</sub>) and default stock change factors (F<sub>LU</sub>, F<sub>MG</sub>, F<sub>I</sub>) 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 occurred since 2007. Therefore, emissions and removals from annual grassland mineral soils are reported only from 2007 (see also description in subsection 6.5.4.1).

**Organic soils**

The total area of organic soils of grassland was 1.15 kha in 2019. Emissions from organic soils are not reported in the 2020 NIR submission. This is because the GPG2003 assumed that emissions from organic soils are caused by drainage and other management disturbances (e.g. grazing management practices). In contrast, 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. However, the organic soil (i.e. histosols) of the marshy grassland of Ljubljana Marsh, evidenced by the system of canals and ditches, can be

considered as drained. Thus, the activity data of the marshy grasslands of Ljubljana Marsh will be obtained to report the emissions in the next annual submissions.

#### 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 2002-2012 is 3,804 ha. The average annual area converted from Forest land in this period is 515 ha, from Settlements 438, from Wetlands 23 ha, and from Other land 364 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.

Country-specific values for carbon accumulation rate were obtained from the SORS database (annual grassland) and from the WISDOM study in 2006 (perennial grassland). The carbon stock in forest land ( $C_{\text{before}}$ ) is presented in subsection 6.4.4.1. The country-specific value for the biomass carbon stocks of perennial cropland ( $C_{\text{before}} = 15.77 \text{ t C ha}^{-1}$ ) was estimated from the monitoring of above-ground biomass on agricultural land (Mali et al., 2017b).

##### **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:

$$\Delta C_{LG_{DOM}} = \Delta C_{LG_{DW}} + \Delta C_{LG_{LT}} \quad \text{(Equation 32)}$$

$\Delta C_{LG_{DOM}}$  – annual change in carbon stocks in dead organic matter [ $\text{t C yr}^{-1}$ ]

$\Delta C_{LG_{DW}}$  – change in carbon stocks in dead wood [ $\text{t C yr}^{-1}$ ]

$\Delta C_{LG_{LT}}$  – change in carbon stocks in litter [ $\text{t C yr}^{-1}$ ]

For calculations of annual change in carbon stocks in dead wood the following equation was used:

$$\Delta C_{LG_{DW}} = \text{annual area of converted land} * \Delta C_{\text{conversion}} \quad \text{(Equation 33)}$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is  $2.27 \text{ t C ha}^{-1}$

$C_{\text{before}}$  – carbon stock in dead wood [ $\text{t C ha}^{-1}$ ]

Values for carbon stock in dead wood ( $C_{\text{before}}$ ) were calculated from FECS 2007, 2012 and 2018.

For calculations of annual change in carbon stocks in litter the following equation was used:

$$\Delta C_{LG_{LT}} = \text{annual area of converted land} * \Delta C_{\text{conversion}} \quad (\text{Equation 34})$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is  $7.58 \text{ t C ha}^{-1}$

$C_{\text{before}}$  – carbon stock in litter [ $\text{t C ha}^{-1}$ ]

The value for carbon stock in litter ( $C_{\text{before}} = 10.41 \text{ t C ha}^{-1}$ ) was used from the Slovenian Forestry Institute study (Kobal and Simončič, 2011).

Country-specific values for dead wood and litter for  $C_{\text{after}}$  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.

$$\Delta C_{LG_{\text{mineral}}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad (\text{Equation 35})$$

$\Delta C_{LG_{\text{mineral}}}$  – annual change in carbon stock in mineral soils [ $\text{t C yr}^{-1}$ ]

$SOC_0$  – soil organic carbon stock in the inventory year [ $\text{t C ha}^{-1}$ ]

$SOC_{0-T}$  – soil organic carbon stock  $T$  years prior to the inventory [ $\text{t C ha}^{-1}$ ]

$T$  – 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:  $SOC_{GL_{\text{annual}}} = 94.86 \text{ t C ha}^{-1}$ ; grassland perennial:  $SOC_{GL_{\text{perennial}}} = 101.53 \text{ t C ha}^{-1}$ ) are presented in Table 6.3.11.

### **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<sub>2</sub>O emissions from N mineralization/immobilization**

Equations 11.1 and 11.8 and default emission factors from Table 11.1 (IPCC 2006) were used for calculations of N<sub>2</sub>O emissions associated with land conversion to grassland. The Tier 1 method was used to estimate direct N<sub>2</sub>O emissions due to land use conversions from forest land and cropland to grassland.

**Indirect N<sub>2</sub>O emission from N leaching and run-off**

For the estimation of indirect N<sub>2</sub>O 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<sub>2</sub>O emissions are estimated due to land use changes from forest land and cropland to grassland.

**6.6.5 Uncertainties and time-series consistency**

Uncertainties were analysed as uncertainty in activity data (Table 6.3.7) 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 2021 NIR submission. However, a general QA/QC was carried 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**

The recalculation of land converted to grassland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

**6.6.8 Source-specific planned improvements**

No major improvements are planned for this category for 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, grassland 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 0.7 % of the country's area in 2020. Wetlands include: swamps, reeds, other marshy areas and water bodies (inland water bodies). Emissions from wetlands ranged from 1.81 Gg CO<sub>2</sub> in 1986 to 2.13 Gg CO<sub>2</sub> in 2020. In 1996 and 1997 wetlands acted as a small net sink of emissions.

Table 6.7.1: Activity data of Wetlands 1986 – 2020 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								
2020	14.35	13.40	0.95	0.53	NO	0.42	NO	NO
2019	14.35	13.43	0.92	0.54	NO	0.38	NO	NO
2018	14.35	13.45	0.90	0.56	NO	0.34	NO	NO
2017	14.35	13.48	0.87	0.57	NO	0.30	NO	NO
2016	14.35	13.50	0.85	0.59	NO	0.26	NO	NO
2015	14.35	13.53	0.82	0.60	NO	0.22	NO	NO
2014	14.35	13.47	0.88	0.62	NO	0.26	NO	NO
2013	14.35	13.41	0.94	0.64	NO	0.30	NO	NO
2012	14.35	13.35	1.00	0.66	NO	0.34	NO	NO
2011	14.27	13.25	1.02	0.61	NO	0.40	NO	NO
2010	14.18	13.15	1.03	0.57	NO	0.47	NO	NO
2009	14.10	13.05	1.05	0.52	NO	0.52	NO	NO
2008	14.02	12.95	1.07	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	1.49	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	14.87	12.87	2.00	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 – 2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>					
2020	2.13	NO,NE	2.13	-1.00	NO	3.14	NO	NO
2019	2.22	NO,NE	2.22	-1.03	NO	3.25	NO	NO
2018	2.31	NO,NE	2.31	-1.06	NO	3.37	NO	NO
2017	2.39	NO,NE	2.39	-1.09	NO	3.48	NO	NO
2016	2.48	NO,NE	2.48	-1.11	NO	3.59	NO	NO
2015	2.57	NO,NE	2.57	-1.14	NO	3.71	NO	NO
2014	2.36	NO,NE	2.36	-1.18	NO	3.54	NO	NO
2013	2.16	NO,NE	2.16	-1.22	NO	3.38	NO	NO
2012	26.65	NO,NE	26.65	27.71	NO	-1.06	NO	NO
2011	26.13	NO,NE	26.13	27.41	NO	-1.28	NO	NO
2010	25.61	NO,NE	25.61	27.10	NO	-1.49	NO	NO
2009	25.09	NO,NE	25.09	26.79	NO	-1.70	NO	NO
2008	24.58	NO,NE	24.58	26.47	NO	-1.90	NO	NO
2007	24.06	NO,NE	24.06	26.16	NO	-2.10	NO	NO
2006	6.80	NO,NE	6.80	9.21	NO	-2.42	NO	NO
2005	6.39	NO,NE	6.39	9.06	NO	-2.67	NO	NO
2004	5.98	NO,NE	5.98	8.91	NO	-2.93	NO	NO
2003	5.57	NO,NE	5.57	8.76	NO	-3.19	NO	NO
2002	1.14	NO,NE	1.14	4.59	NO	-3.45	NO	NO
2001	0.78	NO,NE	0.78	4.49	NO	-3.71	NO	NO
2000	0.43	NO,NE	0.43	4.40	NO	-3.97	NO	NO
1999	0.08	NO,NE	0.08	4.31	NO	-4.23	NO	NO
1998	-0.27	NO,NE	-0.27	4.21	NO	-4.49	NO	NO
1997	-0.62	NO,NE	-0.62	4.12	NO	-4.74	NO	NO
1996	-0.97	NO,NE	-0.97	4.03	NO	-5.00	NO	NO
1995	1.17	NO,NE	1.17	5.88	NO	-4.71	NO	NO
1994	1.08	NO,NE	1.08	5.77	NO	-4.69	NO	NO
1993	1.00	NO,NE	1.00	5.67	NO	-4.67	NO	NO
1992	0.91	NO,NE	0.91	5.56	NO	-4.66	NO	NO
1991	0.82	NO,NE	0.82	5.46	NO	-4.64	NO	NO
1990	2.27	NO,NE	2.27	6.93	NO	-4.66	NO	NO
1989	2.16	NO,NE	2.16	6.81	NO	-4.66	NO	NO
1988	2.04	NO,NE	2.04	6.70	NO	-4.66	NO	NO
1987	1.92	NO,NE	1.92	6.58	NO	-4.66	NO	NO
1986	1.81	NO,NE	1.81	6.46	NO	-4.66	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<sup>2</sup>), is subject to regular flooding and drainage activities (e.g. clearing of the

drainage channels), emissions do occur in this wetland. However, there is currently insufficient data to apply the Wetlands Supplement.

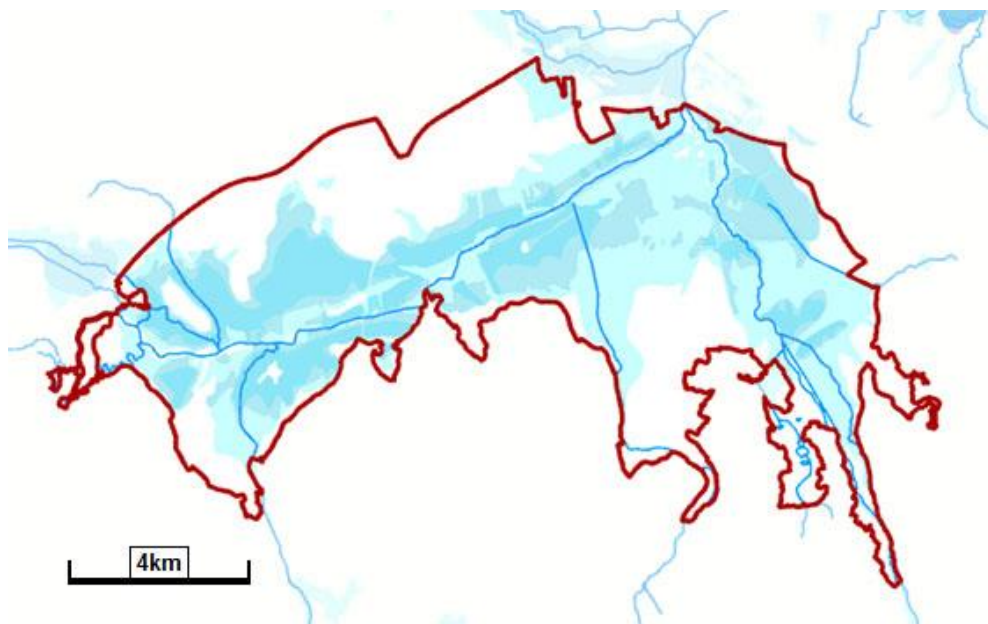


Figure 6.7.1 : Ljubljana Marsh and the Ljubljanica river basin with floodwater area (shaded)

#### 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, excluding 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:

$$\Delta C_{LWflood, LB} = \left[ \sum_i A_i * (B_{After} - B_{Before}) \right] * CF \quad \text{(Equation 36)}$$

$A_i$  – 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

$$\Delta C_{LG \text{ mineral}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad \text{(Equation 37)}$$

$\Delta C_{LG \text{ mineral}}$  – annual change in carbon stock in mineral soils [t C yr<sup>-1</sup>]

$SOC_0$  – soil organic carbon stock in the inventory year [t C ha<sup>-1</sup>]

$SOC_{0-T}$  – soil organic carbon stock T years prior to the inventory [t C ha<sup>-1</sup>]

T – time [default 20 years]

A – land area [ha]

$$SOC = SOC_{WL}$$

$SOC_{WL}$  – country-specific value for organic carbon stock in mineral soil

The country-specific value for organic carbon stock in mineral soil for wetlands:  $SOC_{WL} = 113.68 \text{ t ha}^{-1}$  is presented in Table 6.3.11.

**6.7.5 Uncertainties and time-series consistency**

Uncertainties were applied in accordance with the default values for emission factors (IPCC, 2006), while uncertainties for activity data are presented in Table 6.3.7.

**6.7.6 Category-specific QA/QC and verification**

No specific QA/QC and verification for grassland was used in the 2022 NIR submission. However, a general QA/QC was carried out considering the verification of figures, correctness of calculation used, data sources etc. in the category as it was subject to source-specific recalculation.

**6.7.7 Category-specific recalculations**

The recalculation of land converted to wetlands was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

**6.7.8 Source-specific planned improvements**

Two public tenders are planned for 2022 to collect additional data on organic carbon in the soil of the Ljubljansko barje wetlands, which will help improve emissions estimates. Several stakeholder meetings are planned to improve the use of all available national data to improve wetland emission estimates and harmonise reporting at the international level.

## **6.8 Settlements (4E)**

### **6.8.1 Source category description**

Settlements covered 5.8% of country area in 2020. 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.

Net emissions in settlements decreased from 417.36 to 128.92 Gg CO<sub>2</sub> between 1986 and 2020.

Settlements remaining settlements (CO<sub>2</sub>) was identified as key source category based on the level and trend.

Table 6.8.1: Activity data of Settlements (1986-2020) 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					
2020	116.81	98.43	18.38	4.25	5.85	7.73	0.55	NO
2019	116.59	96.71	19.88	4.48	6.33	8.44	0.62	NO
2018	116.37	95.00	21.37	4.70	6.81	9.16	0.70	NO
2017	116.15	93.29	22.86	4.93	7.29	9.87	0.77	NO
2016	115.93	91.58	24.35	5.15	7.76	10.59	0.85	NO
2015	115.69	89.87	25.82	5.38	8.24	11.28	0.92	NO
2014	115.49	87.75	27.74	5.50	8.84	12.44	0.96	NO
2013	115.27	85.63	29.64	5.62	9.44	13.58	1.00	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 – 2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>					
2020	128.92	-94.99	223.90	76.95	51.34	86.25	9.36	NO
2019	145.56	-93.34	238.89	79.42	55.41	93.66	10.40	NO
2018	162.20	-91.68	253.88	81.89	59.48	101.07	11.43	NO
2017	179.15	-90.03	269.18	84.67	63.55	108.48	12.47	NO
2016	196.10	-88.38	284.47	87.45	67.62	115.90	13.50	NO
2015	212.81	-86.73	299.54	90.23	71.70	123.08	14.54	NO
2014	234.22	-84.68	318.90	91.75	76.94	135.12	15.09	NO
2013	255.39	-82.63	338.03	93.27	82.18	146.94	15.65	NO
2012	358.96	-80.59	439.55	148.03	92.00	185.09	14.43	NO
2011	370.75	-78.59	449.33	146.91	94.93	192.24	15.26	NO
2010	382.53	-76.59	459.12	145.79	97.86	199.39	16.09	NO
2009	392.13	-74.84	466.97	144.31	96.40	209.48	16.78	NO
2008	401.72	-73.10	474.81	142.83	94.95	219.57	17.47	NO
2007	411.31	-71.35	482.66	141.35	93.49	229.66	18.16	NO
2006	552.67	-69.61	622.27	276.14	99.68	223.18	23.27	NO
2005	553.38	-67.97	621.35	268.50	97.07	232.50	23.27	NO
2004	554.10	-66.32	620.43	260.87	94.46	241.83	23.27	NO
2003	554.83	-64.68	619.52	253.25	91.84	251.16	23.27	NO
2002	463.43	-63.04	526.47	155.94	85.87	257.42	27.24	NO
2001	465.27	-61.38	526.65	152.61	82.66	264.76	26.62	NO
2000	467.40	-59.72	527.12	149.58	79.45	272.10	26.00	NO
1999	469.53	-58.06	527.59	146.54	76.24	279.44	25.38	NO
1998	471.65	-56.40	528.05	143.49	73.03	286.78	24.76	NO
1997	473.78	-54.74	528.52	140.45	69.81	294.12	24.14	NO
1996	475.90	-53.08	528.98	137.40	66.60	301.46	23.51	NO
1995	437.55	-51.42	488.96	98.56	60.61	309.98	19.80	NO
1994	435.47	-50.69	486.16	97.34	56.23	312.92	19.67	NO
1993	433.40	-49.96	483.35	96.12	51.85	315.86	19.53	NO
1992	431.32	-49.23	480.55	94.90	47.46	318.80	19.39	NO
1991	429.24	-48.50	477.74	93.67	43.08	321.74	19.25	NO
1990	418.62	-47.77	466.39	83.02	32.36	332.79	18.23	NO
1989	418.31	-47.39	465.69	82.32	32.36	332.79	18.23	NO
1988	417.99	-47.00	464.99	81.61	32.36	332.79	18.23	NO
1987	417.67	-46.61	464.29	80.91	32.36	332.79	18.23	NO
1986	417.36	-46.23	463.59	80.21	32.36	332.79	18.23	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%, which was used from the WISDOM (2006) study. 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<sup>-1</sup> year<sup>-1</sup> was used (IPCC 2019). Urban trees are assumed to be net sinks as the active growing period 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 2002-2012 is 1,666 ha. The average annual area converted from Forest land to Settlements is 258 ha. The average annual area converted from Cropland to Settlements is 465 ha, from Grassland to Settlements is 891 ha, and from Wetlands 52 ha.

According to the results from the point sampling there are no conversions from other land to settlements.

#### **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.

$$\Delta C_{LS\text{mineral}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad \text{(Equation 38)}$$

$\Delta C_{LS\text{mineral}}$  – annual change in carbon stock in mineral soils [t C yr<sup>-1</sup>]

$SOC_0$  – soil organic carbon stock in the inventory year [t C ha<sup>-1</sup>]

$SOC_{0-T}$  – soil organic carbon stock T years prior to the inventory [t C ha<sup>-1</sup>]

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.)

The soil organic carbon stock for settlements was estimated as half a value of the grassland annual value (i.e. 47.49 t C ha<sup>-1</sup>), assuming a constant share of sealed area in settlements is 50%. The expert assessment was made by visual interpretation of digital orthophotos in the period 2002-2012, which includes 20 samples over the country area.

### **N<sub>2</sub>O emissions from N mineralization/immobilization**

For calculations of N<sub>2</sub>O 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<sub>2</sub>O emissions are estimated due to land use conversions from forest land, cropland, grassland and wetlands to settlements.

### **Indirect N<sub>2</sub>O 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<sub>2</sub>O emissions from N mineralization due land use changes in mineral soils through leaching/runoff. Indirect N<sub>2</sub>O 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 NIR submission. However, a general QA/QC was carried 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**

The recalculation of land converted to settlements was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

## **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 1.6 % of the national land area in 2020. 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 13.84 to 3.81 Gg CO<sub>2</sub>) between 1986 and in 2020.

Table 6.9.1: Activity data of other land (1986-2020) 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					
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 (1986-2020) in Gg CO<sub>2</sub>

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 <sub>2</sub>								
2020	3.81	NA	3.81	3.86	NO	NO	NO	-0.05
2019	3.80	NA	3.80	3.86	NO	NO	NO	-0.06
2018	3.78	NA	3.78	3.86	NO	NO	NO	-0.07
2017	3.77	NA	3.77	3.86	NO	NO	NO	-0.09
2016	3.76	NA	3.76	3.86	NO	NO	NO	-0.10
2015	3.74	NA	3.74	3.86	NO	NO	NO	-0.11
2014	4.26	NA	4.26	4.37	NO	NO	NO	-0.11
2013	4.77	NA	4.77	4.89	NO	NO	NO	-0.11
2012	19.77	NA	19.77	19.88	NO	NO	NO	-0.11
2011	19.66	NA	19.66	19.77	NO	NO	NO	-0.11
2010	19.55	NA	19.55	19.66	NO	NO	NO	-0.11
2009	19.24	NA	19.24	19.36	NO	NO	NO	-0.11
2008	18.94	NA	18.94	19.05	NO	NO	NO	-0.11
2007	18.64	NA	18.64	18.75	NO	NO	NO	-0.11
2006	15.86	NA	15.86	15.12	NO	NO	NO	0.74
2005	15.71	NA	15.71	14.96	NO	NO	NO	0.74
2004	15.56	NA	15.56	14.81	NO	NO	NO	0.75
2003	15.42	NA	15.42	14.66	NO	NO	NO	0.75
2002	7.38	NA	7.38	5.14	NO	NO	NO	2.23
2001	7.71	NA	7.71	5.46	NO	NO	NO	2.25
2000	8.05	NA	8.05	5.79	NO	NO	NO	2.26
1999	8.38	NA	8.38	6.11	NO	NO	NO	2.27
1998	8.71	NA	8.71	6.43	NO	NO	NO	2.29
1997	9.05	NA	9.05	6.75	NO	NO	NO	2.30
1996	9.38	NA	9.38	7.07	NO	NO	NO	2.31
1995	20.96	NA	20.96	20.96	NO	NO	NO	NO
1994	20.57	NA	20.57	20.57	NO	NO	NO	NO
1993	20.19	NA	20.19	20.19	NO	NO	NO	NO
1992	19.80	NA	19.80	19.80	NO	NO	NO	NO
1991	19.42	NA	19.42	19.42	NO	NO	NO	NO
1990	14.31	NA	14.31	14.31	NO	NO	NO	NO
1989	14.19	NA	14.19	14.19	NO	NO	NO	NO
1988	14.07	NA	14.07	14.07	NO	NO	NO	NO
1987	13.96	NA	13.96	13.96	NO	NO	NO	NO
1986	13.84	NA	13.84	13.84	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<sub>2</sub> 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 predominantly 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<sup>-1</sup> was used. It was calculated 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**

The recalculation of land converted to other land was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

**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, veneer sheets, particle board, fibreboard, wood pulp, mechanical wood pulp, chemical wood pulp, paper and paperboard. Note that wood products in solid waste disposal sites (SWDS) are not included in the calculation of HWP carbon stock changes in the LULUCF sector.

