



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

# Slovenia's National Inventory Document 2025

GHG emissions inventories 1986 - 2023

Submission under the Regulation (EU) 2018/1999

Ljubljana, March 2025



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

The submission includes the main part of the NID, additional information in five annexes will be provided in the April submission.

The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the common reporting tables (CRT) for the period 1986-2023 with a corresponding JSON file and additional tables from the Commission implementing regulation 2020/1208:

- Annex VII: Overview table of reporting requirements and their submissions
- Annex VIII: Information on implementation of recommendation and adjustments
- Annex X: Uncertainty
- Annex XI: Indicators
- Annex XII: Information on consistency of reported emissions with ETS data
- Annex XIII: Information on consistency of reported data on air pollution
- Annex XIV: Information on consistency with energy data
- Annex XV: Emissions covered by ESR
- Annex XVI: Concluded transfers for LULUCF
- Annex XVII: Concluded transfers for ESR
- Annex XVIII: Intended use of flexibilities
- Annex XIX: Use of revenues
- Annex XX: Accounted LULUCF emissions and removals
- Tier methods in Land-use sub-categories and pools

The updated information on methods, emission factors as listed in the Annex IX is reported directly on the European Commission Share point.



Specific responsibilities for the 2025 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

National inventory document 1986-2023

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., Matic Kozina

Waste Tajda Mekinda Majaron

Registry Romana Stare

Annexes Tajda Mekinda Majaron, Martina Logar D.Sc., Romana Stare

CRT Tables

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

## TABLE OF CONTENTS

|  |            |
|--|------------|
| <b>EXECUTIVE SUMMARY</b>   | <b>12</b>  |
| <b>1 INTRODUCTION</b>  | <b>14</b>  |
| <b>1.1 Background Information on Greenhouse Gas Inventories and Climate Change</b>                                     | <b>14</b>  |
| <b>1.2 A description of the national inventory arrangements</b>  | <b>16</b>  |
| 1.2.1 Institutional, legal and procedural arrangements   | 16         |
| 1.2.2 Overview of inventory planning, preparation and management   | 18         |
| 1.2.3 Quality assurance, quality control and verification plan   | 20         |
| 1.2.4 Changes in the national inventory arrangements since previous annual GHG inventory submission                    | 23         |
| <b>1.3 Inventory preparation, and data collection, processing and storage</b>  | <b>24</b>  |
| <b>1.4 Brief General Description of Methodologies and Data Sources</b>   | <b>25</b>  |
| <b>1.5 Brief Description of Key Categories</b>   | <b>27</b>  |
| <b>1.6 General Uncertainty Evaluation, Including Data on Overall Uncertainty for Inventory Totals</b>                  | <b>31</b>  |
| <b>1.7 General Assessment of Completeness</b>  | <b>32</b>  |
| <b>2 TRENDS IN GREENHOUSE GAS EMISSIONS</b>  | <b>34</b>  |
| <b>2.1 Description and Interpretation of Emission Trends for Aggregated GHG emissions</b>                              | <b>34</b>  |
| <b>2.1 Description and Interpretation of Emission Trends for by Gas</b>  | <b>34</b>  |
| <b>2.2 Description and Interpretation of Emission Trends by Sector</b>   | <b>35</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 (CRT SECTOR 1)</b>   | <b>42</b>  |
| <b>3.1 Overview over the Sector</b>  | <b>42</b>  |
| <b>3.2 Fuel Combustion (CRT 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  | 52         |
| 3.2.4 Energy industries (CRT 1A1)  | 56         |
| 3.2.5 Manufacturing Industries and Construction (CRT 1A2)  | 66         |
| 3.2.6 Transport (CRT 1.A.3)  | 79         |
| 3.2.7 Other Sectors (CRT 1A4)  | 98         |
| 3.2.8 Other (CRT 1A5)  | 108        |
| <b>3.3 Fugitive emissions from solid fuels, oil, natural gas and other emissions from energy production, (CRT 1.B)</b> | <b>110</b> |
| 3.3.1 Solid Fuels (CRT 1.B.1)  | 112        |
| 3.3.2 Oil and natural gas (CRT 1.B.2)  | 118        |
| <b>3.4 CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage</b>                                | <b>124</b> |