In 2020, HWP contributed to a net removals of -142.18 kt CO<sub>2</sub> (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.

**Table 6.10.1: Emissions from Harvested wood products (1986-2020) in Gg CO<sub>2</sub>**

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 <sub>2</sub>					
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

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 <sub>2</sub>					
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 1986-2020 in m<sup>3</sup> or tons**

	Sawnwood [m3]	Wood panels [m3]	Paper and paperboard [tonnes]
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

	Sawnwood [m3]	Wood panels [m3]	Paper and paperboard [tonnes]
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

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 6.10.3: 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.

$$Inflow\ HWP = \sum_i^n (F_{DPPA\ i} \times HWP_i) \quad \text{(Equation 39)}$$

Where:

$HWP_i$  – primary product  $i$  (sawnwood, veneer, particle boards, fibreboards, wood pulp)

$F_{DPPA\ i}$  – 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)

$$F_{DPPA\ i} = \frac{Domestic\ INDRW\ Consumption_i}{WOOD\ Consumption_i} \quad \text{(Equation 40)}$$

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 ( $F_{SW+V}$ )

$$F_{SW+V} = \frac{\text{Production LOGS} - \text{Export LOGS}}{\text{Production LOGS} + \text{Import LOGS} - \text{Export LOGS}} \quad (\text{Equation 41})$$

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 ( $F_{WBP}$ )

$$F_{WBP} = \frac{\text{Domestic INDRW Consumption}_{WBP}}{\text{WOOD Consumption}_{WBP}} \quad (\text{Equation 42})$$

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 ( $F_{WP}$ )

$$F_{WP} = \frac{\text{Domestic INDRW Consumption}_{WP}}{\text{WOOD Consumption}_{WP}} \quad (\text{Equation 43})$$

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 the verification 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<sup>3</sup> and 0.58 t/m<sup>3</sup>, 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 (CRF sector 5)

### 7.1 Overview of sector

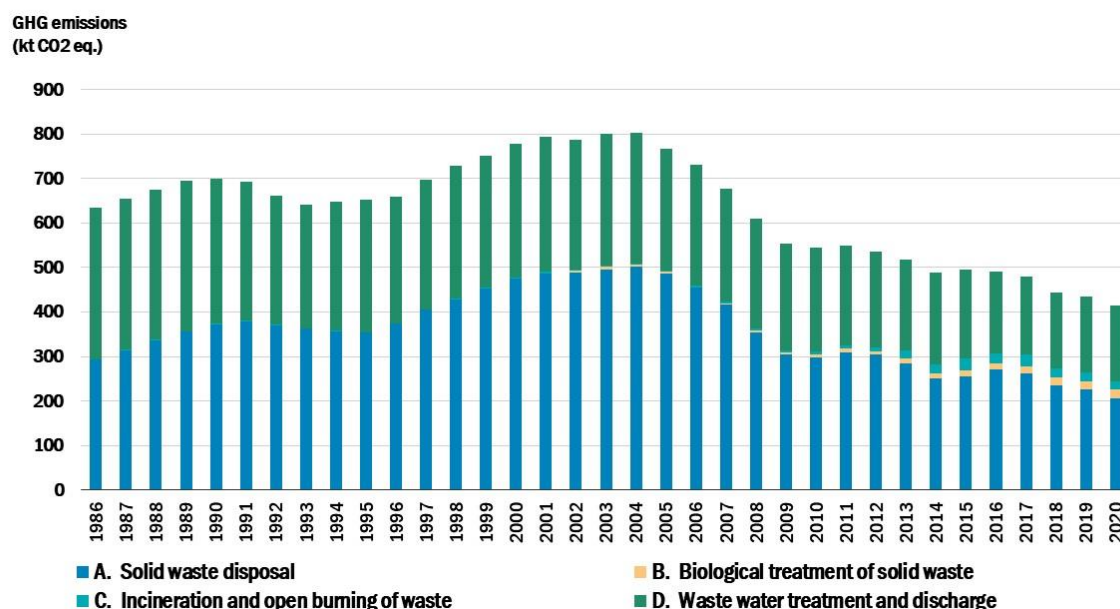
In this chapter the following sources are presented:

- Solid waste disposal (5.A),
- Biological treatment of solid waste – composting (CRF 5.B),
- Incineration of waste (CRF 5.C), and
- Wastewater treatment and discharge (CRF 5.D).

**Table 7.1.1: Methods, EFs used and key categories indications for the year 2020 in the Waste sector.**

	CO <sub>2</sub>			CH <sub>4</sub>			N <sub>2</sub> O		
	Method	EF	Key category	Method	EF	Key category	Method	EF	Key category
<b>Solid waste disposal</b>	NA	NA	NA	T2	CS, D	L	NA	NA	NA
<b>Composting</b>	NA	NA	NA	T1	D	-	T1	D	-
<b>Incineration</b>	T2	D	-	T2	D	-	T2	D	-
<b>Domestic WW</b>	NA	NA	NA	T1	CS, D	L	T1	D	-
<b>Industrial WW</b>	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<sub>2</sub> eq.**



In 2020, emissions from the Waste sector amounted to 415 Gg CO<sub>2</sub> eq, or 2.6 per cent of the total GHG emissions. Since 1986 emissions decreased by 34.5 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. Within the sector 49.7 per cent of the emissions were from solid waste disposal on land, followed by 40.9 per cent from wastewater handling, 4.7 per cent from waste incineration while remaining 4.7 per cent of emissions were from composting (Figure 7.1.1).

Methane emissions from the Waste sector are the second largest source of methane and represents 18.4% of all methane emissions in Slovenia in 2020. The fraction of methane emissions in this sector amounts to 84.1%, while the remaining part represent N<sub>2</sub>O (11.2%) and CO<sub>2</sub> emissions (4.7%).

In 2020, 7.7 million tons of all waste was generated in Slovenia, which is almost 9% less than a year earlier. Despite having declined by 11% compared to 2019, with 4.5 million tons construction and demolition waste still represents 59% of total waste generated. This waste is followed by municipal waste with 13% and waste from thermal processes with 12%. As expected, the amount of waste demanding special treatment in collection and removal to prevent the spread of infection increased in 2020 by 37%.

Waste streams for 2016 are presented on the Figure 7.1.2. This infographics was taken from the publication, prepared by SORS, and is not available for 2020. However, we have decided to keep it in the NIR 2022 due its transparency.

Waste stream, Slovenia, 2016

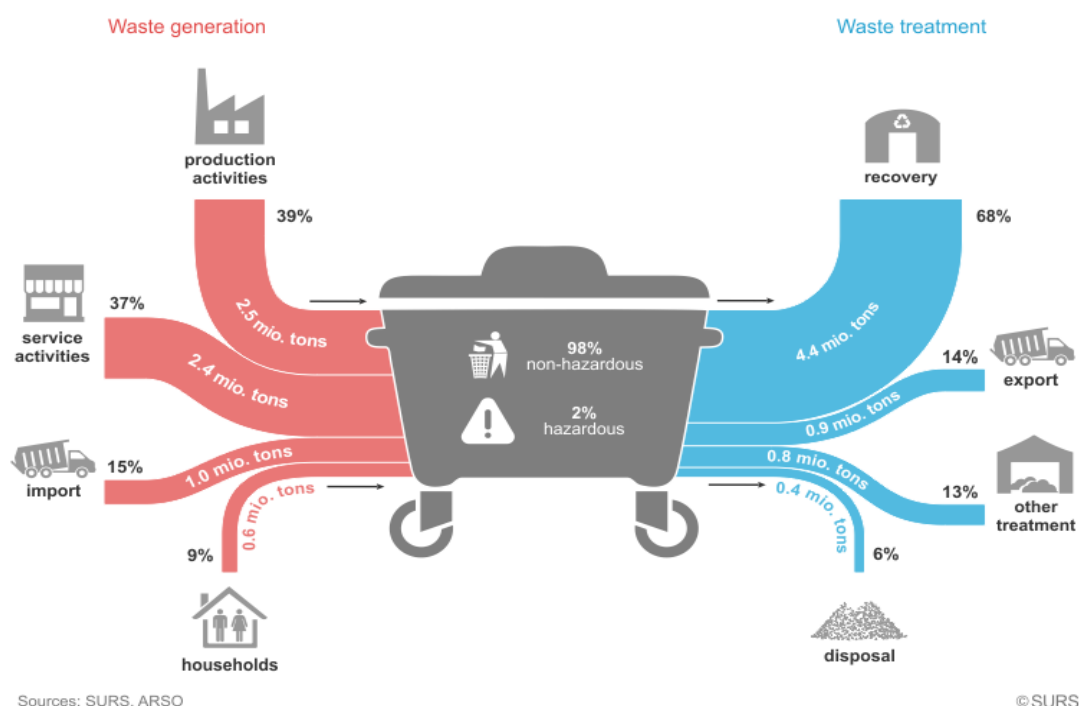


Figure 7.1.2: Waste stream in Slovenia in 2016  
(Source: <http://www.stat.si/StatWeb/en/News/Index/7099> )

In this report “**municipal waste**” is defined as waste generated by households and other waste similar to household waste generated by the manufacturing, trade, service and other industries and the public sector. These types of waste are reported under code 20 according to the List of Waste.

Despite the lower amount of municipal waste generated in 2020 (by almost 4%), as expected regarding the situation in 2020, the amount of municipal waste generated by households increased by almost 2% compared to 2019. A resident of Slovenia generated on average 489 kilograms of municipal waste in 2020, which was 21 kilograms less than in 2019.

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<sub>4</sub> 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 thousand tonnes), compared to 7.4% in 2020 (76 thousand tonnes).

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 2020 emissions from this source (CH<sub>4</sub> and N<sub>2</sub>O) amounted only 19.4 kt CO<sub>2</sub> eq. There is no CH<sub>4</sub> emission from the anaerobic digestion in the MB treatment plant because the generated CH<sub>4</sub> is fully recovered. In addition, all MB treatment plants in Slovenia are very new and meet high technical standards, which ensure that unintentional CH<sub>4</sub> emissions are flared. N<sub>2</sub>O emissions from the process are assumed to be negligible, while the CO<sub>2</sub> 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 2020 were 19.6 Gg CO<sub>2</sub> eq.

**Waste-water treatment and discharge** is the second most important source of GHG emissions in the waste sector. In 2020 emissions from this source amounted to 169.8 kt CO<sub>2</sub> eq. The majority (95%) of this emissions arose from domestic waste waters and remaining 5% 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 2020 data approximately 68% of population in Slovenia was connected to waste-water treatment plants and nearly 32% of the population still uses septic tanks.

## 7.2 Solid Waste Disposal Sites (CRF 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<sub>4</sub> 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<sub>4</sub> and CO<sub>2</sub> are formed. If conditions are constant, the rate of CH<sub>4</sub> production depends solely on the amount of carbon remaining in the waste. As a result the emissions of CH<sub>4</sub> 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<sub>4</sub> and CO<sub>2</sub> 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<sub>4</sub> emissions from solid waste disposal for a single year can be estimated using the equation below. Part of the CH<sub>4</sub> generated is oxidised in the cover of the SWDS, or can be recovered for energy or flaring.

$$\text{CH}_4 \text{ emitted} = \left[ \sum_x \text{CH}_4 \text{ generated}_{x,T} - R_T \right] * (1 - \text{OX}_T)$$

where:

T = inventory year

X = waste category or type/material

R<sub>T</sub> = CH<sub>4</sub> recovered (Gg/yr) in year T

OX<sub>T</sub> = oxidation factor (fraction) in year T

The CH<sub>4</sub> generation potential (L<sub>0</sub>) of the waste that is disposed in a certain year will decrease gradually throughout the following decades. In this process, the release of CH<sub>4</sub> 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<sub>4</sub> and CO<sub>2</sub>.

One key input in the model is the amount of degradable organic matter (DOC<sub>m</sub>) 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<sub>4</sub> generation are given below. As the mathematics are the same for estimating the CH<sub>4</sub> emissions from all waste categories/waste types/materials, no indexing referring to the different categories/waste materials/types is used in the equations below.

$$L_0 = DDOC_m \cdot F \cdot 16/12$$

and

$$DDOC_m = W \cdot DOC \cdot DOC_F \cdot MCF$$

where:

L<sub>0</sub> = methane generation potential, Gg CH<sub>4</sub>

F = fraction by volume of CH<sub>4</sub> in landfill gas (volume fraction)

16/12 = conversion from C to CH<sub>4</sub> (molecular weight ratio)

DDOC<sub>m</sub> = 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<sub>F</sub> = fraction of DOC that can decompose (fraction)

MCF = CH<sub>4</sub> 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<sub>4</sub> 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.

$$DDOC_{ma_T} = DDOC_{md_T} + (DDOC_{ma_{T-1}} \cdot e^{-k})$$

and

$$DDOC_{m\ decomp_T} = DDOC_{ma_{T-1}} \cdot (1 - e^{-k})$$

where:

T = inventory year

DDOCma<sub>T</sub>= DDOCm accumulated in the SWDS at the end of year T, Gg

DDOCma<sub>T-1</sub>= DDOCm accumulated in the SWDS at the end of year (T-1), Gg

DDOCmd<sub>T</sub>= DDOCm deposited into the SWDS in year T, Gg

DDOCm decomp<sub>T</sub>= DDOCm decomposed in the SWDS in year T, Gg

k reaction constant,  $k = \ln(2)/t_{1/2}$  (y<sup>-1</sup>)

t<sub>1/2</sub>= 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<sub>4</sub> and CO<sub>2</sub> 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

The amount of waste in the period 1995 – 2001

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

The amount of waste in the period 2002 – 2020

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 - 2020.**

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	0.09	76.148	6,643,101	75.844

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 - 2020.**

Year	Deposited waste (kt)	Biodegradable waste (kt)	Year	Deposited waste (kt)	Biodegradable waste (kt)
1964	140.078	39.937	1993	483.100	236.035
1965	143.769	41.671	1994	543.898	273.651
1966	147.497	43.424	1995	707.000	384.817
1967	149.941	44.572	1996	748.916	412.092
1968	157.867	48.297	1997	717.364	394.242
1969	159.872	49.240	1998	750.236	414.317
1970	162.444	50.288	1999	759.614	420.654
1971	171.634	54.310	2000	707.444	391.818
1972	177.511	56.928	2001	696.624	361.557
1973	211.165	71.491	2002	821.436	409.880
1974	266.869	95.608	2003	820.132	366.094
1975	293.386	107.228	2004	727.464	304.019
1976	325.486	121.309	2005	752.546	299.099
1977	384.435	147.072	2006	840.338	311.707
1978	449.343	175.532	2007	811.674	293.262
1979	551.571	220.293	2008	822.722	289.315
1980	570.646	228.975	2009	750.743	265.102
1981	569.486	228.822	2010	623.224	187.146
1982	529.545	211.648	2011	504.997	176.665
1983	544.817	218.577	2012	388.365	130.324
1984	567.106	228.599	2013	274.724	93.320
1985	591.036	239.518	2014	257.914	56.831
1986	620.640	252.774	2015	260.820	85.583
1987	642.930	262.844	2016	113.016	5.182
1988	651.626	266.960	2017	142.622	0.125
1989	672.902	298.917	2018	145.045	0.004
1990	620.726	279.192	2019	156.107	0.004
1991	474.293	211.861	2020	198.631	0.085
1992	473.673	226.963			

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, aquaculture, forestry, hunting and fishing	01, 02, 03, 99		100%	
02 01	wastes from agriculture, horticulture, aquaculture, 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 construction 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<sub>2</sub> /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 2020 the composition presented in the table 7.2.7. have been used.

**Table 7.2.7: Composition of deposited biodegradable waste in 2020.**

Main code	Type of wastes	Additional code	A paper and textile	D wood
04 02	Waste from composite materials	09	50%	
04 02	Wastes from the textile industry - other	99	50%	
15 02	Absorbents, filter materials, wiping cloths and protective clothing	03	50%	
19 08	wastes from waste water treatment plants	01, 02	2%	3%
19 12	wastes from the mechanical treatment of waste - other	12	2%	3%

The average yearly values of fractions of degradable waste as used for GHG emission calculations for the period 1964 to 2020 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

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 %
2002	18	4	26	8	56	5.0	0.5	4.5	10
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

### Methane correction factor (MCF)

MCF accounts for the effect of management practices on CH<sub>4</sub> 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  $DOC_f$  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



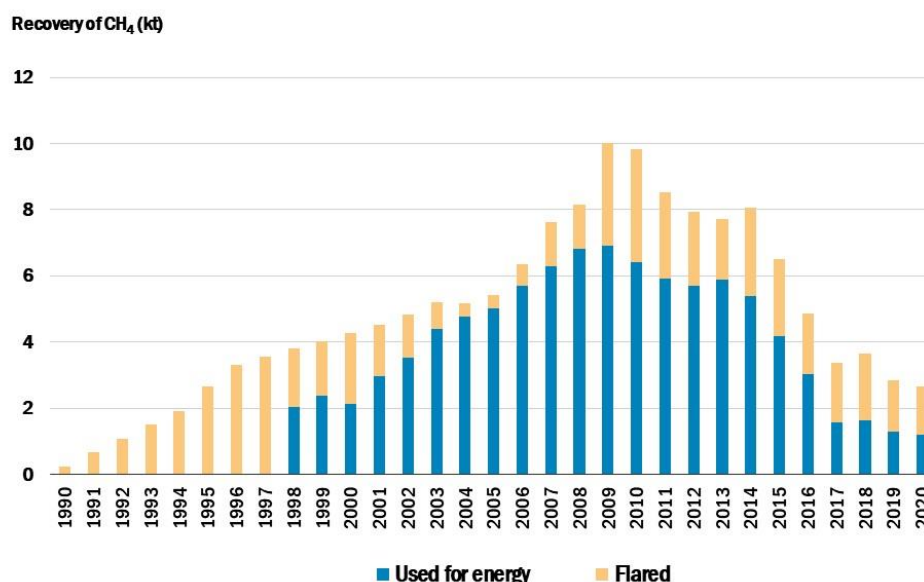
default values for temperate and wet climatic conditions from the 2006 IPCC GL, Vol.5, Table 3.3 have been used (Table 7.2.10).

**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<sub>4</sub> recovery (R) is the amount of CH<sub>4</sub> 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 obtained 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 prepared by installations operating under the EU directive on integrated pollution prevention and control. 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.1.a Public electricity and heat production, 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 <sub>4</sub>	250	667	1,085	1,502	1,920	2,650	3,310	3,552
flared	t CH <sub>4</sub>	250	667	1,085	1,502	1,920	2,650	3,310	3,552
used for electricity	t CH <sub>4</sub>	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 <sub>4</sub>	3,794	4,036	4,278	4,520	4,820	5,210	5,165	5,422
flared	t CH <sub>4</sub>	1,770	1,655	2,155	1,564	1,288	825	383	402
used for electricity	t CH <sub>4</sub>	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 <sub>4</sub>	6,366	7,633	8,165	10,011	9,816	8,513	7,938	7,728
flared	t CH <sub>4</sub>	651	1,344	1,359	3,087	3,396	2,601	2,243	1,835
used for electricity	t CH <sub>4</sub>	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

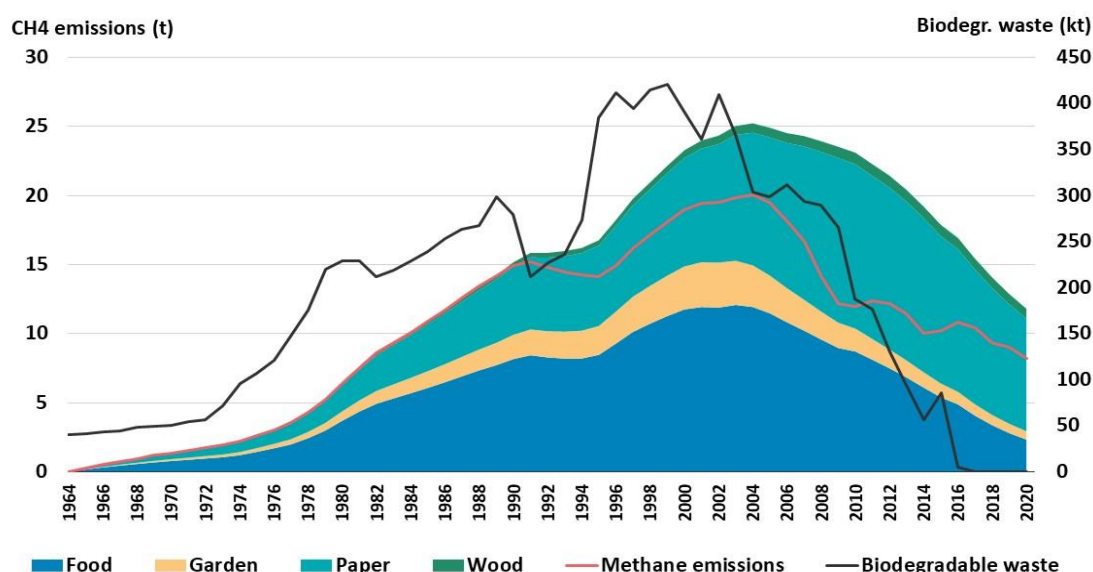
	Unit	2014	2015	2016	2017	2018	2019	2020
Recovery	t CH <sub>4</sub>	8,054	6,517	4,860	3,808	3,664	2,859	2,653
flared	t CH <sub>4</sub>	2,660	2,341	1,824	2,245	2,042	1,574	1,461
used for electricity	t CH <sub>4</sub>	5,394	4,176	3,036	1,563	1,622	1,285	1,193
used for electricity	TJ	272	210	153	79	82	65	60

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<sub>4</sub> 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<sub>4</sub> 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 then 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 NIR.

For calculation of CH<sub>4</sub> 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 has been made.

Activity data are amount of waste deposited on SWD and waste composition. Although these data are of 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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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

No recalculation have been performed.

## 7.2.6 Category-specific planned improvements

No improvements are planned for the next submission.

## 7.3 Biological Treatment of Solid Waste (CRF 5.B)

### 7.3.1 Category description

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste is converted into CO<sub>2</sub>. Composting can also produce emissions of N<sub>2</sub>O and CH<sub>4</sub>.

### 7.3.2 Methodological issues

Amount of composted waste on the wet weight have been obtained from SORS for all years since 2002. In 2020 113.128 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 CRF tables amount of composted 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 CRF tables.

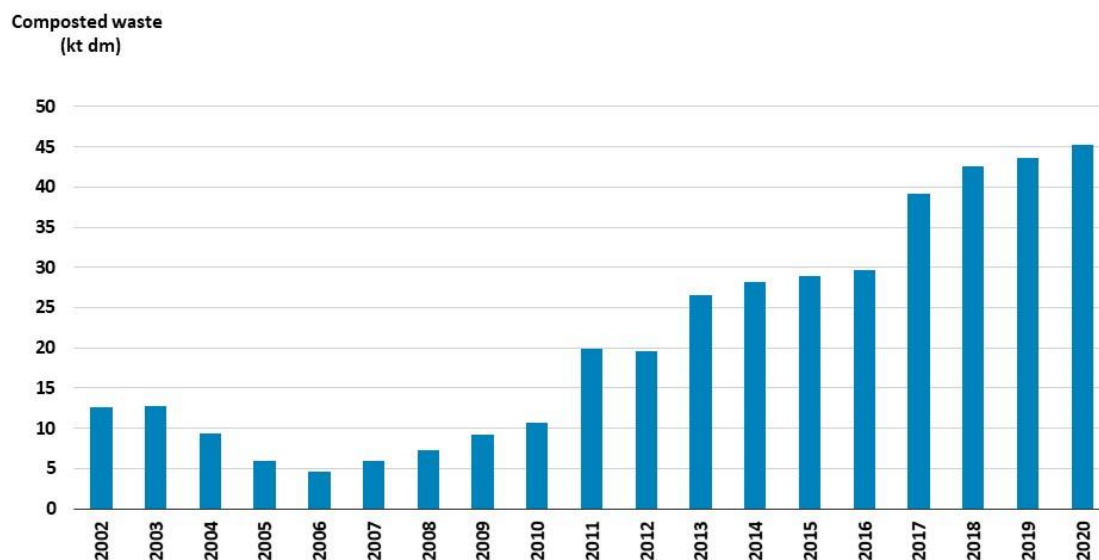


Figure 7.3.1: Amount of composted waste in kt of dry weight.

Emission factors have been taken from 2006 IPCC GL, Vol. 5 Table 4.1 for dry weight: 10 g CH<sub>4</sub> / kg waste and 0.6 g N<sub>2</sub>O / kg waste.

### **7.3.3 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<sub>4</sub> EF and 150% for N<sub>2</sub>O EF.

### **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.

### **7.3.5 Category-specific recalculations**

No recalculation have been performed.

### **7.3.6 Category-specific planned improvements**

No improvements are planned for the next submission.

## 7.4 Waste incineration (CRF 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<sub>2</sub> eq. Since 2009 the incinerated amount of waste has increased and emissions in 2020 were 19.6 kt CO<sub>2</sub> 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.

**Table 7.4.1: Amount of waste incinerated in tons in Slovenia in the period 1986 – 2020.**

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

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<sub>2</sub> 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<sub>2</sub> emission factors have been calculated using Equation 5.1 from 2006 IPCC Guideline as follows:

$$EF = dm * TCC * FCF * OX * 44/12$$

EF – CO<sub>2</sub> 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<sub>2</sub>

The exemption was CO<sub>2</sub> 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<sub>2</sub> 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<sub>4</sub> EF is 2006 IPCC Guidelines, Vol 5, Table 5.3, while N<sub>2</sub>O 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<sub>2</sub> EF.**

	Unit	Wood and paper	MSW	Clinical waste	Fossil liquid waste	Other industrial
dm (%)	%	85	90	35	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 – 2020**

	Unit	Wood and paper	MSW	Clinical waste	Fossil liquid waste	Other industrial
CO <sub>2</sub>	t / t waste	0	0.099	0.308	2.933	0.825
CH <sub>4</sub>	g/ t waste	6	6	6	6	6
N <sub>2</sub> O	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<sub>2</sub> and N<sub>2</sub>O emission factors are presented in the Table 7.4.4.

**Table 7.4.4: CO<sub>2</sub> and N<sub>2</sub>O emission factors used for hazardous waste.**

	Unit	Until 2015	2016	2017	2018	2019	2020
liquid	%	77	84.4	79.7	78.1	78.7	80.7
CO <sub>2</sub>	t / t waste	2.448	2.604	2.505	2.472	2.484	2.525
N <sub>2</sub> O	g/ t waste	30.55	23.87	28.11	29.55	29.04	27.25

### 7.4.3 Uncertainty and time series consistency

According to the 2006 IPCC GL uncertainty of incineration waste in developed countries is around  $\pm 5$  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<sub>2</sub> 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<sub>2</sub> 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 <sub>2</sub> 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  $\pm 10$  percent up to  $\pm 50$  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<sub>2</sub>O and CH<sub>4</sub> emission factors are used and uncertainty ranges have been estimated to be  $\pm 100$  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**

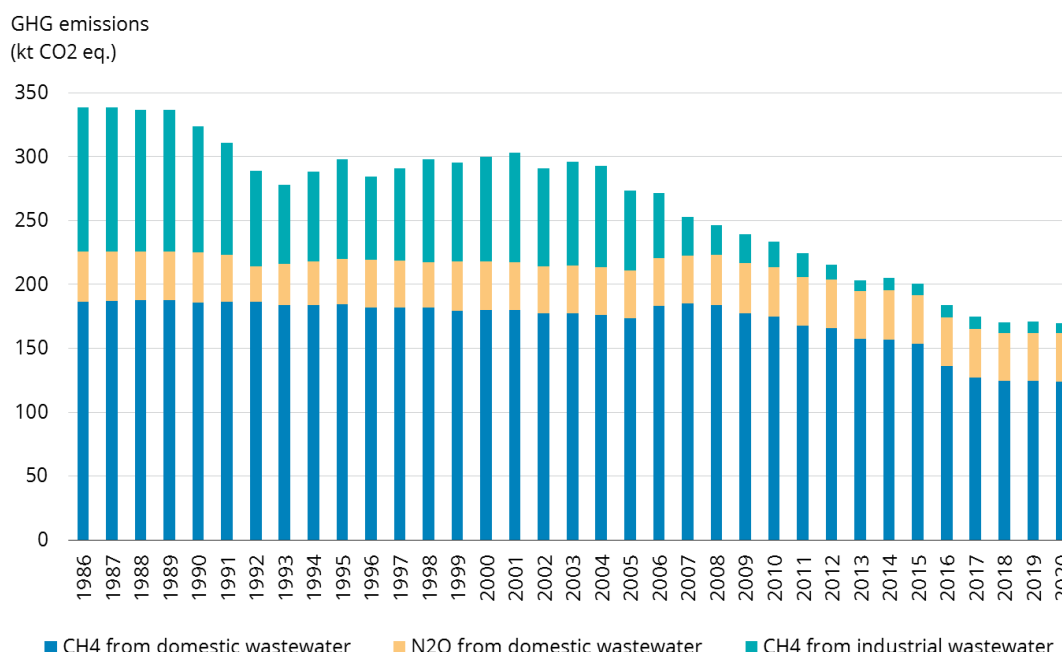
No recalculation have been performed.

#### **7.4.6 Category-specific planned improvements**

No improvements are planned for this category.

## 7.5 Emissions from Wastewater Treatment and Discharge (CRF 5.D)

### 7.5.1 Category description



**Figure 7.5.1: Emissions of methane and nitrous oxide from wastewater treatment.**

Wastewater could be a source of methane (CH<sub>4</sub>) when treated or disposed anaerobically. It can also be a source of nitrous oxide (N<sub>2</sub>O) emissions. Carbon dioxide (CO<sub>2</sub>) 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), sewerage 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.

Wastewater as well as its sludge components can produce CH<sub>4</sub> if it degrades anaerobically. The extent of CH<sub>4</sub> 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<sub>4</sub> production increases. This is especially important in uncontrolled systems and in warm climates. Below 15°C, significant CH<sub>4</sub> production is unlikely because methanogens are not active.

N<sub>2</sub>O 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<sub>2</sub>O 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 <sub>4</sub> emissions (kt)	N <sub>2</sub> O emissions (kt)	CH <sub>4</sub> emissions (kt)	CH <sub>4</sub> emissions (kt CO <sub>2</sub> eq.)	N <sub>2</sub> O emissions (kt CO <sub>2</sub> eq.)	CH <sub>4</sub> Emissions (kt CO <sub>2</sub> eq.)
1986	7.47	0.13	4.53	186.7	38.9	113.3
1987	7.49	0.13	4.52	187.3	38.2	113.1
1988	7.51	0.13	4.46	187.7	37.8	111.5
1989	7.52	0.13	4.44	188.0	37.8	110.9
1990	7.44	0.13	3.94	186.0	39.4	98.5
1991	7.45	0.12	3.50	186.2	37.0	87.5
1992	7.45	0.09	2.98	186.3	28.2	74.6
1993	7.35	0.11	2.47	183.9	32.4	61.7
1994	7.36	0.11	2.82	184.1	34.0	70.5
1995	7.37	0.12	3.12	184.3	35.9	78.1
1996	7.27	0.13	2.61	181.8	37.3	65.2
1997	7.27	0.12	2.89	181.9	36.6	72.4
1998	7.27	0.12	3.22	181.8	35.7	80.6
1999	7.18	0.13	3.08	179.5	38.7	77.0
2000	7.19	0.13	3.29	179.7	38.3	82.1
2001	7.20	0.13	3.42	179.9	37.5	85.6
2002	7.09	0.12	3.07	177.2	37.0	76.8
2003	7.09	0.13	3.25	177.3	37.6	81.3
2004	7.04	0.13	3.17	176.0	37.3	79.2
2005	6.95	0.12	2.51	173.7	36.9	62.8
2006	7.34	0.12	2.02	183.5	37.1	50.6
2007	7.40	0.13	1.23	185.0	37.4	30.6
2008	7.36	0.13	0.95	184.1	38.8	23.7
2009	7.10	0.13	0.91	177.5	39.2	22.7
2010	6.99	0.13	0.79	174.8	38.7	19.7
2011	6.70	0.13	0.75	167.6	38.2	18.9
2012	6.64	0.13	0.46	165.9	38.0	11.6
2013	6.30	0.13	0.33	157.5	37.3	8.2
2014	6.28	0.13	0.39	156.9	38.4	9.7
2015	6.14	0.13	0.38	153.6	37.8	9.4
2016	5.43	0.13	0.38	135.8	38.3	9.6
2017	5.09	0.13	0.38	127.2	37.9	9.6
2018	4.98	0.13	0.33	124.4	37.7	8.2
2019	4.97	0.13	0.34	124.3	38.0	8.4
2020	4.96	0.13	0.31	123.9	38.2	7.7

Calculations of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O emissions from domestic

and industrial wastewater treatment for the period 1986-2020. Emissions in Figure 7.5.1 are expressed in kt CO<sub>2</sub> equivalent. Conversion factors of 25 for CH<sub>4</sub> and 298 for N<sub>2</sub>O were used in the calculations. Referring to the fourth IPCC assessment report, 1 g CH<sub>4</sub> and 1 g N<sub>2</sub>O have the greenhouse effect of 25 and 298 g CO<sub>2</sub>, respectively.

## 7.5.2 Methodological issues

### Domestic Wastewater

#### CH<sub>4</sub> EMISSIONS

Modified 2006 IPCC methodology has been used in calculating the emission of methane from domestic wastewater treatment and discharge. Emissions of CH<sub>4</sub> from domestic wastewater were calculated separately per individual discharge pathway. Sum up of CH<sub>4</sub> 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<sub>j</sub> - 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<sub>j</sub> - 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<sub>4</sub> producing potential (B<sub>0</sub>) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The B<sub>0</sub> is the maximum amount of CH<sub>4</sub> that can be produced from a given quantity of organics in the wastewater. The MCF indicates the extent to which the CH<sub>4</sub> producing capacity (B<sub>0</sub>) 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<sub>4</sub>/kg of degradable organic component:

$$EF_j = B_0 * MCF_j$$

EF<sub>j</sub> - emission factor (kg CH<sub>4</sub>/kg BOD)

j - each treatment and discharge pathway

B<sub>0</sub> - maximum CH<sub>4</sub> producing capacity (kg CH<sub>4</sub>/kg BOD)

MCF<sub>j</sub> - 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.

$$CH_4 Emissions\_j = ((TOW_j - S_j) * EF_j) - R_j$$

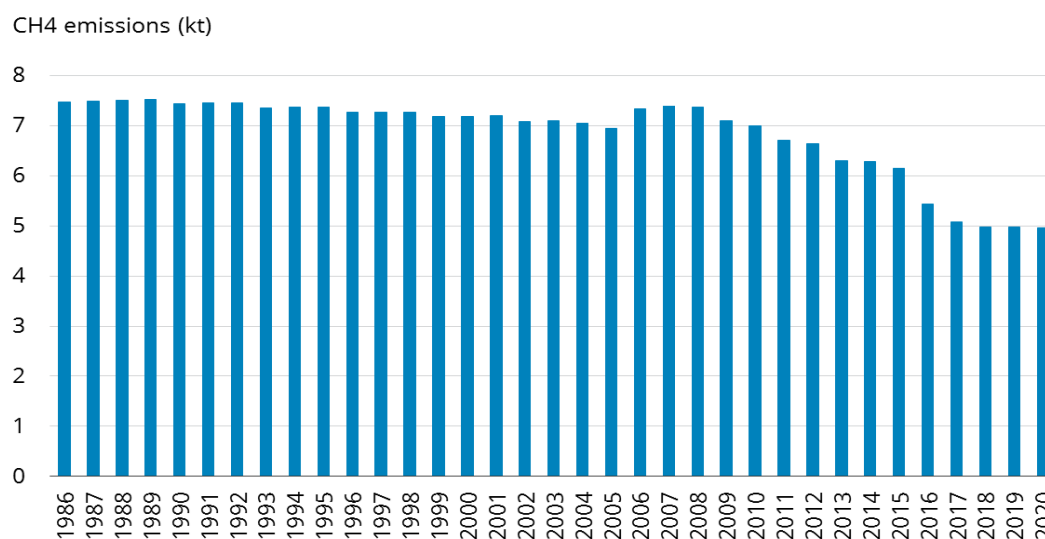
- CH<sub>4</sub> Emissions\_<sub>j</sub> - CH<sub>4</sub> emissions for each discharge pathway (kg CH<sub>4</sub>/year)  
TOW<sub>j</sub> - total organics in wastewater for each discharge pathway, j (kg BOD/year)  
S<sub>j</sub> - organic component removed as sludge for each discharge pathway (kg BOD/year)  
R<sub>j</sub> - amount of CH<sub>4</sub> recovered for each discharge pathway (kg CH<sub>4</sub>/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<sub>4</sub> emissions is as follows:

$$CH_4 Emissions = \sum_j CH_4 Emissions\_j$$

- CH<sub>4</sub> Emissions - total annual CH<sub>4</sub> emissions in the country (kg CH<sub>4</sub>/year)  
CH<sub>4</sub> Emissions\_<sub>j</sub> - CH<sub>4</sub> emissions for each discharge pathway (kg CH<sub>4</sub>/year)



**Figure 7.5.2: CH<sub>4</sub> emissions from domestic wastewater treatment.**

CH<sub>4</sub> emissions from domestic wastewater treatment and discharge for the period 1986 - 2020 are shown in Figure 7.5.2. Emissions were decreased in 2016 - 2020 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	1995	47.48	2004	48.91	2013	51.47
1987	47.03	1996	47.47	2005	49.22	2014	51.55
1988	47.15	1997	47.49	2006	49.15	2015	51.71
1989	47.21	1998	47.41	2007	49.63	2016	52.40
1990	47.36	1999	47.68	2008	49.82	2017	52.73
1991	47.40	2000	47.80	2009	50.48	2018	53.21
1992	47.36	2001	47.95	2010	50.68	2019	53.63
1993	47.33	2002	48.04	2011	51.09	2020	54.01
1994	47.39	2003	48.14	2012	51.26		

### 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 2020, about 68% of the population was connected to centralized aerobic wastewater treatment plants (secondary and tertiary treatment). 32% of the population use septic tanks and only 0.1% 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 is obtained from the Statistical Office of the Republic of Slovenia (SORS) and the database on municipal wastewater treatment plants collected by the Slovenian Environment Agency (SEA).

5.D.1 Domestic Wastewater CRF 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	900	483	1985
1987	311	303	902	478	1994
1988	315	311	904	467	1996
1989	319	319	905	453	1996
1990	323	327	907	443	2000
1991	327	335	909	428	1999
1992	331	343	911	409	1994
1993	335	351	913	390	1989
1994	339	359	915	377	1989
1995	343	367	916	364	1990
1996	347	375	918	347	1987
1997	351	383	920	331	1985
1998	355	391	922	310	1978
1999	359	399	924	306	1988
2000	363	407	925	294	1990
2001	367	415	927	284	1994
2002	371	423	929	271	1995
2003	375	431	931	259	1996
2004	383	560	934	120	1998
2005	359	618	946	80	2003
2006	52	884	1014	60	2010
2007	51	910	1025	41	2026
2008	25	946	1041	20	2032
2009	8	1024	997	18	2047
2010	8	1047	979	16	2050
2011	9	1101	931	14	2055
2012	9	1117	920	12	2059
2013	9	1147	894	10	2061
2014	9	1155	890	8	2063
2015	0	1189	869	6	2064
2016	0	1307	755	4	2066
2017	0	1363	699	4	2067
2018	0	1396	681	4	2081
2019	0	1413	679	4	2096
2020	0	1429	676	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<sub>4</sub>/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 CH<sub>4</sub> producing capacity ( $B_0$ ) 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<sub>4</sub> 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 2020 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<sub>2</sub>O 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 ( $N_{\text{EFFLUENT}}$ ). The equation for calculation of  $N_{\text{EFFLUENT}}$  is:

$$N_{\text{EFFLUENT}} = (P * \text{Protein} * F_{\text{NPR}} * F_{\text{NON-COM}} * F_{\text{IND-COM}}) - N_{\text{SLUDGE}}$$

$N_{\text{EFFLUENT}}$  - total annual amount of nitrogen in the wastewater effluent (kg N/year)

P - human population



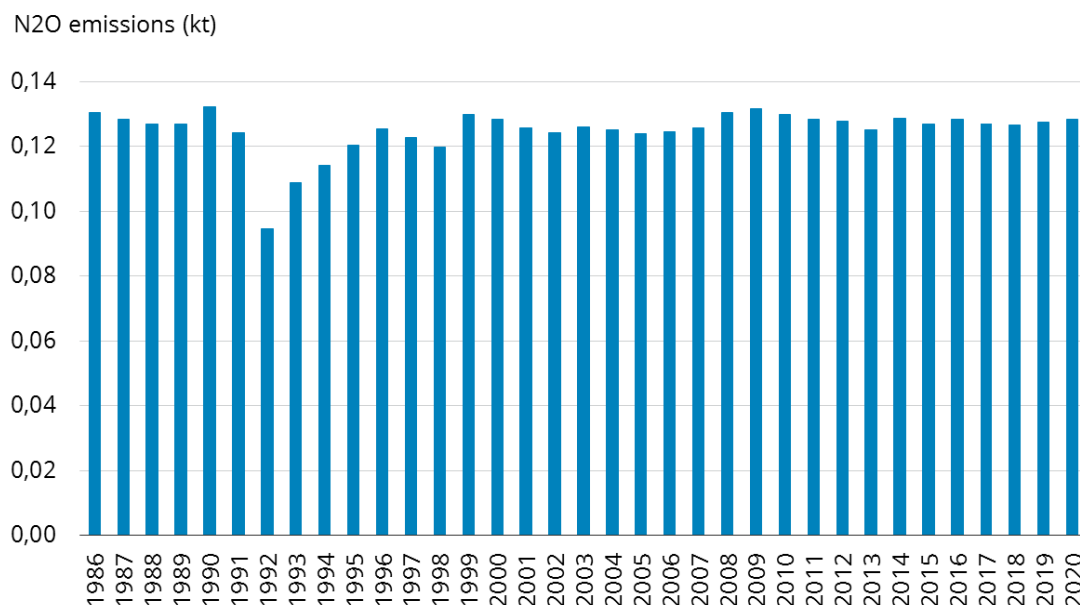
Protein	- annual per capita protein consumption (kg/person/year)
$F_{NPR}$	- fraction of nitrogen in protein
$F_{NON-CON}$	- factor for non-consumed protein added to the wastewater
$F_{IND-COM}$	- factor for industrial and commercial co-discharged protein into the sewer system
$N_{SLUDGE}$	- nitrogen removed with sludge (kg N/year)

Finally, emissions of  $N_2O$  from wastewater effluent are calculated as follows:

$$N_2O \text{ emissions} = N_{EFLUENT} * EF_{EFLUENT} * 44 / 28$$

$N_2O$ emissions	- $N_2O$ emissions in inventory year (kg $N_2O$ /year)
$N_{EFLUENT}$	- nitrogen in the effluent discharged to aquatic environments (kg N/year)
$EF_{EFLUENT}$	- 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 - 2020 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. Referring to the fourth IPCC assessment report, 1 g  $N_2O$  has a greenhouse effect of 298 g  $CO_2$ .