|            |   |            |
|------------|---|------------|
| <b>4</b>   | <b>INDUSTRIAL PROCESSES AND PRODUCT USE (CRT SECTOR 2)</b>      | <b>125</b> |
| <b>4.1</b> | <b>Overview of Sector</b>                                       | <b>125</b> |
| <b>4.2</b> | <b>MINERAL INDUSTRY (CRT 2.A)</b>                               | <b>128</b> |
| 4.2.1      | Cement Production (CRT 2.A.1)                                   | 128        |
| 4.2.2      | Lime Production (CRT 2.A.2)                                     | 132        |
| 4.2.3      | Glass Production (CRT 2.A.3)                                    | 137        |
| 4.2.4      | Other Process Uses of Carbonates                                | 139        |
| <b>4.3</b> | <b>CHEMICAL INDUSTRY (CRT 2.B)</b>                              | <b>142</b> |
| 4.3.1      | Nitric Acid Production (CRT 2.B.2)                              | 142        |
| 4.3.2      | Carbide Production (CRT 2.B.5)                                  | 143        |
| 4.3.3      | Titanium dioxide production (CRT 2.B.6)                         | 144        |
| 4.3.4      | Petrochemical and carbon black production (CRT 2.B.8)           | 146        |
| 4.3.5      | Other - Hydrogen production (CRT 2.B.10)                        | 147        |
| <b>4.4</b> | <b>METAL PRODUCTION (CRT 2.C)</b>                               | <b>148</b> |
| 4.4.1      | Iron and Steel Production (CRT 2.C.1)                           | 148        |
| 4.4.2      | Ferroalloys Production (CRT 2.C.2)                              | 151        |
| 4.4.3      | Aluminium Production (CRT 2.C.3)                                | 153        |
| 4.4.4      | Lead Production (CRT 2.C.5)                                     | 158        |
| 4.4.5      | Zinc Production (CRT 2.C.6)                                     | 159        |
| <b>4.5</b> | <b>NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE (CRT 2.D)</b> | <b>161</b> |
| 4.5.1      | Lubricant use (CRT 2.D.1)                                       | 161        |
| 4.5.2      | Paraffin wax use (CRT 2.D.2)                                    | 162        |
| 4.5.3      | Other (CRT 2.D.3)   | 163        |
| <b>4.6</b> | <b>Product uses as substitutes for ODS (CRT 2.F)</b>            | <b>166</b> |
| 4.6.1      | Category description  | 166        |
| 4.6.2      | Methodological issues   | 168        |
| 4.6.3      | Uncertainties and time-series consistency                       | 177        |
| 4.6.4      | Source-specific QA/QC and verification                          | 177        |
| 4.6.5      | Category-specific recalculations                                | 178        |
| 4.6.6      | Source-specific planned improvements                            | 178        |
| <b>4.7</b> | <b>Other Product Manufacture and Use (CRT 2.G)</b>              | <b>179</b> |
| 4.7.1      | Electrical equipment (CRT 2.G.1)                                | 179        |
| 4.7.2      | SF <sub>6</sub> and PFCs from other product use (CRT 2.G.2)     | 181        |
| 4.7.3      | N <sub>2</sub> O from Product Uses (CRT 2.G.3)                  | 185        |
| <b>5</b>   | <b>AGRICULTURE (CRT SECTOR 3)</b>                               | <b>187</b> |
| <b>5.1</b> | <b>Overview of sector</b>                                       | <b>187</b> |
| <b>5.2</b> | <b>Enteric Fermentation (CRT 3.A)</b>                           | <b>189</b> |
| 5.2.1      | Category description  | 189        |
| 5.2.2      | Methodological issues   | 189        |
| 5.2.3      | Uncertainties and time-series consistency                       | 200        |
| 5.2.4      | Category-specific QA/QC and verification                        | 201        |
| 5.2.5      | Category-specific recalculations                                | 201        |
| 5.2.6      | Category-specific planned improvements                          | 201        |
| <b>5.3</b> | <b>CH<sub>4</sub> Emissions from Manure Management (3.B)</b>    | <b>202</b> |
| 5.3.1      | Source category description                                     | 202        |
| 5.3.2      | Methodological issues   | 203        |