**Figure 7.5.3:  $N_2O$  emissions from wastewater effluent.**

#### Emission factor for $N_2O$ emissions from discharged to wastewater ( $EF_{EFLUENT}$ )

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 2019 and 2020 value for the year 2018 has been applied for the following years as well. 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 1986-2020.**

Year	Population	Protein consumption (kg/person/year)	Year	Population	Protein consumption (kg/person/year)
1986	1985486	38.0	2004	1997590	36.2
1987	1994066	37.2	2005	2003358	35.8
1988	1996325	36.8	2006	2010377	35.8
1989	1996377	36.8	2007	2025866	35.9
1990	1999945	38.2	2008	2032362	37.1
1991	1998912	35.9	2009	2046976	37.2
1992	1994084	27.4	2010	2050189	36.7
1993	1989408	31.6	2011	2055496	36.1
1994	1989477	33.2	2012	2058821	35.9
1995	1990266	35.0	2013	2061085	35.1
1996	1986989	36.5	2014	2062874	36.1
1997	1984923	35.8	2015	2064188	35.5
1998	1978334	35.0	2016	2065895	36.0
1999	1987755	37.8	2017	2066880	35.6
2000	1990094	37.4	2018	2080908	35.2
2001	1994026	36.5	2019	2095861	35.2
2002	1995033	36.0	2020	2108977	35.2
2003	1996433	36.5			

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 ( $F_{\text{IND-COM}}$ )

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  $\text{N}_2\text{O}$  emission calculation (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

Nitrogen removed with sludge ( $N_{\text{SLUDGE}}$ )

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<sub>4</sub> EMISSIONS**

IPCC methodology has been used in calculating the emissions of methane from industrial wastewater handling. This chapter includes CH<sub>4</sub> emissions from on-site industrial wastewater treatment. Assessment of CH<sub>4</sub> 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<sub>4</sub>.

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:

$$TOW_i = Q * COD_i$$

TOW - total organically degradable material in the wastewater for industry i (kg COD/year)

Q - quantity of wastewater

COD<sub>i</sub> - degradable organics concentration in wastewater (kg COD/m<sup>3</sup>)

i - industrial sector

Secondly, the emission factors for each industrial wastewater treatment and discharge pathways for each industrial sector have to be estimated.

$$EF_j = B_0 * MCF_j$$

EF<sub>j</sub> - emission factor (kg CH<sub>4</sub>/kg COD)

j - each treatment and discharge pathway or system

B<sub>0</sub> - maximum CH<sub>4</sub> producing capacity (kg CH<sub>4</sub>/kg COD)

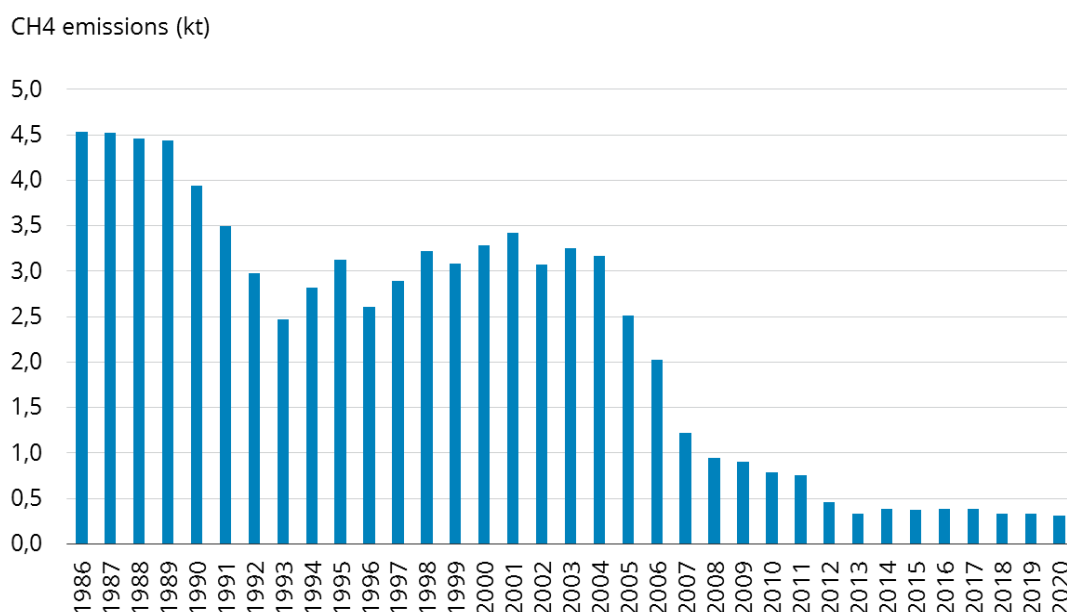
MCF<sub>j</sub> - methane correction factor (fraction)

In the end, the total emission of methane from industrial wastewater is estimated. The equation for the calculation of annual CH<sub>4</sub> emissions is as follows:

$$CH_4 \text{ emissions} = \sum_i \left( (TOW_i - S_i) * EF_i \right) - R_i$$

CH <sub>4</sub> emissions	- CH <sub>4</sub> emissions (kg CH <sub>4</sub> /year)
TOW	- total organically degradable material in the wastewater for industry i (kg COD/year)
S <sub>i</sub>	- organic component removed as sludge for industry i (kg COD/year)
EF <sub>i</sub>	- emission factor for industry i
R <sub>i</sub>	- amount of CH <sub>4</sub> recovered (kg CH <sub>4</sub> /year)
i	- industrial sector

CH<sub>4</sub> emissions from industrial wastewater treatment for the period 1986 - 2020 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<sub>4</sub> 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 1986-2020 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 <sup>3</sup> )							
1986	18612812	960966	1993330	513066	992776	854301	2869840	850107
1987	18560824	948137	1993276	479440	1008278	908295	2906530	860975
1988	18199349	935331	1993223	445821	1023777	962289	3123115	925132
1989	17992579	922503	1993164	412196	1039279	1016283	3542363	1049322
1990	17785835	909674	1993106	378570	1054778	1070278	2616783	775146
1991	15813639	778661	1897174	369069	1034204	1059647	1632471	483572
1992	13167759	736567	1773698	245566	921828	764296	2540141	752443
1993	12056736	686178	1812219	272168	767155	650592	2339726	693076
1994	13879156	678212	1906083	296905	835621	634050	3021457	895019
1995	15431625	459865	1879191	304715	911369	574572	4238305	1255475
1996	14369458	529332	1881993	300437	885387	662932	3926516	1163117
1997	16266638	496348	1941510	282961	926754	663706	3948196	1169539
1998	18163843	463364	2001042	265483	968119	664480	4864277	1440901
1999	20061023	430379	2060559	248007	1009486	665255	5294039	1568206
2000	21397736	397395	2120086	230529	1050850	666029	5954235	1763770
2001	22734450	364411	2179603	213054	1092218	666803	5133504	1520652
2002	24071163	331427	2239130	195578	1133582	667578	5255464	1556779
2003	25407851	298442	2298652	178100	1174950	668352	5943503	1760591
2004	27675000	274700	1970685	136140	1133980	662367	5327103	1578000
2005	26950000	233185	1362038	178400	1230000	1420996	5024194	1368600
2006	21120000	238400	2074000	164100	986700	1143262	5530843	1545000
2007	12233000	281863	1771724	185000	985000	1393753	5205447	1488000
2008	16500000	228651	1572889	191900	982000	1334951	5404169	1523000
2009	15881919	11617	1533764	223853	901292	1162973	5405131	1765726
2010	13596494	9224	1431036	167710	865144	1268351	5406094	1633612
2011	12514742	22597	1507163	213732	871805	1161579	5005424	1560375
2012	12773572	39893	1319973	297757	820968	1119638	4867181	1465488
2013	10408933	44994	1238251	343151	835151	1074228	5250133	1528190
2014	11206175	47428	1267076	320628	838646	1144594	5586674	1578317
2015	11456759	40083	1166442	301864	750391	1307631	5265902	1684019
2016	11491537	35961	1048714	232644	805551	1346137	5466717	1747853
2017	11387032	45468	1031081	246433	854688	1457879	5798674	1783843
2018	11464901	49773	1162256	235111	909694	1405198	5505064	1793415
2019	11675106	46431	1352696	201818	1008039	1359105	5782326	1752544
2020	10795758	40085	1146404	207140	1057467	1325690	5855693	1580681

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 chemical
- production of the pharmaceutical industry

The annual amount of wastewater output for an individual industry for the period 2004-2020 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. According to the ERT recommendations, the pharmaceutical industry as an industrial sector with potential methane production is included in wastewater output. The pharmaceutical industry has been introduced as an additional source. The annual amount of wastewater from pharmaceutical production has been used for CH<sub>4</sub> emissions calculation for the whole period 1986-2020.

#### Industrial degradable organic component indicator (COD<sub>i</sub>)

The principal factor in determining the CH<sub>4</sub> 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<sub>4</sub> 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 NIR, 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 <sup>3</sup> )							
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<sub>4</sub> emissions.

For the comparison Table 7.5.8. shows the entire amount of TOW considered to have been treated in centralized wastewater treatment plants.

**Table 7.5.7: 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	200.3	1995	172.5	2004	264.0	2013	60.6
1987	200.0	1996	162.2	2005	257.6	2014	71.2
1988	197.6	1997	179.6	2006	207.7	2015	69.2
1989	197.5	1998	200.5	2007	125.7	2016	70.7
1990	192.1	1999	219.4	2008	121.9	2017	70.5
1991	169.5	2000	234.2	2009	116.7	2018	60.5
1992	146.3	2001	243.3	2010	101.2	2019	62.0
1993	134.8	2002	256.0	2011	97.0	2020	56.5
1994	154.6	2003	271.0	2012	85.3		

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 58% 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 2004-2020 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 79 % in 2020.

**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	200.3	1995	172.5	2004	286.9	2013	128.7
1987	200.0	1996	162.2	2005	279.3	2014	137.4
1988	197.6	1997	179.6	2006	230.6	2015	138.8
1989	197.5	1998	200.5	2007	149.2	2016	139.3
1990	192.1	1999	219.4	2008	186.9	2017	140.0
1991	169.5	2000	234.2	2009	180.5	2018	140.4
1992	146.3	2001	243.3	2010	159.0	2019	143.9
1993	134.8	2002	256.0	2011	148.1	2020	134.6
1994	154.6	2003	271.0	2012	149.0		

Methane conversion factor (MCF):

According to the ERT recommendation description of the fraction of the wastewater undergoing various treatment methods and the corresponding MCF applied to the various fractions is included.

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 2020 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 2020 77% of industrial wastewater from the production of soft drinks and alcohol beverages and 21% 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 2020. MCF was estimated in the same way as for domestic wastewater treatment plant. In 2020 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).

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<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> 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.

**Table 7.5.4: Uncertainties used to determine AD and CH<sub>4</sub> EF uncertainties for domestic WW**

Parameter	CH <sub>4</sub> emissions	Parameter	N <sub>2</sub> O 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		

A total uncertainty of AD is 30% for CH<sub>4</sub> emissions and 15,5% for N<sub>2</sub>O emissions. Calculated uncertainty for CH<sub>4</sub> EF in 2020 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<sub>2</sub>O from effluent EF is 0.005 kg

N<sub>2</sub>O\_N/kg N but the range of possible values is extremely wide. In the 2019 IPCC 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  $\pm 10$  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<sub>4</sub> EF is 42%.

### **7.5.5 Source-specific recalculations**

#### 5.D.1 Domestic Wastewater

Emissions of N<sub>2</sub>O have been recalculated for the period 2014-2019 due to new values on protein consumption applied. Updated values were obtained from the World Health Organisation.

### **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<sub>2</sub> AND N<sub>2</sub>O 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 2020 and NECD comprehensive review from 2021. 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<sub>2</sub> eq. due to the recalculation with a respect to the previous submission.**

	1986	1990	1995	2000	2005	2010	2015	2019
1. Energy	10.9	13.2	-12.4	-3.7	26.1	28.0	29.8	40.7
2. IPPU	0.004	0.008	0.008	0.004	0.001	-0.157	0.050	-33.282
3. Agriculture	5.57	3.36	4.84	3.72	3.13	2.40	2.29	1.25
4. LULUCF	55.5	47.8	115.2	158.2	168.8	178.1	122.8	-4,786.3
6. Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1
Total w/o LULUCF	16.5	18.6	-7.8	0.1	29.2	30.2	32.6	8.7
Total with LULUCF	72.0	66.4	107.4	158.3	198.0	208.3	155.3	-4,777.6
Total in % w/o LULUCF	0.08	0.10	-0.04	0.00	0.14	0.15	0.19	0.05
Total in % with LULUCF	0.46	0.47	0.79	1.28	1.49	1.67	0.89	-39.20

#### 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<sub>2</sub> eq.**

Energy	1986	1990	1995	2000	2005	2010	2015	2019
A. Fuel Combustion	10.9	13.2	-12.4	-3.7	26.1	28.0	29.8	40.6
1. Energy Industries	1.4	2.0	1.6	1.0	3.9	5.3	3.1	5.5
2. Manufacturing Ind.	8.6	9.4	8.9	7.3	18.9	17.7	22.4	29.3
3. Transport	0.7	1.5	-23.8	-13.8	-0.9	0.2	-1.1	-3.7
4. Other Sectors	0.2	0.4	1.0	1.8	4.2	4.8	5.4	9.5
5. Other								
B. Fugitive Emissions								0.1
1. Solid Fuels								
2. Oil and Natural Gas								0.1
Total of Energy in kt CO <sub>2</sub> eq	10.9	13.2	-12.4	-3.7	26.1	28.0	29.8	40.7
Total of Energy in %	0.1	0.1	-0.1	0.0	0.2	0.2	0.2	0.3

1.A.Fuel combustion, CO<sub>2</sub>

Following recommendation from the UNFCCC review, composition data for the natural gas for the period 1998-2019 has been obtained and accordingly CS CO<sub>2</sub> emission factor have been updated. In addition an error in CO<sub>2</sub> emission factor for the period 1986-1997 have been corrected and CO<sub>2</sub> emission from combustion of natural gas have been recalculated for the entire period 1986-2019 and for the all categories.

1.A.2 Manufacturing industries and construction, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

For the period 2012 to 2019 data on other fuel (waste solvents) has been obtained and all GHG emissions for this category have been recalculated for this period.

1.A.3.b Road transportation, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Recalculation of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O emissions for the whole period 1986-2019 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.5.1) was used for emissions calculation.

1A4.c.iii Fishing, gas diesel oil, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Updated data on fuel used for fishing in 2019 has been obtained and corresponding GHG emissions have been recalculated for this year.

1.B.2.Venting and Flaring, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

For the year 2019 updated data for natural gas production and use has been obtained and fugitive GHG emissions for 2019 have been recalculated accordingly.

## 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<sub>2</sub> eq.**

Industrial Proc. and Prod. Use	1986	1990	1995	2000	2005	2010	2015	2019
A. Mineral Products								
B. Chemical Industry								
C. Metal Production								
D. Non-energy products	0.004	0.008	0.008	0.004	0.001	-0.157	-0.212	-1.87
F. ODS substitutes							0.261	0.99
G. Other products								-32.40
Total IPPU in kt CO <sub>2</sub> eq.	0.004	0.008	0.008	0.004	0.001	-0.157	0.050	-33.28
Total of IPPU in %	0.000	0.001	0.001	0.000	0.000	-0.016	0.004	-2.71

2.D.1 Lubricant Use

Recalculation of CO<sub>2</sub> emissions for the whole period 1986-2019 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.5.1) 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<sub>2</sub> emissions in 2.D.1 sector.

### 2.D.3 Other

Recalculation of CO<sub>2</sub> emissions for the period 2006-2019 was performed due to changes in CO<sub>2</sub> 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 5.5.1) 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<sub>2</sub> emissions in 2.D.3 sector.

### 2.F.4 Product uses as a substitute for ODS, Fire protection , HFC 227ea

Emissions have been recalculated for the entire period 1997-2018 due to the availability of a better data on amount in the existing equipment as well as emissions during firefighting.

### 2.F.4 Product uses as a substitute for ODS/ Aerosol, HFC 134a

Data on HFC used in the MDIs in 2019 has been updated and corresponding emissions of HFC 134a in 2019 have been recalculated.

### 2.G.3.a Medical Applications

Emissions of N<sub>2</sub>O have been recalculated for the year 2019 due to new activity data obtained by the Statistical Office of the Republic of Slovenia.

## **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<sub>2</sub> eq.**

3. Agriculture	1986	1990	1995	2000	2005	2010	2015	2019
A. Enteric Fermentation								
B. Manure Management	-1.76	-1.64	-1.31	-0.78	-0.63	-0.36	-0.32	-0.44
D. Agricultural Soils	7.33	7.00	5.84	4.50	3.76	2.76	2.60	2.17
G. Liming								
H. Urea application								
I. Other C-containing fertilizers								
Total in Agriculture in kt CO <sub>2</sub> eq.	5.57	3.36	4.84	3.72	3.13	2.40	2.29	1.25
Total of Agriculture in %	0.29	0.29	0.26	0.21	0.18	0.14	0.13	0.07

### 3.A.1 Enteric fermentation, CH<sub>4</sub>

The 2017-2019 horse number data has been updated based on the recently released Census of Agriculture 2020 data. No additional recalculations have been made since the last submission.

3.B.1 Manure management, CH<sub>4</sub>

The 2017-2019 horse number data has been updated based on the recently released Census of Agriculture 2020 data and corresponding emissions have been recalculated.

3.B.1 Manure management, N<sub>2</sub>O

Emission factors for ammonia from the tied dairy cow housing system were updated. This affected the amount of N entering the manure stores. As a result, nitrous oxide emissions from livestock manure storage and nitrous oxide emissions due to livestock manure application (3.D. Agricultural Soils) were slightly increased. The overall impact on emissions was small. The recalculations were performed for the entire reporting period.

Following the recommendations of TERT, the percentage of total ammonia-N in the liquid fraction formed in the farmyard manure system was increased. This impacted nitrous oxide emissions from manure storage and from the application of animal manures (3.D. Agricultural Soils). The overall impact of the recalculations on emissions was small. The recalculations were performed for the entire reporting period.

Based on new information on C stocks in agricultural soils, C emissions/sinks from cropland were updated. This also impacted the nitrous oxide emissions associated with loss/gain of soil organic matter. The impact of the recalculations on emissions ranged from +0.078% of total greenhouse gas emissions from agriculture at the beginning of the reporting period to +0.107% of total emissions at the end of the reporting period.

Estimates of indirect nitrous oxide emissions have been revised. In previous reports, we inadvertently omitted ammonia emissions from cattle barns that installed anaerobic digesters. On the other hand, we included ammonia and nitric oxide emissions from anaerobic digesters at pigs that are not part of the agricultural sector. The overall impact of the recalculations on emissions was small.

Data on the number of horses and resulting N excretion for 2017-2019 have been updated based on recently released Census of Agriculture 2020 data.

3.D. Agricultural soils, N<sub>2</sub>O

An error was found in estimating the amount of N in livestock manure, which is the basis for estimating nitrous oxide emissions due to manure application. The error was due to incorrect accounting for N losses with nitrous oxide during storage of farmyard manure. In the case of liquid manure the calculations were in order. The recalculations were performed for the entire reporting period. The effect of the error on emissions was small.

Emission factors for ammonia from the tied dairy cow housing system were updated. This affected the amount of N in animal manures. As a result, nitrous oxide emissions due to livestock manure application were slightly increased. The recalculations were performed for the entire reporting period.

Following the recommendations of TERT, the percentage of total ammonia-N in the liquid fraction formed in the farmyard manure system was increased. This impacted nitrous oxide

from the application of animal manures. The recalculations were performed for the entire reporting period.

Estimates of indirect nitrous oxide emissions from animal houses and manure storage facilities have been revised. In previous reports, we inadvertently omitted ammonia emissions from cattle barns that installed anaerobic digesters. On the other hand, we included ammonia and nitric oxide emissions from anaerobic digesters at pigs that are not part of the agricultural sector. The recalculations affected the amount of N in animal manure and the resulting direct and indirect nitrous oxide emissions from agricultural soils. The overall impact of the recalculations on emissions was small.

Data on the number of horses and resulting N in animal manures for 2017-2019 have been updated based on recently released Census of Agriculture 2020 data.

Based on new information on C stocks in agricultural soils, C emissions/sinks from cropland were updated. This also impacted the nitrous oxide emissions associated with loss/gain of soil organic matter. The impact of the recalculations on emissions ranged from +0.078% of total greenhouse gas emissions from agriculture at the beginning of the reporting period to +0.107% of total emissions at the end of the reporting period.

#### 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<sub>2</sub> eq.**

5. LULUCF	1986	1990	1995	2000	2005	2010	2015	2019
A. Forest Land	-17.4	-25.4	54.1	98.2	110.9	114.3	68.4	-4824.2
B. Cropland	14.3	14.3	13.0	15.9	17.8	24.3	16.3	13.9
C. Grassland	-71.7	-71.7	-86.9	-88.4	-89.3	-79.7	-57.5	-55.2
D. Wetlands	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	-0.02	0.02
E. Settlements	127.0	127.3	131.8	130.3	127.9	118.1	95.2	78.4
F. Other Land				-1.0	-1.6	-1.6	-1.6	-0.9
G. HWP								
Total in LULUCF	55.5	47.8	115.2	158.2	168.8	178.1	122.8	-4786.3
Total of LULUCF in %	-1.2	-1.1	-2.2	-2.6	-2.3	-2.5	17.2	97.9

##### 4. A Forest land

For 2019, recalculations were made in forest land remaining forest land as the projected growing stock for 2020 was taken into account according to the Global Forest Resources Assessment 2020. In 2020, the first panel of the new NFI (grid 2 x 2 km) was established and about 760 plots were monitored for the first time. The latter are therefore not comparable to the old plots on the 4 x 4 km grid. The new plots will be re-surveyed after 5 years, when the NFI will provide first results on increment, harvest and mortality.



For the period 1986-2019, recalculations in forest land remaining forest land were made because there was an incorrect reference to the mass of available fuel in the estimate of emissions from biomass burning. The reference in the Excel spreadsheet was linked to soil organic carbon and not litter and deadwood, resulting in overestimated emissions.

The recalculation of land converted to forest land was made for the period 1986-2019 based on improved emission factors for soil organic carbon (SOC) for cropland, grassland and settlements.

#### 4. B Cropland

The recalculation of land converted to cropland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

#### 4. C Grassland

The recalculation of land converted to grassland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

#### 4. D Wetlands

The recalculation of land converted to grassland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

#### 4. E Settlements

The recalculation of land converted to grassland was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

#### 4. F Other land

The recalculation of land converted to wetlands was based on improved SOC emission factors for cropland, grassland, and settlements for the period 1986-2019.

## 10.1.5 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<sub>2</sub> eq.**

6. Waste	1986	1990	1995	2000	2005	2010	2015	2019
A. Solid waste disposal								
B. Biological treatment								
C. Incineration								
D. Waste water treatment							0.47	0.07
Total in Waste in kt CO <sub>2</sub> eq							0.47	0.07
Total of Waste in %							0.09	0.02

#### 5.D.2 Industrial Wastewater

Emissions of N<sub>2</sub>O have been recalculated for the period 2014-2019 due to new values on protein consumption applied. Updated values were obtained from the World Health Organisation.

## **10.2 Response to the Review Process**

In 2020 Slovenian GHG inventory was included in the ESD comprehensive review and UNFCCC centralised review. The details of Slovenian response to the recommendations from both review processes are in the Table 10.2.1 below. The majority recommendations were implemented already in the 2021 submission.

Table 10.2.1: A response to the recommendations from the UNFCCC and ESD review process.

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
<b>GENERAL</b>				
Article 3, paragraph 14, of the Kyoto Protocol	Provide information on any change(s) in its reporting of the minimization of adverse impacts in accordance with Article 3, paragraph 14, of the Kyoto Protocol, in accordance with decision 15/CMP.1 in conjunction with decision 3/CMP.11.	UNFCCC 2018, G.4 UNFCCC 2020, G1	Implemented	NIR 2021
CPR	Ensure that the reported calculation of the commitment period reserve uses the most recent GHG inventory.	UNFCCC 2020, G3	Implemented	NIR 2021
QA/QC and verification	Implement additional general QA/QC procedures to ensure the uncertainty analysis is correctly documented and consistently reported between the NIR and its annex 2, including the uncertainty information required to be reported in accordance with the 2006 IPCC Guidelines (vol. 2, chap. 3.2.3.1 and 3.5) when using approach 1 to assess uncertainties.	UNFCCC 2020, G.4	Implemented	NIR 2022
Uncertainty analysis	Improve the transparency of the uncertainty analysis by including, in both the NIR and its annex 2, comprehensive information on the underlying assumptions of the source- and sink-level quantitative uncertainty estimates.	UNFCCC 2020, G.5	Implemented	NIR 2022

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
Recalculations	The ERT recommends that Slovenia provide in the NIR a discussion of the impact of any recalculations as well as explanatory information on and justification for the recalculations in accordance with paragraphs 43–45 and 50(h) of the UNFCCC Annex I inventory reporting guidelines.	UNFCCC 2020, G.6	Implemented	NIR 2021
<b>ENERGY</b>				
Fuel combustion – reference approach – all fuel types – CO <sub>2</sub>	Indicate, for the reference approach, which data sources were used for the NCVs of individual fuel types, along with the respective carbon EFs.	UNFCCC 2018, E.13 UNFCCC 2020, E.1	Implemented	NIR 2021
1.A. Fuel combustion - liquid fuels - CO <sub>2</sub>	Develop country-specific CO <sub>2</sub> EFs for all fuels that have a significant share in the fuel mix for each category.	UNFCCC 2018, E.4 UNFCCC 2020, E.3	Not implemented - no data available	In the improvement plan
1.A. Fuel combustion - liquid fuels - CO <sub>2</sub>	Include in the submission the results of discussions with SORS regarding the use of constant NCVs for liquid fuels for most of the time series (1986–2013).	UNFCCC 2018, E.5 UNFCCC 2020, E.4	Implemented	NIR 2021
1.A. Fuel combustion - liquid fuels - CO <sub>2</sub>	Report in the submission how Slovenia intends to periodically monitor NCVs for liquid fuels.	UNFCCC 2018, E.5 UNFCCC 2020, E.5	Not implemented	In the improvement plan
1.A. Fuel combustion - CO <sub>2</sub>	Make all possible efforts to obtain the missing composition data for natural gas after 1996 and recalculate the emissions	UNFCCC 2018, E.7 UNFCCC 2020, E.6	Implemented	CRF Tables 1A NIR 2022
1.A.3.b Road transportation – liquid fuels – CO <sub>2</sub>	Continue to improve the characterization of the physical and chemical properties of gasoline and diesel fuel for road transportation and report on the results achieved.	UNFCCC 2018, E.8 UNFCCC 2020, E.9	Not implemented - no data available	In the improvement plan

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
1.A.4.c.i Stationary – liquid fuels and biomass – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	Correct the notation key from “NO” to “IE” for GHG emissions from biomass fuels for the subcategory 1.A.4.c.i stationary, and explain in CRF table 9 where in the inventory these emissions are reported.	UNFCCC 2018, E.9 UNFCCC 2020, E.14	Implemented	CRF Table1.A(a)s4
Fuel combustion – reference approach – other fossil fuels	The ERT recommends that Slovenia investigate and document the reasons for the differences in other fossil fuels consumption between the reference and the sectoral approach and provide explanations for the observed significant differences in CO <sub>2</sub> emissions from other fossil fuels.	UNFCCC 2020, E.15	Implemented	NIR 2021
1.A.1.a Public electricity and heat production – other fossil fuels – CO <sub>2</sub>	Apply the default values for the CO <sub>2</sub> EF (91.7 t CO <sub>2</sub> /TJ) and CH <sub>4</sub> EF (0.03 t CH <sub>4</sub> /TJ) from table 2.2 of the 2006 IPCC Guidelines (vol. 2) for the non-biogenic fraction of municipal waste or provide a justification for the choice of the CO <sub>2</sub> EF (73.3 t CO <sub>2</sub> /TJ) and CH <sub>4</sub> EF (0.01 t CH <sub>4</sub> /TJ) used.	UNFCCC 2020, E.16	Implemented	CRF Table 1.A(a)1 NIR 2021
1.A.2.d Pulp, paper and print – biomass	Include in the NIR for this category (1) the NCVs and EFs applied for all biomass types (black liquor, wood, fibrous sludge and biogas), and (2) a description of the data sources used for the AD, NCVs and EFs. The ERT also recommends that the Party correct the NCVs for 2007–2009 in NIR table 3.2.31 to reflect the correct values applied for wood.	UNFCCC 2020, E.17	Implemented	NIR 2021
1.A.3.b Road transportation – liquid fuels – CO <sub>2</sub>	Correctly report AD for biodiesel and fossil diesel under categories 1.A.3.b.i (cars), 1.A.3.b.ii (light-duty trucks) and 1.A.3.b.iii (heavy-duty trucks and buses) so that the CO <sub>2</sub> IEF for diesel reflects the	UNFCCC 2020, E.18	Implemented	CRF Table1.A(a)s4 NIR 2021

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	CO2 EF of the COPERT model used for all vehicle categories.			
1.A.3.b Road transportation –liquid fuels – CO2	Report the correct amount of (fossil) gasoline consumption (i.e. without the amount of bioethanol) under category 1.A.3.b (road transportation) in CRF table 1.A(a)s3 and correctly allocate bioethanol to biomass under this category to avoid the CO2 IEF reported in CRF table 1.A(a)s3 being impacted by the amount of bioethanol blended into gasoline.	UNFCCC 2020, E.19	Implemented	CRF Table1.A(a)s4 NIR 2021
1.A.3.b Road transportation –liquid fuels – CO2	Include in the NIR the reasons for the observed variation in the CO2 IEF for gasoline throughout the time series.	UNFCCC 2020, E.20	Implemented	NIR 2021
1.A.4.b Residential – biomass – CH4	Include in the NIR a brief description of the methodological approach used to derive country-specific CH4 EFs for residential wood combustion installations, including the information that the CH4 EFs applied by the Party are based on a literature search of CH4 EFs for residential wood combustion installations and that two publications (from Sweden and Italy) were selected and include references to those two publications.	UNFCCC 2020, E.21	Implemented	NIR 2021
1A3b Road Transportation, CH4, CO2, N2O, 2017	For 1A3b Road Transportation and diesel oil for 2017, the TERT noted that in the NIR, chapter 3.2.6.1.6 it is mentioned, as a planned improvement, that in the next submission the GHG emissions from 2017 will be corrected, because the Statistical Office of the Republic of Slovenia (SORS) made a recalculation of	ESD review, SI-1A3b-2020-0003	Implemented	CRF Table1.A(a)s3

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	consumption of gas diesel oil. The TERT recommends that Slovenia include the revised estimate in its next submission.			
1A3b Road Transportation, CO <sub>2</sub> , 2017-2018	For category 1A3bi Road Transportation - Cars, diesel oil and CO <sub>2</sub> for years 2017-2018 the TERT noted that the implied emission factor (IEF) values are above the IPCC upper default value of 74.8 t/TJ. In response to a question raised during the review, Slovenia explained that for 1A3bi, the use of biomass is subtracted manually from fossil fuel consumption, since COPERT 4 does not provide this option. The TERT recommends that Slovenia uses the newest version of COPERT 5, which provides the possibility to report biomass emissions separately across all vehicle categories automatically.	ESD review, SI-1A3b-2020-0004	Implemented	CRF Table1.A(a)s3
1A3b Road Transportation, CO <sub>2</sub> , 2017-2018	For category 1A3bii Road Transportation - Light Duty Trucks, diesel oil and CO <sub>2</sub> for years 2017-2018, the TERT noted that the implied emission factor (IEF) values are below the IPCC lower default value of 72.6 t/TJ. In response to a question raised during the review and based also on information included in the CRF 2020 and NIR 2020, Slovenia explained that for 1A3bii emissions from biomass are included with diesel oil, since COPERT 4 does not provide distribution of biomass among vehicle categories. The TERT recommends that Slovenia uses the newest version of COPERT 5, which provides the	ESD review, SI-1A3b-2020-0002	Implemented	CRF Table1.A(a)s3

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	possibility to report biomass emissions separately across all vehicle categories.			
<b>INDUSTRIAL PROCESSES AND PRODUCT USE</b>				
2.A.4 Other process uses of carbonates - CO2	Estimates the emission levels for 1990 - 1994 using a robust extrapolation method relevant to the country's circumstances, taking into account factors like the peaking of the country's construction industry in 2006 and the 2008 economic crisis, and include the estimates in its next annual submission.	UNFCCC 2018, I.2 UNFCCC 2020, I.3	Not implemented	In the improvement plan
2.C.1 Iron and steel production - CO2	Estimate CO2 emissions from the pig iron production based on a basic carbon balance method considering the inputs (e.g. iron ore, coke) and outputs (e.g. pig iron) in the process and report in the next submission.	UNFCCC 2018, I.12 UNFCCC 2020, I.6	Not implemented	In the improvement plan
2.F.1 Refrigeration and air conditioning - HFCs	Provide in its NIR evidence that all transport equipment is exported before decommissioning.	UNFCCC 2018, I.15 UNFCCC 2020, I.8	Implemented	NIR 2021
2.F.1 Refrigeration and air conditioning - HFCs	Investigate if part of the transport refrigeration equipment is not disposed on national market without recovery (broken equipment but with working refrigeration system, equipment containing less than 50 per cent fill-in and not efficiently cooling, leakage during accidents).	UNFCCC 2018, I.15 UNFCCC 2020, I.9	Implemented	NIR 2021
2.B.10 Other (chemical industry) – CO2	The ERT recommends that Slovenia improve the description in the NIR of how AD on natural gas for hydrogen production were obtained, with	UNFCCC 2020, I.12	Implemented	NIR 2021



## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	reference to the data sources and including the assumptions and values of the CO2 EF applied for calculating emissions from hydrogen production.			
2.F.1 Refrigeration and air conditioning HFC	Correct the number of vehicles used in estimating emissions from transport refrigeration for 2018 and report the corresponding revised emissions in CRF table 2(II)B-Hs2.	UNFCCC 2020, I.13	Implemented	CRF Table2(II)B-Hs2
2.G.1 Electrical equipment – SF6	Reassess the value of disposal loss factor applied to estimate SF6 emissions from the disposal of electrical equipment and based on the analysis provide documentation and references that justify the value of 0.10 or revise it accordingly.	UNFCCC 2020, I.14	Implemented	NIR 2021
2F1 Refrigerant and Air Conditioning, HFCs, 2018	For 2F1a Commercial Refrigeration, 2F1d Transport Refrigeration, 2F1f Stationary Air-Conditioning, HFCs in 2018, the TERT noted that emissions decreased in 2018, and almost reached 2013 levels. In response to a question raised during the review, Slovenia explained that emission estimates are actually based on information from servicing companies and are decreasing due to better maintenance. However, Slovenia found during their QA/QC checks that information provided for 2018 was indeed underestimated due to a problem in their query forms. Slovenia provided a revised estimate for 2018 and stated that it will be included in their next submission. The TERT agreed with the revised estimate provided by Slovenia. The TERT recommends that Slovenia include the revised estimate in its next submission	ESD review, SI-2F1-2020-0001	Implemented	CRF Table2(II)B-Hs2

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
<b>AGRICULTURE</b>				
3.B - Manure management - N <sub>2</sub> O	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.	UNFCCC 2018, A.3 UNFCCC 2020, A.3	Implemented	NIR 2021
3.B Manure management – CH <sub>4</sub>	The ERT recommends that Slovenia include in the NIR an explanation for the inter-annual variation in the CH <sub>4</sub> IEF for 2009 and 2010 for non-dairy cattle to clarify the trend in the time series for those years.	UNFCCC 2020, A.10	Implemented	NIR 2021
3.B Manure management – CH <sub>4</sub>	The ERT recommends that Slovenia change its assumption on the average annual temperature used to select MCF values to reflect the data available, that is, a temperature of 10 °C in the early part of the time series, increasing to 11 °C during the time series and possibly increasing further in later and future years.	UNFCCC 2020, A.11	Implemented	CRF Table 3.B(a)s1 NIR 2021
3.B Manure management – CH <sub>4</sub>	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 CH <sub>4</sub> emissions are not underestimated for this MMS.	UNFCCC 2020, A.12	Implemented	NIR 2021
3.A.1 Cattle – CH <sub>4</sub>	Explain any major inter-annual changes within the category non-dairy cattle, so it is easier to interpret the trends reported in the CRF.	UNFCCC 2020, A.13	Implemented	NIR 2021

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
3.B Manure management – N <sub>2</sub> O	Specify the source for each parameter used in estimating N <sub>2</sub> O emissions from manure management of cattle (in NIR table 5.4.4) and swine (in NIR table 5.4.5). Furthermore, the ERT recommends that Slovenia checks whether the latest version of the EMEP/EEA air pollutant emission inventory guidebook (2019 version) contains updated guidance compared to the currently used values from the 2016 version, assess the applicability for its national circumstances and report on any changes made in the next submission.	UNFCCC 2020, A.13	Implemented	NIR 2021
3.B Manure management – N <sub>2</sub> O	Check whether the latest version of the EMEP/EEA Guidebook (2019) contains updated guidance compared to the currently used values from the 2016 version and report on any changes in the next submission.	UNFCCC 2020, A.14	Implemented	CRF Table 4 NIR 2021
3I Other Carbon Containing Fertilizers, CO <sub>2</sub> , 2005, 2016, 2017, 2018	For CRF Category 3I Other Carbon-Containing Fertilizers, the TERT noted that Slovenia does not report CO <sub>2</sub> emissions ('NO'). The TERT acknowledged that this is a non-mandatory category. The TERT wanted to raise this issue to inform the Party on the possibility to estimate such emissions and improve the completeness of the reporting. Slovenia decided to include CO <sub>2</sub> emissions from the use of CAN fertilizers in the inventory and in response to the review provided a revised estimate. The emission factor for the revised estimate was derived under the assumption that CAN fertilizers contain 27% N	ESD review, SI-3I-2020-0001	Implemented	CRF Table 3.G-I

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	and 8% Ca and based on the ratio of Ca to C in CaCO <sub>3</sub> . The TERT agreed with the revised estimate provided by Slovenia. The TERT recommends that Slovenia include the revised estimate in its next submission.			
<b>LULUCF and KP LULUCF</b>				
4. LULUCF – general – CO <sub>2</sub>	Make efforts to complete the uncertainty assessment of all carbon pools and gases in the LULUCF sector.	UNFCCC 2018, L.2 UNFCCC 2020, L.1	Implemented	NIR 2021
4.A Forest land	Carefully consider the choice of BEF values for estimation of emissions and removals in the Forest Land Category, especially in Equations 6 and 12 from the 2006 IPCC Guidelines . The rationale for the choice of BEF2 that was provided to the ERT during the review session should be added to the NIR. Additionally the adjustment for BEF1 should be reflected in the next submission and calculations need to be updated accordingly.	UNFCCC 2018, L.32 UNFCCC 2020, L.3	Implemented	CRF Table 4.A; NIR 2021
4.B.2 - Land Converted To Cropland – CO <sub>2</sub>	Determine and use country-specific parameters such as the changes in carbon stocks from one year of cropland growth for annual cropland.	UNFCCC 2018, L.8 UNFCCC 2020, L.7	Implemented	CRF Table 4.B NIR 2021
4.B.2 Land converted to cropland – CO <sub>2</sub>	Make efforts to improve the completeness of reporting of carbon stock changes in land conversions to other perennial cropland for carbon gains that occurred after two years or more.	UNFCCC 2018, L.10 UNFCCC 2020, L.9	Implemented	CRF Table 4.B NIR 2021
4.E Settlements – CO <sub>2</sub>	Provide information on methodology used in living biomass in settlements remaining settlements in the NIR, take further consideration whether	UNFCCC 2018, L.17 UNFCCC 2020, L.11	Implemented	NIR 2021

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	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 (V) Biomass burning – CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	Further examine whether, where forest wildfires occur in Slovenia, these affect the DOM pool and, if appropriate, add the DOM to mass of fuel available for combustion.	UNFCCC 2018, L.24 UNFCCC 2020, L.13	Implemented	CRF Table 4(V)
4.G Harvested wood products – CO <sub>2</sub>	Fully revise Section 6.9 in the NIR in its next submission based on the latest methodologies applied and provide all necessary information on activity data, parameters and equations applied.	UNFCCC 2018, L.26 UNFCCC 2020, L.15	Implemented	NIR 2021
4. General (LULUCF) – CO <sub>2</sub>	Further improve the transparency of its reporting on the LULUCF sector by completing the table provided during the review (which shows carbon stocks for each pool by land-use type, further separated by subcategory) with values for gains and losses for living biomass, and including the table in its next NIR submission.	UNFCCC 2020, L.16	Implemented	NIR 2021
Land representation – CO <sub>2</sub>	Include in the NIR the crown cover classification parameters applied for different land uses.	UNFCCC 2020, L.17	Implemented	NIR 2021
4.A.1 Forest land remaining forest land – CO <sub>2</sub>	Includes in its next NIR 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.	UNFCCC 2020, L.18	Implemented	NIR 2021