|            |   |            |
|------------|---|------------|
| 5.3.3      | Uncertainties and time-series consistency   | 212        |
| 5.3.4      | Category-specific QA/QC and verification  | 212        |
| 5.3.5      | Category-specific recalculations  | 213        |
| 5.3.6      | Category-specific planned improvements  | 213        |
| <b>5.4</b> | <b>N<sub>2</sub>O Emissions from Manure Management (CRF 3.B)</b>  | <b>214</b> |
| 5.4.1      | Source category description   | 214        |
| 5.4.2      | Methodological issues   | 214        |
| 5.4.3      | Uncertainties and time-series consistency   | 223        |
| 5.4.4      | Category-specific QA/QC   | 223        |
| 5.4.5      | Category-specific recalculations  | 224        |
| 5.4.6      | Category-specific planned improvements  | 224        |
| <b>5.5</b> | <b>N<sub>2</sub>O Emissions from Agricultural Soils (CRF 3.D)</b>   | <b>225</b> |
| 5.5.1      | Overview of category  | 225        |
| 5.5.2      | Direct N <sub>2</sub> O Emissions from Managed Soils (CRF 3.D.a)  | 225        |
| 5.5.3      | Indirect N <sub>2</sub> O Emissions from Managed Soils (CRF 3.D.b)  | 231        |
| <b>5.6</b> | <b>Liming (CRF 3.G)</b>   | <b>236</b> |
| 5.6.1      | Category description  | 236        |
| 5.6.2      | Methodological issues   | 236        |
| 5.6.3      | Uncertainties and time-series consistency   | 237        |
| 5.6.4      | Category-specific QA/QC   | 237        |
| 5.6.5      | Category-specific recalculations  | 238        |
| 5.6.6      | Category-specific planned improvements  | 238        |
| <b>5.7</b> | <b>Urea application (CRF 3.H)</b>   | <b>238</b> |
| 5.7.1      | Category description  | 238        |
| 5.7.2      | Methodological issues   | 238        |
| 5.7.3      | Uncertainties and time-series consistency   | 238        |
| 5.7.4      | Category-specific QA/QC and verification  | 238        |
| 5.7.5      | Category-specific recalculations  | 238        |
| 5.7.6      | Category-specific planned improvements  | 238        |
| <b>5.8</b> | <b>Other carbon containing fertilizers (CRF 3.I)</b>  | <b>239</b> |
| 5.8.1      | Category description  | 239        |
| 5.8.2      | Methodological issues   | 239        |
| 5.8.3      | Uncertainties and time-series consistency   | 239        |
| 5.8.4      | Category-specific QA/QC and verification  | 239        |
| 5.8.5      | Category-specific recalculations  | 239        |
| 5.8.6      | Category-specific planned improvements  | 239        |
| <b>6</b>   | <b>LULUCF (CRT SECTOR 4)</b>  | <b>240</b> |
| <b>6.1</b> | <b>Overview of sector</b>   | <b>240</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>244</b> |
|            | Land use and land-use change  | 244        |
| 6.2.1      | Forest land   | 245        |
| 6.2.2      | Cropland  | 245        |
| 6.2.3      | Grassland   | 245        |
| 6.2.4      | Wetlands  | 245        |
| 6.2.5      | Settlements   | 245        |
| 6.2.6      | Other land  | 246        |