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
4.A.1 Forest land remaining forest land – CO <sub>2</sub>	Include in its NIR the information provided during the review concerning the natural disturbances, that explains the reasons for the difference in net emissions and removals for forest land remaining forest land between 2013 and 2014.	UNFCCC 2020, L.19	Implemented	NIR 2021
4.A.2 Land converted to forest land – CO <sub>2</sub>	Update the description in the NIR of the methodology applied for this category to reflect the use of the stock difference method (tier 2) and equation 2.23 of the 2006 IPCC Guidelines (vol. 4) for calculating carbon stock change in deadwood and litter.	UNFCCC 2020, L.20	Implemented	NIR 2021
4.B.1 Cropland remaining cropland – CO <sub>2</sub> 4.C.2 Grassland remaining grassland – CO <sub>2</sub>	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 NIR the reason that national circumstances do not allow a higher-tier method to be applied.	UNFCCC 2020, L.21	Implemented	NIR 2021
4.B.1 Cropland remaining cropland – CO <sub>2</sub> 4.C.2 Grassland remaining grassland – CO <sub>2</sub>	Improve the transparency in the NIR 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 between annual and perennial cropland (i.e. that there is no differentiation in the method for calculating carbon stock change in mineral soils	UNFCCC 2020, L.22	Implemented	NIR 2021

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	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	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).	UNFCCC 2020, L.24	Implemented	NIR 2021
4.C.1 Grassland remaining grassland – CO2	Include in the NIR 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.	UNFCCC 2020, L.25	Implemented	NIR 2021
4.D Wetlands – CO2, CH4 and N2O	The ERT reiterates the encouragement from the previous review report for Slovenia to use the Wetlands Supplement in preparing its annual inventory for future annual submissions.	UNFCCC 2020, L.26	Not implemented - no data available	In the improvement plan
4.E.2 Land converted to settlements – CO2	Include in the NIR 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	UNFCCC 2020, L.27	Implemented	NIR 2021

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	of digital orthophotos, as well as to the expert judgement as described above).			
4(V) Biomass burning - CO2	Include in the next NIR documentation showing that wildfires are not covered by the forest ecosystem condition survey because of the applied grid size (to large) and that therefore there is no double counting of CO2 emissions from wildfires in forest land remaining forest land.	UNFCCC 2020, L.28	Implemented	NIR 2021
KP-LULUCF - Forest management - CO2, CH4, N2O	Work further on harmonization of the forest definition and its implementation to classify the same patches of land as forest under both Convention and the Kyoto Protocol.	UNFCCC 2018, KL.14 UNFCCC 2020, KL.4	Not implemented	In the improvement plan
KP-LULUCF - Forest management - CO2, CH4, N2O	Update the FM cap in the annual submission, reporting the value of 5,691.720 t CO2 eq in CRF accounting table, as contained in the review of the report of facilitate the calculation of the assigned amount.	UNFCCC 2018, KL.15 UNFCCC 2020, KL.5	Implemented	CRF Table 4(KP)
KP-LULUCF - Deforestation - CO2	Include in the next NIR the information that the data from the Slovenia Forest Service on deforestation are now used only for verification because data on land-use conversion to and from forest land are obtained from digital orthophotos.	UNFCCC 2020, KL.9	Implemented	NIR 2021
FM – CO2	Include in the next NIR the list of elements identified as key in making a technical correction to the FMRL.	UNFCCC 2020, KL.10	Implemented	NIR 2021
FM – CO2	Include in its calculation of the technical correction to the FMRL all elements identified in ID# KL.10 above as well as the recommendations in the report of the technical assessment of the FMRL	UNFCCC 2020, KL.11	Implemented	CRF Table 4(KP-I)B.1.1, NIR 2021



## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
	submission of Slovenia in 2011 (FCCC/TAR/2011/SVN). The ERT, noting the fact that the final accounting of the second commitment period is within less than two years, strongly encourages Slovenia to start on the calculation of the technical correction to the FMRL as soon as possible, and if possible, provide information on this calculation in the next annual submission.			
HWP – CO <sub>2</sub>	Provide values on harvesting for the information item in the CRF Table 4(KP-I)C.	UNFCCC 2020, KL.12	Not implemented	In the improvement plan
<b>WASTE</b>				
5. Waste	Include information about how expert judgments in each category in the waste sector were conducted in the NIR.	UNFCCC 2018, W.10 UNFCCC 2020, W.1	Implemented	NIR 2022
5. Waste	Ensure that the use of multiple sources of data for municipal solid waste disposal for different periods is in accordance with chapter t of the IPCC good practice guidance.	UNFCCC 2018, W.2 UNFCCC 2020, W.2	Implemented	NIR 2021
5.D.2 Industrial waste water	Provide in the NIR a detailed description and justification for the total amount of industrial wastewater produced, the fraction of the wastewater undergoing various treatment methods (treated (e.g. well managed and not well managed) and untreated discharge to rivers, lakes and sea, if any) and the corresponding MCFs applied to the various fractions.	UNFCCC 2018, W.13 UNFCCC 2020, W.6	Implemented	NIR 2021

SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
5.A Solid waste disposal on land – CH <sub>4</sub>	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 NIR 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.	UNFCCC 2020, W.9	Implemented	NIR 2021
5.D.2 Industrial wastewater – CH <sub>4</sub>	If recalculations are performed for this category for the next submission, Slovenia include in the NIR explanatory information on the recalculations consistent with paragraphs 43–45 and 50(i) of the UNFCCC Annex I inventory reporting guidelines, including reporting any changes in emission estimates and the reason for the changes compared with the previously submitted inventory, as well as changes in response to the review process.	UNFCCC 2020, W.10	Implemented	NIR 2021
5.D.2 Industrial wastewater – CH <sub>4</sub>	Estimate CH <sub>4</sub> emissions from pharmaceutical industry or provide in the NIR clear justification for its exclusion based on expert judgment (e.g. documentation showing that the pharmaceutical industry does not generate organic carbon).	UNFCCC 2020, W.11	Implemented	CRF Table5.D
5.D.2 Industrial wastewater – CH <sub>4</sub>	Include in the NIR a clear explanation justifying 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.	UNFCCC 2020, W.12	Implemented	NIR 2021

## SLOVENIA'S NATIONAL INVENTORY REPORT 2022

CRF category / issue	Review recommendation	Review report, paragraph	Status of the implementation	Comment
5.D Wastewater treatment and discharge – CH <sub>4</sub>	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 CH <sub>4</sub> emissions from wastewater treatment and discharge in accordance with the 2006 IPCC Guidelines, and report in the NIR 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.	UNFCCC 2020, W.13	Not implemented - no data available	In the improvement plan

## PART II: SUPPLEMENTARI INFORMATION UNDER ARTICLE 7, PARAGRAPH 1

### 11 KP-LULUCF

#### 11.1 General information

Slovenia provides supplementary information under Article 7 of the Kyoto Protocol for the LULUCF sector. The information is prepared and reported in line with the requirements as specified in Decision 16/CMP.1, 2/CMP.8, 6/CMP.9 and the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014).

Slovenia reports and accounts emissions and removals from Deforestation (D) under Article 3.3. and emissions and removals from Forest Management (FM) under Article 3.4. No emissions and removals from Afforestation and Reforestation (AR) are reported under Article 3.3. as these activities are not considered human-induced.

Emissions from Article 3.3 activity (D) were 262.50 Gg CO<sub>2</sub> eq in 2020. The area subjected to D was 27.295 kha at the end of 2020. Removals from Article 3.4 activity (FM) were -4,411.51 Gg CO<sub>2</sub> eq in 2020. The area subjected to FM was 1,164.19 kha at the end of 2020.

##### 11.1.1 Definition of forest and any other criteria

Forest is defined as land spanning more than 0.25 hectares with trees higher than 2 meters and canopy cover more than 30 percent, or trees able to reach these threshold in situ. It includes abandoned agricultural land on area more than 0.25 ha, which have been abandoned for more than 20 years, with minimal tree height 5.0 m and have a tree crown cover between up to 75 % are defined as forests. The selected values are listed in the CRF table NIR1 under the KP LULUCF and in table below.

**Table 11.1.1: Elected values for forest parameters.**

Parameter	Range	Selected value
Minimum land area	0.05 – 1 ha	0.25 ha
Minimum crown cover	10 – 30 %	30 %
Minimum tree height	2 – 5 m	2 m

Activity data of forest land between KP and UNFCCC reporting are consistent, as a new approach using point sampling method (1 km x 1 km grid) has been used to acquire activity data since 2016 annual submission. Activity data of forest land and deforestation from forest management plans being provided annually by Slovenia Forest Service, as well as data of forest areas from the official land-use map (ALUM) are expected to be used for verification in the future.

All land converted to forest land occurs through process of spontaneous afforestation of abandoned agricultural lands. There was no human planting or seedling of forests in the specified time period. According to national policy it is also unlikely that this will occur in the future.

The selected threshold values are consistent with those values used in the reporting to the FAO and FRA forest definition. Differences of definitions are not relevant for final estimation of CO<sub>2</sub> sinks under Articles 3.3 and 3.4.

### **11.1.1 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol**

In accordance with Paragraph 6 of the Annex to Decision 16/CMP.1 Slovenia has decided to elect the activity Forest Management (FM) under Article 3.4 of the Kyoto Protocol, for inclusion in the accounting for the first commitment period. Therefore, the accounting of FM become mandatory in the second commitment period.

For the accounting of LULUCF-activities under Article 3.4 during the second commitment period, Slovenia has not elected any other voluntary activity.

### **11.1.2 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time**

The information about the areas for activities under Articles 3.3. and 3.4. is based on the same methodology as that for the UNFCCC reporting. The methodology was developed in the targeted project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”. By applying the same source of activity data in the KP and UNFCCC reporting overall consistency was improved. For D area all conversions from Forest land to other land uses taken into account. Note that the data from the Slovenia Forest Service on deforestation are now only used for verification, as the data on land-use conversion to and from forest land are obtained from digital orthophotos. Forest land remaining Forest land area was used to define FM. The activity Forest management (FM) is assumed occurring on all land fulfilling the forest definition (see subchapters 6.2.2 and 6.4.3). Areas of spontaneous afforestation was added to category Other. Afforestation/Reforestation does not occur in Slovenia.

### **11.1.3 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified**

Slovenia has elected to report Forest Management under Article 3.4 activities. So far, no other 3.4 activity, such as Cropland Management or Grazing Land Management, was elected in the

first nor in the second commitment period. Therefore, there is no need to build up a hierarchy between Forest Management and other Article 3.4 activities. To ensure that the reported Forest Management activities have occurred on forest land, the total land area was classified into six land-use categories as for the UNFCCC reporting, and each land area was classified only under one land-use category. Besides, the definition of forest has remained the same, irrespective of data source.

## **11.2 Land-related information**

### **11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3**

The spatial assessment unit to determine the area of units of land under Article 3.3 is 0.25 ha, which is the same as the minimum area of the forest. The spatial assessment unit under Article 3.3 is the same as for the UNFCCC reporting.

### **11.2.2 Methodology used to develop the land transition matrix**

The methodology used to develop the land transition matrix under KP is the same as for the UNFCCC reporting. The methodology is based on the point sampling on the 1 km x 1km grid (20,253 sampling plots) set over the whole territory of Slovenia (see description in the subchapter 7.2.1.). Thus, annual and total areas under Articles 3.3 and 3.4 for Deforestation (D) and Forest Management (FM) are consistent with the data used for developing the land-use matrix under the UNFCCC reporting. Areas of spontaneous afforestation were added from Other to FM when those areas meet the definition of forest.

### **11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations**

Forestry spatial information system, managed by SFS, is based on stand level inventory for forest management purposes. There are 14 forest management regions, which are further divided into 136 management units. For both management levels forest management plans are prepared for the period of 10 years. Smallest spatial unit for forest management is compartment (2 – 5 ha). All data are georeferenced and can be aggregated to higher levels. Therefore, according to 2006 Guidelines Slovenia uses Reporting Method 1 with national border as geographical boundary to identify the geographical location. As Slovenia is considered relatively small, the use of one geographic area is assumed not to lead to increase uncertainty nor reduce heterogeneity of forest status, which is in line with the good practice of the KP Supplement (p. 2.16, IPCC 2014).

Due to strict environmental legislation at all conversions from forest, a permit from SFS is needed. Therefore, all areas converted from forests are documented in forestry spatial information system database and included in annual reports (Annual reports on forests). Slovenian legislation forbids clear cutting as forest management practices. Deforestation activities according to SFS occur due to urbanization, infrastructure, agriculture, mining, power

industry and other reasons, but in recent years mostly for agricultural purposes. Although SFS records all deforestation activities, there is lack of data on specific purposes within each of the category abovementioned. Areas of spontaneous expansion of forest are annually documented in forestry spatial information system database for 1/10 of forest management units (10 years period cycle for whole country) and added to FM area and included in annual reports.

## **11.3 Activity-specific information**

### **11.3.1 Methods for carbon stock change and GHG emission and removal estimates**

#### **11.3.1.1 Description of the methodologies and the underlying assumptions used**

##### **11.3.1.1.1 Carbon pools**

Methodological principles used for estimatons of carbon stock changes and greenhouse gas emissions/removals under Kyoto Protocol were the same as for estimations under UNFCCC reporting. Calculations were made in accordance with IPCC 2006 Guidelines and with the IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

Under Article 3.3 activities (D) estimation of carbon stock changes in living biomass (above and belowground biomass), dead organic matter (dead wood, litter) and soils were made. Also calculations for N<sub>2</sub>O emission from disturbance associated with conversion from Forest land to Cropland, Grassland, Settlements, and Other land were taken into account.

Main methodological approach for calculations of carbon stock change estimates during the commitment period was by determining the carbon stocks in all pools prior to and after deforestation event. Biomass carbon stock after deforestation was assumed to be equal to zero. More detailed description of calculations for conversion of forest to other land uses were made in accordance to chapters 6.5.4.2, 6.6.4.2, 6.7.4.2, 6.8.4.2, 6.9.4.2.

Under Article 3.4 activities (FM) estimation of carbon stock changes in living biomass (above and belowground biomass), dead organic matter (dead wood, litter) and soils were made. Methodologies used for estimation changes in carbon stocks are desribed in the section 6.4.4.1. Also calculations for non-CO<sub>2</sub> emissions from biomass burning were taken into account.

##### Carbon stock changes in living biomass

In accordance with the decision tree provided in the 2006 Guidelines, carbon stock changes in living biomass in Forest land remaining Forest land are estimated by Tier 3, Stock-Difference method (Equation 2.8). 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 the inventories. Data from the national forest inventory (i.e. FECS), carried out in years 2000, 2007, 2012 and 2018, were used in calculations.

#### Carbon stock changes in dead organic matter

In accordance with the decision tree provided in the 2006 Guidelines, carbon stock changes in dead organic matter in Forest land remaining Forest land are estimated by Tier 2.

For carbon stock changes in litter “a pool is not a source” approach was used. In the latter, 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 change is zero. Results of the soil expertise for period 1996–2006 (Kobal and Simoncic, 2011) show relative stable carbon stocks in litter in Forest land remaining forest land. Carbon stock changes in dead wood were estimated based on FECS data from 2007, 2012 and 2018 using the Equation 2.19 of the 2006 Guidelines. Note that dead wood carbon stock for the year 2000 was estimated using the surrogate method (see chapter 6.4.4.1).

#### Carbon stock changes in soils

In accordance with GPG2003, for carbon stock changes in soils “a pool is not a source” approach was applied. Under the latter, it is assumed that when forest remains forest, the carbon stock in soil organic matter does not change, regardless of change in forest management, types, and disturbances regimes; in other words that the carbon stock in mineral soil remains constant so long as the land remains forest. Results of the soil expertise for period 1996–2006 (Kobal and Simoncic, 2011), show relative stable carbon stocks in forest soils. In the last 20-year period no large fluctuation in forest management regime has been occurring. However, forests were hardly damaged by ice storm in 2014. Carbon stock monitoring of forest soil has started in 2016 in the region of Postojna, where disturbance was the worst. Preliminary results at 30 sites show that carbon in litter and soil organic carbon increased, but the results are not published yet. Soil monitoring continued in 2018. Soil as that depends along with the climate and bedrock factors largely on the source of carbon coming from dead wood and litter. For additional explanation, please see chapters 6.4.4.1 and 6.3.2 under the Convention.

#### Emissions from Wildfires

As controlled burning is not allowed in Slovenia, all fires are assigned to “wildfires”. It is assumed that all fires affected productive forests. The area of wildfires in Slovenia is very small, less than half percent in the year 2003, which was the most problematic year in the following period. For calculations the Tier 2 (country level estimated of area burned) was used and estimation of GHGs directly released in fires. Data on wildfires, such as frequency, type of fires and burnt forest area, are collected annually by Slovenia Forest Service.

More detailed explanation about calculations is described in chapter 6.4.4.2.

### **11.3.1.1.2 Other emissions**

Emissions of N<sub>2</sub>O and CH<sub>4</sub> are estimated in the same way as under the UNFCCC. Estimations of N<sub>2</sub>O and CH<sub>4</sub> emissions due to biomass burning were made using default emission factors from table 2.5 for N<sub>2</sub>O and Equation 2.27 according to 2006 Guidelines default methodology



(see chapter 6.4.4.2). The reporting of N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions in mineral soils are reported for D (see chapter 6.5.4.2).

#### **11.3.1.1.3 Pools reported under Article 3.3 and elected activities under Article 3.4 of the KP**

Slovenia reports and accounts for all carbon pools (aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon) as well as for all non-carbon pool emissions.

#### **11.3.1.1.4 Natural disturbances**

Slovenia does not intend to use the provision to exclude emissions caused by natural disturbances during the second commitment period of the Kyoto Protocol.

#### **11.3.1.1.5 Harvested wood products**

The methodology used for accounting for net emissions from the HWP pool is equal to the method used for the reporting of HWP under the UNFCCC with the exception that HWP from deforestation is excluded.

Data sets cover production figures from year 1900-2015 for: Roundwood separately for logs and pulpwood, sawnwood, veneer, particle board, fibreboard, pulp production. Time series start from year 1900 using all existing sources of information (historical records, official statistics and independent industry reports and other studies). Imported wood is not accounted. Equations 35 and 36 provide information how imported wood is excluded. Emissions occurring during the second commitment period from the HWP removed from forests before the start of the second commitment period were also accounted for. Additionally, equations 37, 38 and 39 define how imported wood is excluded for different product categories (see chapter Calculation model excludes all wood residues (instant oxidation), excludes double counting issues (plywood could be a product where double counting exists as plywood subcategories use products already reported in other product groups: e.g. CN 44129490 use sawnwood as input material) and excludes use of recovered paper (it is difficult to trace origin of recovered paper which is dominant input material in paper and paperboard production and could severely overestimate real HWP contribution originating from domestic harvest).

Initial stock figures and data for each HWP type are provided in this year submission.

HWP resulting from deforestation has been accounted based on instantaneous oxidation. Datasets regarding areas of deforestation and harvested volume were used for determining factor  $f_{FM}$  according to IPCC 2013 KP Supplement. CO<sub>2</sub> emissions from SWDS and energy purposes are accounted based on instantaneous oxidation and are excluded from calculations.

In the first commitment period of the Kyoto Protocol, in line with the Marrakesh Accords (Decision 16/CMP.1) and in accordance with the IPCC 2003 GPG (IPCC 2003), the contribution to emissions and removals from the HWP pool was taken into account on the basis of instantaneous oxidation and thus was neither reported nor accounted (cf. IPCC 2014, Chapter 2.8.2).

#### **11.3.1.2 Justification when omitting any carbon pool or GHG emissions and removals from activities under Article 3.3 and elected activities Article 3.4**

For calculations of carbon stock changes in litter and soils “a pool is not a source” approach was used. According to this approach the net emissions/removals from litter and soils is balanced and therefore equal to zero. Results of the soil expertise for period 1996 – 2006 (Kobal and Simoncic 2011), show relative stable carbon stocks in litter in forest land remaining forest land. Estimates under FM for carbon stock changes in litter and soils were therefore not reported. See also the comments being provided in the 6.4.1.1. section (Convention part).

#### **11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out**

Slovenia has not factored out effects from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of age structure resulting from activities prior to 1 January 1990. However, such effects are however balanced in terms of accounting for Forest Management, since they are included in the FMRL and in the reported figures.

#### **11.3.1.4 Changes in data and methods since the previous submission (recalculations)**

Considering ERT revision report and recommendations data and methodologies were internally revised and recalculations were made.

#### **11.3.1.5 Uncertainty estimates**

The uncertainties for Article 3.4 have not been estimated separately for lands under FM. It was assumed that uncertainty estimates for Forest land remaining Forest land apply also for lands under FM (Section 7.4.4.). The uncertainties for Article 3.3 activities have not been estimated separately.

#### **11.3.1.6 Information on other methodological issues**

Slovenia has decided to account for the emissions and removals under Article 3, paragraphs 3 and 4 at the end of the commitment period. Slovenia will further develop the methods for area estimation as well the methods to estimate emissions and removals of greenhouse gases and their uncertainties.

National forest inventory (FECS) provides data about growing stock and dead wood. The monitoring of soil and litter was also implemented within the FECS framework, however since 2007 it has not been repeated yet. The argument for applying FECS data is that it is the only large scale sample plot based monitoring system in Slovenia that covers all forest land and gives reliable estimates for the living biomass and dead organic matter. It is also a system, which can produce the input data for the soil model.

In 2018 the repetition of the national forest inventory, so called Forest and Forest Ecosystem Condition Survey was carried out for the fourth time. The methodology stayed the same from the one from 2000, although some improvements were made to ensure consistency over time when reporting the GHG emissions/removals for the first commitment period. A detailed protocol was established for the FECS 2012 (see Annex 3).

**11.3.1.7 For the purpose of accounting as required in paragraph 18 of the annex to draft decision -/CMP. 1 (Land use, land-use change and forestry) attached to decision 11/CP.7, an indication of the year of the onset of an activity, if after 2008.**

Forest management (FM) area increases during the first commitment period, as well in the beginning of the second commitment period due to inclusion of new forest area by natural (spontaneous) afforestation of abandoned agricultural land. The land of natural afforestation is added to FM only when land meets exact definition of forest area under FM.

According to requirement of paragraph 6(d) of Annex to decision 15/CMP.1, Slovenia declares that new FM area is not accounted (estimated as removals) in previous years during the first and in the second commitment period. Therefore, new area of FM is estimated by its removals and accounted under FM only the years since the area has been recognized as forest.

## **11.4 Article 3.3**

### **11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced**

All data for areas under Articles 3.3 in the period 1986-2014 were adopted from the targeted project "Bases for improving the methodology of greenhouse gas emissions in relation to land use, land use change and forestry" to improve consistency among the UNFCCC and KP reporting. However, data of Slovenia Forest Service serve as additional data source to verify deforestation acquired by the point sampling. Conversions from Forest land to Wetlands and from Forest land to Other land are also accounted for deforestation under Article 3.3 reporting, since the previous land was managed as suggested by the ERT.

Deforestation in Slovenia, which is human-induced, have to be permitted by legal entities. Forest Act (Section 2, paragraph 1) states: "A permit for a spatial intervention in accordance with regulations on regional planning shall be necessary for interventions in forests or a forest

land. The Forest Service must give its agreement to the permit for a spatial intervention (clearing a forest)", including a human-induced deforestation activities that started in 1990. Human-induced Afforestation/Reforestation (AR) do not occur in Slovenia, because all land converted to forest land occurs through process of natural afforestation of abandoned agricultural lands. There was no human planting or seedling of forests in the specified time period. According to national policy it is also unlikely that this will occur in the second commitment period.

#### **11.4.1 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation**

Any type of harvesting, regular or sanitary shall be approved by Slovenia Forest Service according to the Forest Act. If a large forest area is mainly or totally damaged, the legislation on prevention of insect and fungus disturbances binds owners to implement the sanitation harvest. After that, the re-establishment work in terms of restoration should be started immediately as possible. That areas remain registered as forest land in forestry spatial information system database of the SFS.

#### **11.4.2 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested**

All areas converted from forests are documented in forestry spatial information system database and are included in annual reports. Therefore, there are no forest areas without forest cover, which are not yet classified as deforested.

#### **11.4.3 Emissions and removals from Deforestation**

Deforestation in the second commitment period is a net source of emissions. The latter amounted to 262.50 Gg CO<sub>2</sub> equivalent in 2020.

Area of deforestation under KP is the same as sum of areas of Forest land converted to other land uses reported under Convention. Reconstructed land-use change matrices assume objective areas on deforestation, although trends are not completely in line with the annual estimates of Slovenia Forest Service. All deforested areas are spatially located (geo-referenced) and are documented in annual report of Slovenia Forest Service, which is entitled by legislation to approve all conversions from forest (deforestation). In their annual reports, they include also illegally deforested areas.

## **11.5 Article 3.4**

### **11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since January 1990 and are human-induced**

All data for areas under Articles 3.4 in the period 1986-2017 were adopted based on the methodology of targeted project "Bases for improving the methodology of greenhouse gas emissions in relation to land use, land use change and forestry" to improve consistency among the UNFCCC and KP reporting. All selected forest areas (for KP reporting) were at 1 January 1990 under FM activities, because Slovenia includes all these forests in forest management plans. The first forest management plans for all 14 forest management regional units, covering entire territory of Slovenia, were developed for the period 1971-1980. All FM activities that are human-induced have been tracked by Slovenia Forest Service since 1990. The latter also includes forest plantations that were established through human-induced planting on forest land. However, it should be noted that all forest plantations in Slovenia that occur on non-forest land, are part of cropland, regardless of the name. Forest plantation in terms of national land-use class ID 1420 (see Table 6.2.1) mainly include poplar and willow stands with high rotation cycle. Emissions and removals from forest plantations are currently reported in Cropland under Convention and will be reported under Cropland Management in the next commitment period.

### **11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year**

Slovenia has not elected Cropland Management, Grazing Land Management or Revegetation nor B.5. Wetland drainage and rewetting under Article 3.4.

### **11.5.3 Information relating to Forest Management**

All forests in Slovenia are considered managed, because forest management plans are prepared for all forests, regardless ownership, conservation degree or natural conditions.

Slovenian forests are part of sustainable and multipurpose management with the principles of environmental protection and natural values. Our main concerns are: permanent and optimal functioning of forest as ecosystems and implementation of all of their functions (productive, ecological and social) on a permanent basis.

### **11.5.4 Emissions and removals from Forest Management**

Forest management (FM) was a net sink in the beginning of the second commitment period. The emissions from carbon stock changes were -4,411.51 Gg CO<sub>2</sub> equivalent in 2020.

According to paragraph 9(c) of Annex to decision 15/CMP.1, Slovenia declares that FM removals are not accounted for under activities under Article 3.3 (Deforestation for Slovenia case).

### **11.5.5 Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for**

The natural forests in sense of the decisions for the second commitment period do not exist in Slovenia. The national legislation (e.g. Forest Act) in Slovenia does not define the term “natural forests” either the IPCC. Moreover, all forests are considered managed in Slovenia, thus all forests are reported. Moreover, emissions and removals of FM land in Slovenia cover emissions and removals of all forests, except those resulting from deforestation (in the year of D) which are accounted under Article 3.3 activities.

### **11.5.6 Information that demonstrates methodological consistency between the reference level and reporting for forest management during the second commitment period**

Slovenia reported a FMRL of -3.171 Mt CO<sub>2</sub> eq per year (including HWP) in 2011 as requested by the Cancún decisions. The reported value is the average of the projected data series from FM for the period 2013-2020, taking account policies implemented before the end of 2009. The construction of the FMRL took into account the elements included in footnote 1 of paragraph 4 of the decision ([-/CMP.6]) on LULUCF.

The emissions from harvested wood products (HWP) until the second commitment period have been calculated using a revised FOD ("first order decay") method according to IPCC GL (2006) and Pingoud and Wagner (2006). The calculation of net emissions follows recommended method as outlined in IPCC 2006, Vol.4, Ch. 12 (Equation 12.1). The estimation uses the product categories, half-lives and methodologies as suggested in paragraph 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4.

The projected emissions and removals from the HWP pool have been calculated in line with the methodological requirements as set out in IPCC (2014), including the guidance on how to calculate the initial carbon stock in the HWP pool at the start of the second commitment period.

### **11.5.7 Technical corrections**

The technical correction for the FMRL was made in accordance with Decision 2.CMP/7 to ensure methodological consistency between the FMRL and reporting for FM during the second commitment period. Following the guidance to identify the need for a technical correction (Section 2.7.6; IPCC, 2014) Slovenia performed a technical correction for the FMRL for the reasons described below.

The following list of identified elements was considered key to make a technical correction of the FMRL:

- Methodological inconsistency: the Gain-Loss method was used to produce the FMRL, while the Stock-Difference method was used to estimate GHG emissions and removals for FM in the second commitment period
- Modification of some methodological elements:
  - addition of new pools or gasses, namely dead wood and emissions from biomass burning, which were not included in the FMRL,
  - recalculated historical data on (forest) area due to change in data source,
  - recalculated historical data for FM in the GHG inventory (i.e. recalculated growing stock based on the NFI data for the years 2007 and 2012 and change in parameters used to convert volume to biomass).

At the time of preparation of the FMRL submitted in 2011, Slovenia had used the gain-loss method, forest area, and volume-to-biomass conversion parameters that are not consistent with the method and other data currently used for reporting under the UNFCCC and KP. Therefore, the same data used for reporting were used to define the updated FMRL and consequently to calculate the FMRL<sub>corr</sub>. However, the policy assumption on harvesting rates for the 2013-2020 period was considered the same as that in the 2011 submission. When new projections are made, it is essential to keep all policy assumptions under the business-as-usual scenario (as reported in the FMRL submission) unchanged (IPCC, 2014).

**Table 11.5.1: Forest area in the second commitment period**

Year	2013	2014	2015	2016	2017	2018	2019	2020
Area [kha]	1052.07	1068.17	1084.27	1100.26	1116.24	1132.22	1148.20	1164.19

**Table 11.5.2: Parameters to convert volume to biomass**

Parameter / tree species	WD	BEF	CF	R
Beech	0,58	1,19	0,47	0,30
Spruce	0,40	1,15	0,47	0,29
Fir	0,39	1,15	0,47	0,29
Oak	0,58	1,20	0,47	0,42
Scotch Pine	0,42	1,17	0,47	0,31
Maple	0,52	1,18	0,47	0,34
Hornbeam	0,63	1,20	0,47	0,35
Chestnut	0,48	1,19	0,47	0,37
Black Pine	0,42	1,20	0,47	0,33
Hop Hornbeam	0,63	1,20	0,47	0,38
Remaining	0,49	1,18	0,47	0,32

The following new carbon pools or gasses were included in the FMRL:

- Dead wood; average net emissions from dead wood for 2000-2009,
- Emissions from biomass burning; average net emissions from wildfires for 2000-2009.

**Table 11.5.3: Forest Management Reference Level recalculated for the purpose of calculating the Technical Correction**

FMRL <sub>corr</sub>	2013-2020 [kt CO <sub>2</sub> eq]
Above-ground biomass	-2,242.46
Below-ground biomass	-690.00
Dead wood	-293.85
Biomass burning	31.93
Harvested wood products	138.00
<b>Total</b>	<b>-3,194.37</b>
<b>Total with HWP</b>	<b>-3,332.37</b>

The forest management reference level (with HWP) was recalculated to -3.332,37 kt CO<sub>2</sub> eq and the technical correction applied to the original value was estimated to 161.37 kt CO<sub>2</sub> eq (Table 11.5.4).

**Table 11.5.4: Technical correction for the second commitment period**

Value	[kt CO <sub>2</sub> eq]
FMRL <sup>1</sup>	-3,171
FMRL <sub>corr</sub>	-3,332.37
<b>TC without HWP</b>	<b>-299,37</b>
<b>TC with HWP</b>	<b>-161.37</b>

<sup>1</sup> Forest Management Reference Level inscribed in Appendix to Decision 2/CMP.7

## 11.6 Other information

### 11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Key category analysis for KP-LULUCF was performed according to section 5.4 of the IPCC good practice guidance for LULUCF (IPCC 2006). The key categories, also reported in CRF table NIR.3, are CO<sub>2</sub> emissions from deforestation (conversion to grassland). CO<sub>2</sub> removals due to forest management is also a key category.

## 11.7 Information relating to Article 6

There are no Article 6 activities concerning the LULUCF sector in Slovenia.



### **11.8 Legal entities authorized to participate in mechanisms under Article 6, 12 and 17 of the Kyoto Protocol**

In order to reduce GHG emissions installation operators may use up to 15.761 % of their issued allowances in the period 2008-2012. They can surrender emission reduction units (ERU) from the projects of joint investment (JI) and certified emission reductions (CER) from the projects of clean development mechanism (CDM).

There is no project under Article 6, 12 or 17 of the Kyoto Protocol in Slovenia.

## 12 INFORMATION ON ACCOUNTING OF KYOTO UNITS

### 12.1 Background information

Annex I Parties are required to report their national registries' holdings and transactions of Kyoto units and inform about related issues as specified in Decision 15/CMP.1 Section E. The following chapters serve this purpose.

### 12.2 Summary of information reported in the SEF tables, discrepancies and notifications

**Table 12.2.1: SEF, discrepancies and notifications**

Reporting Item	Description
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2021 generated on 14 April 2022 (RREG_SI_2021_2_2.xlsx) contains the information required in paragraph 11 of the annex to decision 15/CMP.1.  The content of the SEF is attached to the submission.
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2021.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2021.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2021.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2021.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

## 12.1 Publicly Accessible Information

The public has access via the national registry website, URL:

<https://www.gov.si teme/trgovanje-spraviciami-do-emisije/> under the title "Poročila za javnost skladna s sklepi Kjotskega protokola" where are available Information on registry account types and account holders, information regarding Article 6 projects, information on transactions and the list of account holders authorised to hold Kyoto units in their accounts (Table 12.1.1).

The public information could also be found on the website of the Slovenian part of the Union Registry, maintained by the European Commission, at:

<https://unionregistry.ec.europa.eu/euregistry/SI/public/reports/publicReports.xhtml>

**Table 12.1.1: Publicly Accessible Information**

Annual Submission Item	Report
15/CMP.1 annex I.E  Publicly accessible information	Public available information could be found on the national registry website at: <a href="https://www.gov.si teme/trgovanje-spraviciami-do-emisije/">https://www.gov.si teme/trgovanje-spraviciami-do-emisije/</a> under the title "Poročila za javnost skladna s sklepi Kjotskega protokola" and also on the website of the Slovenian part of the Union Registry, maintained by the European Commission, at: <a href="https://unionregistry.ec.europa.eu/euregistry/SI/public/reports/publicReports.xhtml">https://unionregistry.ec.europa.eu/euregistry/SI/public/reports/publicReports.xhtml</a>  In accordance with the requirements of Annex E to decision 13/CMP.1, all required information for a Party is provided.

## 12.2 Calculation of the Commitment Period Reserve

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and paragraph 18 of Decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8.

For the purposes of the joint fulfilment, the commitment period reserve applies to the EU, its Member States and Iceland individually.

The national commitment period reserve is calculated in accordance with paragraph 6 of the Annex to decision 11/CMP.1 as 90% of the proposed assigned amount or 100% of eight times its most recently reviewed inventory, whichever is the lowest. The Slovenian commitment period reserve is calculated either as:

99,425,782 t CO<sub>2</sub> equivalent \* 0.9 = 89,483,204 t CO<sub>2</sub> equivalent                      or

17,502,138 t CO<sub>2</sub> equivalent (emission level 2018) \* 8 = 140,017,101 t CO<sub>2</sub> equivalent

Slovenia has interpreted the 'most recently reviewed inventory' as the year 2018, which has been reviewed in October 2020. The Slovenian commitment period reserve is therefore 89,483,204 t CO<sub>2</sub> equivalent.

**Table 12.2.2: Slovenia's emission level and commitment period reserve**

Assigned amount for the second commitment period (t CO <sub>2</sub> eq)	90 % of assigned amount (t CO <sub>2</sub> eq)	100% of most recently reviewed inventory multiplied by 8 (t CO <sub>2</sub> eq)	Commitment period reserve (t CO <sub>2</sub> eq)	Article 3.7
99,425,782	89,483,204	140,017,101	89,483,204	Does not apply

## 12.3 KP-LULUCF Accounting

Slovenia has chosen to account for emissions and removals from the LULUCF for the entire commitment period at the end of the commitment period.

## 13 Changes to National System

No changes have been made since the previous submission.

## 14 Information on changes in the national registry

The following changes to the national registry of Slovenia have occurred in 2021. Note that the 2021 SIAR confirms that previous recommendations have been implemented and included in the annual report.

**Table 14.1: Information on changes according to Decision 15/CMP.1**

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change in the name or contact information of the registry administrator occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	There was a change in the cooperation arrangement during the reported period as the United Kingdom of Great Britain and Northern Ireland no longer operate their registry in a consolidated manner within the Consolidated System of EU registries, CS EUR.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	The use of soft tokens for authentication and signature was introduced for the registry end users.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reported period.

*SLOVENIA'S NATIONAL INVENTORY REPORT 2022*

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.

## 15 Information on Minimization of Adverse Impacts in Accordance with Article 3, Paragraph 14

Under Article 3.1 of the Kyoto Protocol and UNFCCC Decision 31/CMP.1, Annex I Parties shall report on how they are striving to implement the commitments, together minimizing adverse social, environmental and economic impacts on developing country Parties. And according to the BR reporting guidelines (2/CP.17) Annex I party is encouraged to provide, to the extent possible, information on the assessment of the economic and social consequences of response measures.

Annex I countries, including Slovenia, implement measures aimed at substantially reducing greenhouse gas emissions and thus contributing to climate change mitigation. The implementation of increasingly stringent environmental legislation and other measures aimed at fulfilling this obligation might be associated with a range of side effects. It is not excluded that potentially associated adverse economic effects could affect some developing and least developed countries having less capacity for adequate remedial response measures. The magnitude of these potential impacts is conditioned by the selection of the policy measures, their stringency, the size of the economy implementing the measures, as well as the characteristics of the possibly affected developing countries.

As a Member State of the European Union, Slovenia, designs and implements most of its policies in the framework of EU directives, regulations, decisions and recommendations. To ensure that all relevant possible impacts are taken into account, the EU has established processes that assess the economic and social consequences of climate policy measures. For the development of new policy initiatives through legislative proposals by the European Commission, an impact assessment system have been established in which all proposals are examined before any legislation is passed. It is based on an integrated approach which analyses both benefits and costs, and addresses all significant economic, social and environmental impacts of possible new initiatives.

When adopting national measure Slovenia is mindful of the principle that its policies and measures to reduce greenhouse gas emissions are designed in a way to have no, or minimum, adverse impacts on developing countries, particularly on the least developed ones. One of the examples in this regard is the possibility of carbon leakage which would entail higher greenhouse gas emissions in countries which have lower environmental standards. Slovenia is promoting the implementation of measures that ensure that carbon leakage would not take place. As regards fiscal policy instruments, no significant impact on third countries is expected from the already implemented fiscal policies and therefore no specific policies to offset any negative effects have been considered. Negative effects are also potentially linked with the increased promotion of biofuels, as increased demand and subsequent production of biofuels may be linked to rising commodity prices and potentially induced land use change, however taking into account the low quantities of biofuels in use in Slovenia, we do not expect any negative effects neither on forests destruction nor contribution to the rising world prices of agricultural commodities.

Slovenia has strived to increase its climate finances in recent years. In 2016, Slovenia has for the first time also added resources from the Slovenian Climate change fund, where resources are gathered from the sale of allowances from the EU greenhouse gas emissions trading scheme (EU-ETS) and from this source contributed to the Green Climate Fund in 2019 at its first replenishment an amount of 1 million EUR. In the previous report Slovenia announced it will strive to obtain the amount of EUR 3.5 million for climate assistance by 2020. That amount has already been achieved in 2019, while not in 2020 due to a different global situation of the pandemic year. In 2019, Slovenia allocated EUR 2,084,526 for climate financing in the part of multilateral development aid through the payment of contributions to the Green Climate Fund, the UNFCCC, the Montreal Protocol, the Global Environment Facility (GEF) and the International Development Association (IDA) and EUR 3,699,829 with bilateral contributions and projects (of which EUR 3,612,026 under program development assistance). The latter includes projects through the Center for International Development Cooperation (CMSR), projects of non-governmental organizations in partner countries, contribution to the Trust Fund for Economic Resilience at the European Investment Bank, membership fees and activities within DPPI SEE and preparation of proposals for financing climate measures and projects in the Western Balkans. However, in 2020, Slovenia allocated a total of 2,256,420 euros for climate financing, which is a 61% drop compared to the previous year, both due to the absence of payments to the Green Climate Fund, delayed payments to the World Environment Fund and lower implementation of projects through CMSR. In 2020, Slovenia allocated EUR 1,053,674 for climate financing in as part of multilateral development assistance through contributions to the UNFCCC, the Montreal Protocol, the International Development Association, the Food and Agriculture Organization and the payment of additional capital to the International Bank for Reconstruction and Development. Development (IBRD), and € 1,202,746 through bilateral contributions and projects. The latter includes projects through the CMSR, NGO projects in partner countries, contributions to the European Investment Bank's Economic Resilience Trust Fund, membership fees and DPPI SEE activities, and preparation of proposals for financing climate action and projects in the Western Balkans. Among the projects implemented through the CMSR, co-financing of measures for sustainable forest use in the municipality of Adigeni in Georgia is worth mentioning, as well as water projects such as projects for the reconstruction and upgrade of sewage treatment plants in Zhytomyr and Nevesinje. Among the projects of non-governmental organizations in the partner countries, the project for more efficient use of resources for sustainable survival in Karongi County in Rwanda and the project for greater food security and more equality in Uganda are worth mentioning.

In the field of climate finance, Slovenia will also follow joint decisions and guidelines, both at EU and UNFCCC level agreements.

With regard to the guidelines for the preparation of the information required under article 7 of the Kyoto protocol (Decision 15/CMP.1, Section H), the following detailed information under point 24 can be provided:

(a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Slovenia has in recent years strived to progressively reduce environmentally harmful subsidies in line with the national programs and plans, however not fully incorporated or accounted for



externalities. Being part of the internal market of the EU, Slovenian policies are determined to a considerable extent by the EU (for details see Section 15 of the EU's National Inventory Report) and neighbouring countries, as due to its small territory having considerably different tax exemptions would not have a desirable climate effect.

(b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies

Incentives that go against the goal of reducing greenhouse gas GHG emissions have grown steadily in recent years, and in 2018 and 2019 they were reduced. In 2019, they decreased by 28% compared to 2018. Target knowledge is not set, the direction of "gradual significant reduction of environmentally harmful incentives" is pursued. The refunds of excise duties on diesel fuel stand out, which have decreased compared to the previous year, but still represent 40% of the total amount of all incentives that go against the goal of reducing GHG. More information can be found at <http://kazalci.arso.gov.si/en/content/incentives-work-against-goal-reducing-ghg-emissions-1>.

(c) Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

Slovenia cannot report any activity to this end.