|            |  |            |
|------------|--|------------|
| <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>247</b> |
| 6.3.1      | Development of land-use change matrices  | 247        |
| <b>6.4</b> | <b>Forest Land (4A)</b>  | <b>254</b> |
| 6.4.1      | Source category description  | 254        |
| 6.4.2      | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation        | 257        |
| 6.4.3      | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories                     | 257        |
| 6.4.4      | Methodological issues  | 258        |
| 6.4.5      | Uncertainties and time-series consistency  | 270        |
| 6.4.6      | Source specific QA/QC and verification   | 270        |
| 6.4.7      | Source specific recalculations   | 271        |
| 6.4.8      | Source specific planned improvements   | 271        |
| <b>6.5</b> | <b>Cropland (4B)</b>   | <b>272</b> |
| 6.5.1      | Source category description  | 272        |
| 6.5.2      | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation        | 275        |
| 6.5.3      | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories                     | 275        |
| 6.5.4      | Methodological issues  | 275        |
| 6.5.5      | Uncertainties and time-series consistency  | 284        |
| 6.5.6      | Category-specific QA/QC and verification   | 285        |
| 6.5.7      | Category-specific recalculations   | 285        |
| 6.5.8      | Source-specific planned improvements   | 285        |
| <b>6.6</b> | <b>Grassland (4C)</b>  | <b>286</b> |
| 6.6.1      | Source category description  | 286        |
| 6.6.2      | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation        | 289        |
| 6.6.3      | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories                     | 289        |
| 6.6.4      | Methodological issues  | 289        |
| 6.6.5      | Uncertainties and time-series consistency  | 295        |
| 6.6.6      | Category-specific QA/QC and verification   | 296        |
| 6.6.7      | Category-specific recalculations   | 296        |
| 6.6.8      | Source-specific planned improvements   | 296        |
| <b>6.7</b> | <b>Wetlands (4D)</b>   | <b>297</b> |
| 6.7.1      | Source category description  | 297        |
| 6.7.2      | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation        | 300        |
| 6.7.3      | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories                     | 300        |
| 6.7.4      | Methodological issues  | 301        |
| 6.7.5      | Category-specific QA/QC and verification   | 302        |
| 6.7.6      | Category-specific recalculations   | 302        |
| 6.7.7      | Source-specific planned improvements   | 302        |
| <b>6.8</b> | <b>Settlements (4E)</b>  | <b>303</b> |
| 6.8.1      | Source category description  | 303        |

|             |   |            |
|-------------|---|------------|
| 6.8.2       | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation | 306        |
| 6.8.3       | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories              | 306        |
| 6.8.4       | Methodological issues   | 306        |
| 6.8.5       | Uncertainties and time-series consistency   | 308        |
| 6.8.6       | Category-specific QA/QC and verification  | 308        |
| 6.8.7       | Category-specific recalculations  | 308        |
| 6.8.8       | Category-specific planned improvements  | 308        |
| <b>6.9</b>  | <b>Other land (4F)</b>  | <b>309</b> |
| 6.9.1       | Source category description   | 309        |
| 6.9.2       | Information on approaches used for representing land areas and on land-use databases used for the inventory preparation | 312        |
| 6.9.3       | Land-use definitions and the classification systems used and their correspondence to the LULUCF categories              | 312        |
| 6.9.4       | Methodological issues   | 312        |
| 6.9.5       | Uncertainties and time-series consistency   | 313        |
| 6.9.6       | Category-specific QA/QC and verification  | 313        |
| 6.9.7       | Category-specific recalculations  | 313        |
| 6.9.8       | Category-specific planned improvements  | 314        |
| <b>6.10</b> | <b>Harvested wood products (4G)</b>   | <b>315</b> |
| 6.10.1      | Source category description   | 315        |
| 6.10.2      | Methodological issues   | 315        |
| 6.10.3      | Uncertainties and time-series consistency   | 320        |
| 6.10.4      | Category-specific QA/QC and verification  | 320        |
| 6.10.5      | Category-specific recalculations  | 320        |
| 6.10.6      | Category-specific improvements  | 320        |
| <b>7</b>    | <b>WASTE (CRT SECTOR 5)</b>   | <b>321</b> |
| <b>7.1</b>  | <b>Overview of sector</b>   | <b>321</b> |
| <b>7.2</b>  | <b>Solid Waste Disposal Sites (CRT 5.A)</b>   | <b>326</b> |
| 7.2.1       | Category description  | 326        |
| 7.2.2       | Methodological issues   | 326        |
| 7.2.3       | Uncertainty and time series consistency   | 339        |
| 7.2.4       | Category-specific QA/QC and verification  | 340        |
| 7.2.5       | Category-specific recalculations  | 340        |
| 7.2.6       | Category-specific planned improvements  | 340        |
| <b>7.3</b>  | <b>Biological Treatment of Solid Waste (CRT 5.B)</b>  | <b>341</b> |
| 7.3.1       | Composting  | 341        |
| 7.3.2       | Anaerobic Digestion at Biogas Facilities  | 342        |
| <b>7.4</b>  | <b>Waste incineration (CRT 5.C)</b>   | <b>344</b> |
| 7.4.1       | Category description  | 344        |
| 7.4.2       | Methodological issues   | 344        |
| 7.4.3       | Uncertainty and time series consistency   | 347        |
| 7.4.4       | Category-specific QA/QC and verification  | 347        |
| 7.4.5       | Category-specific recalculations  | 347        |
| 7.4.6       | Category-specific planned improvements  | 347        |