(d) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

Slovenia has stipulated in the Decree on the implementation of the international development cooperation and humanitarian aid of the Republic of Slovenia (accessible at <http://www.pisrs.si/Pis.web/pregledPredpisa?id=URED7517>) that one of the preconditions for financing programs and project in the bilateral development cooperation is that the project or program does not contribute to increased use of fossil fuels. To this end, Slovenia does not cooperate in development of fossil fuel technologies or their carbon capture and storage.

(e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Due to the same reasons as above, no action was taken in this regard.

(f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies.

Slovenia did not take action in this area.

## ABBREVIATIONS

4AR	IPCC - Forth Assessment Report
AD	Activity data
CH <sub>4</sub>	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 <sub>2</sub>	Carbon dioxide
CO <sub>2</sub> eq.	CO <sub>2</sub> equivalent
CRF	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 (SF <sub>6</sub> )
FOD	First order decay method for calculating CH <sub>4</sub> 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 ( <a href="#">525/2013</a> )
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
NH <sub>3</sub>	Ammonium hydroxide
NIR	National Inventory Report
NMVOC	Non Methane Volatile Organic Compounds
NO <sub>x</sub>	Nitrogen oxides
N <sub>2</sub> O	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 <sub>6</sub>	Sulphur hexafluoride
SWDS	Solid waste disposal sites
LEG	Statistical Yearbook of Energy Economics
SO <sub>2</sub>	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

## SOURCES AND LITERATURE

- Babnik D., Verbič J. 2007. Skladiščenje in vrsta živinskih gnojil: gospodarjenje na kmetijah v kontroli prireje mleka. *Kmečki glas*, 64: 8-9.
- Bole D. 2015. Transformation of Transportation Land Use in Slovenia. Ljubljana, Založba ZRC.
- Breskvar B., Torkar M. 1999. Določitev emisij toplogrednih plinov pri proizvodnji aluminija, železa in jekla ter ferozlitin. Ljubljana, Inštitut za kovinske materiale in tehnologije.
- Budkovič T., Šajn R., Gosar, M. 2005. Usklajevanje z aktivnostmi Evropske Unije – Pregled delujočih in opuščanih premogovnikov ter rudnikov nekovinskih mineralnih surovin v republike Sloveniji. Ljubljana, Geološki zavod Slovenije.
- Canaveira P., Manso S., Pellis G., Perugini L., De Angelis P., Neves R., Papale D., Paulino J., Pereira T., Pina A., Pita G., Santos E., Scarascia-Mugnozza G., Domingos T., Chiti T. 2018. Biomass Data on Cropland and Grassland in the Mediterranean Region. Final Report for Action A4 of Project MediNet.
- Chamber of Commerce and Industry of Slovenia. 1999. Določitev emisij HFC, PFC in SF<sub>6</sub> iz industrijskih procesov, potencialov za njihovo zmanjševanje ter priprava projekcij emisij. Ljubljana, Gospodarska zbornica Slovenije.
- COPERT 5, Computer programme to calculate emissions from road transport, Emisia SA, <https://copert.emisia.com/manual/>, <https://www.emisia.com/utilities/copert/documentation/>
- Česen M. 2020. Analiza emisijskih faktorjev za zgorevanje lesne biomase. Ljubljana, Institut Jožef Stefan.
- Česen M. et al. 2017. Izboljšanje modelskih podatkov o rabi energije v prometu ter ocen o vplivu tranzitnega prometa, Ljubljana, Institut Jožef Stefan.
- DLG. 1997. Futterwerttabellen. Wiederkäuer. Frankfurt, DLG Verlag.
- de Groot, M., Ogris, N., Kobler, A., 2018. The effects of a large-scale ice storm event on the drivers of bark beetle outbreaks and associated management practices. *Forest Ecology and Management*, 408: 195–201. (available on-line: <https://doi.org/10.1016/j.foreco.2017.10.035>)
- EMEP/EEA air pollutant emission inventory guidebook 2019, Technical guidance to prepare national emission inventories, EEA Report No 13/2019, European Environment Agency
- EPA.2004. National Emission Inventory—Ammonia Emissions from Animal Husbandry Operations, United States Environmental Protection Agency.
- European Database of Vehicle Stock for the Calculation and Forecast of Pollutant and Greenhouse Gases Emissions with TREMOVE and COPERT, Final report, Thessaloniki, July 2008
- Ferreira A., Kobler A. 2005. Land-use changes and the resulting socio-economic population structure in the Upper Gorenjska region. Research reports: forest and wood science and technology, 77: 159-178.
- Gasperič M., Dornik M. 1998. Določitev emisijskega faktorja CO<sub>2</sub> pri energetski izrabi zemeljskega plina. Ljubljana, Inštitut za energetiko.

- GIZ DZP. 2006. Strokovne podlage za izračun ubežnih emisij zaradi distribucije zemeljskega plina, končno poročilo, Ljubljana, 2006.
- Gruber, L., Pries, M., Schwartz, F.-J., Spiekers, H., Staudacher, W. 2006. Schätzung der Futteraufnahme bei der Milchkuh. DLG-Information, 1, 2006, DLG, 29 p.
- Hiederer R. 2016. Processing a Soil Organic Carbon C-stock Baseline under Cropland and Grazing Land Management. EUR 28158 EN. Publications Office of the European Union, 2016, Luxembourg, doi:10.2791/64144
- Hladnik D., Žižek Kulovec L. 2012. Ocenjevanje gozdnosti v osnovi gozdne inventure na Slovenskem. Zbornik gozdarstva in lesarstva, 97: 31-42. (available on-line: <http://www.gozdis.si/zbq/2012/zbq-97-3.pdf> )
- Hlebčar B. et al. 2006. Izdelava evidenc emisij žveplovega heksa-fluorida (SF<sub>6</sub>) v slovenskem elektroenergetskem sistemu (EES) za obdobje 1986-2005. Študija št. 1796, Elektroinštitut Milan Vidmar, Ljubljana.
- Hočevar M., Kušar G., Japelj A. 2006. Integralni monitoring gozdnih virov v Sloveniji – stanje in potrebe v luči vseevropskih meril. V: Monitoring gospodarjenja z gozdom in gozdnato krajino. Hladnik D. (ur.). Ljubljana, BF, Oddelek za gozdarstvo in obnovljive gozdne vire: 27-51.
- Hoekstra C., Poelman J.N.B. 1982. Density of soils measured at the most common soil types in the Netherlands (in Dutch). Report 1582, Soil Survey Institute, Wageningen, The Netherlands.
- INRA. 1989. Ruminant nutrition, Recommended allowance & feed tables, Paris, INRA.
- Intergovernmental Panel on Climate Change (IPCC). 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IGES, Japan.
- Intergovernmental Panel on Climate Change (IPCC). 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IGES, Japan.
- Interpretation key. 2013. Interpretacijski ključ, Podroben opis metodologije zajema dejanske rabe kmetijskih in gozdnih zemljišč. Verzija 6.0. Ljubljana, MKGP, Služba za register kmetijskih gospodarstev.
- JQ Annual Questionnaire - Coal, Liquid, Gaseous, Renewables, Statistični urad RS, 2004-2012.
- Kahnt G. 1998. Grün-düngung. Frankfurt, DLG Verlag.
- Kirchgeßner M., Roth F.X., Schwartz F.J., Stangl, G.I. 2008. Tierernährung. Frankfurt, DLG Verlag.
- Kobal, M. et al. 2007. Forest soil and drought. In: JURC, Maja (ed.). Climate changes: impact on forest and forestry, (Studia forestalia Slovenica, No. 130). Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources Slovenia.
- Kobal M., Eler K., Simončič P., Kraigher H. 2014. Assessment of organic matter changes in the soil of the Brdo plot under different climate change scenarios through the YASSO07 model application. Acta Silvae et Ligni, 103: 21-34.
- Kobler A., Cunder T., Pirnat J. 2005. Modelling spontaneous afforestation in Postojna area, Slovenia. Nature Conservation, 13: 127-135.
- Krajnc N., Piškur M. 2006. Roundwood and wood wastes flow analysis for Slovenia. Zbornik gozdarstva in lesarstva, 80: 31-54.
- Kušar G., Kovač M., Simončič P. 2010. Slovenia. In: National Forest Inventories: Pathways for Common Reporting. Tomppo E.(Ed.). New York, Springer: 505-526.

- Logar M., Mekinda Majaron T., Verbič J. 2020. Slovenian Informative Inventory Report 2020, Submission under the UNECE Convention on Long-range Transboundary Air Pollution and Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, Ljubljana, Slovenian Environment Agency, March 2020.
- Loveland T.R., Sohl T.L., Saylor K., Gallant A., Dwyer J., Vogelmann J.E., and Zylstra G.J. 2001. Land Cover Trends: Rates, Causes, and Consequences of Late-Twentieth Century U.S. Land Cover Change, EPA journal: 1-52.
- MAFF. 2005. Map of actual agriculture and forest land use. (available on-line: <http://rkg.gov.si/GERK/>)
- Mali B. et al. 2016. Izdelava pilotnega vzorčenja tal za oceno zalog ogljika na kmetijskih zemljiščih, Gozdarski inštitut Slovenije, Ljubljana, November 2016.
- Mali B. et al. 2017a. Vzorčenja tal za oceno zalog ogljika na kmetijskih zemljiščih, v letu 2017, Gozdarski inštitut Slovenije, Ljubljana, Oktober 2017.
- Mali B. et al. 2017b. Vzorčenje in ocena zalog ogljika v nadzemni lesni biomasi na kmetijskih zemljiščih v letu 2017. Ljubljana, Gozdarski inštitut Slovenije. Oktober 2017
- Mali B. et al. 2018a. Vzorčenja tal za oceno zalog ogljika na kmetijskih zemljiščih v letu 2018. Ljubljana, Gozdarski inštitut Slovenije, Oktober 2018.
- Mali B., Grah A., Žlindra D., Marinšek A., Kozamernik E. 2018b. Vzorčenje in ocena zalog ogljika v odmrli organski snovi in nadzemni lesni biomasi na kmetijskih zemljiščih v letu 2018. Ljubljana, Gozdarski inštitut Slovenije, Januar 2018.
- Mapping Manual. UBA. 2004. Manual on methodologies and criteria for modelling and mapping critical loads & levels and air pollution effects, risks and trends. UNECE Convention on Long-range Transboundary Air Pollution, Federal Environmental Agency (Umweltbundesamt), Berlin.
- Martinčič A. 2010. Variabilnost gostote lesa debla, vej in korenin jelk s snežniškega območja. Dipl. delo. Ljubljana, Univerza v Lj., Biotehniška fakulteta, Odd. za lesarstvo. (available on-line: [http://www.digitalna-knjiznica.bf.uni-lj.si/vs\\_martincic\\_andrej.pdf](http://www.digitalna-knjiznica.bf.uni-lj.si/vs_martincic_andrej.pdf))
- Menzi H., Frick R., Kaufmann R. 1997. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Zürich, FAL.
- Mikkelsen J., Cools N., Langohr R., Kobal M., Urbančič M., Kralj T., Simončič P. 2006. Navodila za opis talnega profila za projekt BIOSOIL. Ljubljana, Gozdarski inštitut Slovenije.
- Mihelič R et al. 2010. Smernice za strokovno utemeljeno gnojenje. Ljubljana, Ministrstvo za kmetijstvo, gozdarstvo in prehrano.
- Miličič V., 2007. Analiza osuševalnih sistemov na območju jugozahodne Ljubljane. Dipl. delo, Ljubljana, Univerza v Ljubljani, BF, Oddelek za agronomijo.
- Miličič V., Udovč A. 2012. Uporabnost prostorskih podatkov kmetijskega sektorja za analize sprememb rabe kmetijskih zemljišč na primeru izbranega območja varovanja narave v Sloveniji. Geodetski vestnik, 56: 84-104. (available on-line: [http://www.geodetski-vestnik.com/56/1/gv56-1\\_083-104.pdf](http://www.geodetski-vestnik.com/56/1/gv56-1_083-104.pdf))
- Ministry of Agriculture and the Environment (MAFF), Slovenian Forestry Institute (SFI), Slovenia Forest Service (SFS). 2011. Submission of information on forest management reference levels by Slovenia, (available on-line: [http://unfccc.int/files/meetings/ad\\_hoc\\_working\\_groups/kp/application/pdf/awgkp\\_slovenia\\_2011.pdf](http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_slovenia_2011.pdf))
- Ministrstvo za gospodarske dejavnosti: Letopis energetskega gospodarstva RS, Ministrstvo za gospodarske dejavnosti, Ljubljana 1986-2003

- Nagel, T.A., Firm, D., Rozenberger, D., Kobal, M., 2016. Patterns and drivers of ice storm damage in temperate forests of Central Europe. *European Journal Forest Research*, 135: 519–530. (available on-line: <https://doi.org/10.1007/s10342-016-0950-2>)
- Nastran M., Žižek Kulovec L. 2014. (In)consistency in the official spatial data in assessment of deforestation in Slovenia. *Geodetski vestnik*, 58: 724-745. (available on-line: [http://www.geodetski-vestnik.com/58/4/gv58-4\\_nastran.pdf](http://www.geodetski-vestnik.com/58/4/gv58-4_nastran.pdf))
- Nowak D., Greenfield E., Hoehn R., Lapoint E. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*, 178: 229-236.
- Operativni program doseganja nacionalnih zgornjih mej emisij onesnaževal zunanjega zraka (revizija operativnega programa doseganja Nacionalnih zgornjih mej emisij onesnaževal zunanjega zraka iz leta 2005) sprejetega na podlagi tretjega odstavka 6. člena uredbe o nacionalnih zgornjih mejah emisij onesnaževal zunanjega zraka (Uradni list RS, št.24/05).
- Operativni program odstranjevanja odpadkov s strategijo zmanjševanja odloženih količin biološko razgradljivih odpadkov za obdobje od 2003-2008. Ljubljana, Ministrstvo za okolje, prostor in energijo.
- Paradiž B. 2000. Ocena emisij metana in priprava njihovih projekcij pri ravnanju z odpadki. Ljubljana, Ministrstvo za okolje in prostor.
- Petek F. 2005. Land Use Changes in Slovenian Alpine Regions. Ljubljana, Založba ZRC.
- Pirnat J., Kobler A. 2014. The stability of forest areas in Slovenia as a criterion of landscape diversity and durability. *Acta Silvae et Ligni*, 104: 35-42.
- Pingoud K., Wagner F. 2006. Methane emissions from landfills and carbon dynamics of harvested wood products: the first-order decay revisited. *Mitigation and Adaptation for Global Change*, 11: 961-978 (available on-line: <http://link.springer.com/article/10.1007%2Fs11027-006-9029-6>)
- Pišek R. 2010. Vpliv strukturnih posebnosti sestojev v gozdnih rezervatih na razvoj monitoringa gozdnih rezervatov. Magistrsko delo. Ljubljana, Univerza v Lj., Biotehniška fakulteta (available on-line: [http://www.digitalna-knjiznica.bf.uni-lj.si/md\\_pisek\\_rok.pdf](http://www.digitalna-knjiznica.bf.uni-lj.si/md_pisek_rok.pdf))
- Pišek J. 2012. The analysis of land use change in Pomurska statistical region for the period 2001-2011. Graduation thesis. University of Ljubljana, Faculty of Civil and Geodetic Engineering.
- Prelec F. 1993. Varstvo gozdov na kraškem gozdnogospodarskem območju. *Gozdarski vestnik*, 51.
- Reichert J., M. Schön. 2000. Methanemissionene durch den Einsatz von Gas in Deutschland von 1990 bis 1997 mit einem Ausblick auf 2010 (available on-line: [http://publica.fraunhofer.de/eprints/urn\\_nbn\\_de\\_0011-n-36320.pdf](http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-36320.pdf))
- Reinds G.J., Posch M., De Vries A. 2001. A semi-empirical dynamic soil acidification model for use in spatially explicit integrated assessment models for Europe. *Alterra Report 084*, Alterra Green World Research, Wageningen, The Netherlands.
- Rules on the protection of forests. Official Journal of the RS, nr. 92-3942/2000, 56-2361/2006.
- Sadar M., Jeretina J., Logar B., Opara A., Perpar T., Podgoršek P. Rezultati kontrole prireje mleka in mesa: Slovenija 2020 = Results of dairy and beef recording : Slovenia 2020,. Ljubljana, Kmetijski inštitut Slovenije, 2021, 98 p.



[https://www.govedo.si/files/cpzg/knjiznica/strokovne\\_publicacije/PI\\_302\\_Pregled\\_zakola\\_in\\_klavne\\_kakovosti\\_goveda\\_v\\_Sloveniji\\_za\\_let\\_2020.pdf](https://www.govedo.si/files/cpzg/knjiznica/strokovne_publicacije/PI_302_Pregled_zakola_in_klavne_kakovosti_goveda_v_Sloveniji_za_let_2020.pdf)

- Shiver B.D., Borders. B.E. 1996. Sampling Techniques for Forest Resource Inventory. John Wiley & Sons, NY.
- Simončič P., Kobler A., Robek R., Žgajnar L. 1999. Ocena emisij oz. ponora TGP za gozdarstvo ter spremembe rabe zemljišč. Ljubljana, Gozdarski inštitut Slovenije.
- Skumavec D., Šabić D. 2005. Land cover in Slovenia 1993-2001. Results of surveys. Ljubljana, Statistical Office of the Republic of Slovenia.
- Spiekers, H., Potthast, V. 2004: Erfolgreiche Milchvieh-fütterung. Frankfurt, DLG Verlag.
- Statistični urad Republike Slovenije. 1987-1997. Rezultati raziskovanj - Letni pregled industrije 1986-1996, Ljubljana
- Šinkovec M., Bergant J., Vrščaj B. 2020. Vzorčenje v tleh in v lesnih ostankih iz trajnih nasadov za oceno zalog ogljika na kmetijskih zemljiščih v letu 2019: Sklop B – Lesni ostanki iz trajnih nasadov. Ljubljana, Kmetijski inštitut Slovenije.
- Šušteršič A. et al. 2004. National CO2 emission factor for lignite from Velenje coalmine. Elektroinštitut Milan Vidmar, Ljubljana
- Teobaldelli M., Somogyi Z., Migliavacca M., Usoltsev V.A. 2009. Generalized functions of biomass expansion factors for conifers and broadleaved by stand age, growing stock and site index. Forest Ecology and Management, 257: 1004-1013.
- Torelli N. 1996. Ekološki, surovinski in energetske pomen gozda in lesa. Ljubljana, Gozdarski inštitut Slovenije.
- Urad RS za statistiko: Statistični letopis RS 1987, Urad RS za statistiko, Ljubljana 1986-2003
- Urbančič M., Kobal M., Zupan M., Šporar M., Eler K., Simončič P. 2007. Organska snov v gozdnih tleh. V: Knapič M. (ur.). Strategija varovanja tal v Sloveniji : zbornik referatov Konference ob svetovnem dnevu tal 5. decembra 2007. Ljubljana, Pedološko društvo Slovenije: 217-230.
- Uršič A. 2011. Poročilo o sestavi lahke frakcije odpadkov, ki se v Toplarni Celje uporablja kot gorivo. Služba za varstvo okolja.
- Van Wallenburg C. 1988. The density of peaty soils (in Dutch). Internal Report, Soil Survey Institute, Wageningen, The Netherlands.
- Velazquez-Marti B., Fernandez-Gonzalez E., Lopez-Cortez I., Salazar-Hernandez D.M. 2011. Quantification of the residual biomass obtained from pruning of vineyards in Mediterranean area. Biomass and Bioenergy, 35: 3453-3464.
- Verbič J., Sušin J., Podgoršek P. 1999. Emisije toplogrednih plinov v kmetijstvu – ocene in možnosti za zmanjšanje. Ljubljana, Kmetijski inštitut Slovenije.
- Verbič J., Babnik, D. 1999. Oskrbljenost prežvekovalcev z energijo. Neto energija za laktacijo (NEL) in presnovljiva energija (ME), Prikazi in informacije 200. Ljubljana Kmetijski inštitut Slovenije.
- Veselič Ž., Grejs Z., Kolšek M., Oražem D., Matijašič D., Jurij B. 2015. Žled v slovenskih gozdovih in njihova sanacija. Ujma, 25: 188.194.
- Wisdom Slovenia. 2006. Spatial woodfuel production and consumption analysis applying the Woodfuel Integrated Supply / Demand Overview Mapping (WISDOM) methodology. Slovenia Forest Service, FAO.



- Zapušek A., Orešnik K. 1998. Določitev emisijskih faktorjev ogljikovega dioksida pri izkopu premoga za leto 1986 in leta v obdobju 1990-1996. Velenje, ERICO - Inštitut za ekološke raziskave.
- Zapušek A., Orešnik K., Avberšek F. 1999. Določitev emisijskih faktorjev metana pri izkopu premoga za leto 1986 in leta v obdobju 1990-1996. Velenje, ERICO - Inštitut za ekološke raziskave.
- Žabjek A., Čandek-Potokar M., Perpar T.: Zakol in klavna kakovost goveda - pregled po letih. V: Žabjek A. (ur.). Pregled zakola in klavne kakovosti goveda v Sloveniji za leto 2020, (Prikazi in informacije, 302). Ljubljana, Kmetijski inštitut Slovenije. 2021, p. 3-38.  
[https://www.govedo.si/files/cpzg/knjiznica/strokovne\\_publicacije/PI\\_302\\_Pregled\\_zakola\\_in\\_klavne\\_kakovosti\\_goveda\\_v\\_Sloveniji\\_za\\_leto\\_2020.pdf](https://www.govedo.si/files/cpzg/knjiznica/strokovne_publicacije/PI_302_Pregled_zakola_in_klavne_kakovosti_goveda_v_Sloveniji_za_leto_2020.pdf)