|             |  |            |
|-------------|--|------------|
| <b>7.5</b>  | <b>Emissions from Wastewater Treatment and Discharge (CRT 5.D)</b>                           | <b>348</b> |
| 7.5.1       | Category description   | 348        |
| 7.5.2       | Methodological issues  | 350        |
| 7.5.3       | Category-specific QA/QC and verification   | 363        |
| 7.5.4       | Uncertainty and time-series consistency  | 364        |
| 7.5.5       | Source-specific recalculations   | 364        |
| 7.5.6       | Future improvements  | 364        |
| <b>8</b>    | <b>OTHER</b>   | <b>365</b> |
| <b>9</b>    | <b>INDIRECT CO<sub>2</sub> AND N<sub>2</sub>O EMISSIONS</b>                                  | <b>365</b> |
| <b>10</b>   | <b>RECALCULATIONS AND IMPROVEMENTS</b>   | <b>366</b> |
| <b>10.1</b> | <b>Explanations and justification for recalculations, and implication for emission level</b> | <b>366</b> |
| 10.1.1      | Energy   | 366        |
| 10.1.2      | Industrial processes and product use   | 367        |
| 10.1.1      | Agriculture  | 368        |
| 10.1.2      | LULUCF   | 370        |
| 10.1.1      | Waste  | 371        |
| <b>10.2</b> | <b>Response to the Review Process</b>  | <b>372</b> |
|             | <b>ABBREVIATIONS</b>   | <b>387</b> |
|             | <b>SOURCES AND LITERATURE</b>  | <b>389</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 document as an opportunity to fulfil these commitments.

This document summarizes the latest information on Slovenian anthropogenic greenhouse gas emission trends from 1986 through 2023. To ensure that the Slovenian emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The structure of this document is consistent with the [UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention](#). The national greenhouse gas inventory has to be submitted to the UNFCCC Secretariat every year no later than 15 April.

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



# 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 since 2023 for some categories calculations are improved using methodology from 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories ([2019 Refinement](#)).

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

The document presents estimates for the following greenhouse gases included in Annex A to the Kyoto Protocol: carbon dioxide (CO<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 tri-fluoride (NF<sub>3</sub>) emissions do not occur in Slovenia and, therefore, they are not included in this document.

### 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 AR4 shall be used for all submissions started with 2015. Since 2023 submission GWPs from AR5 are used. For this reason all three sets of GWPs are presented in the table 1.1.1. Only GHGs which are reported in this report are included in this table.

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

| Gas – common name             | Chemical formula                   | GWP from SAR | GWP from AR4 | GWP from AR5 |
|-------------------------------|------------------------------------|--------------|--------------|--------------|
| Carbon dioxide                | CO <sub>2</sub>                    | 1            | 1            | 1            |
| Methane*                      | CH <sub>4</sub>                    | 21           | 25           | 28           |
| Nitrous oxide                 | N <sub>2</sub> O                   | 310          | 298          | 265          |
| HFC-32                        | CH <sub>2</sub> F <sub>2</sub>     | 650          | 675          | 677          |
| HFC-125                       | CHF <sub>2</sub> CF <sub>3</sub>   | 2,800        | 3,500        | 3,170        |
| HFC-134a                      | CH <sub>2</sub> FCF <sub>3</sub>   | 1,300        | 1,430        | 1,300        |
| HFC-143a                      | CH <sub>3</sub> CF <sub>3</sub>    | 3,800        | 4,470        | 4,800        |
| HFC-227ea                     | CF <sub>3</sub> CHFCF <sub>3</sub> | 2,900        | 3,220        | 3,350        |
| CF <sub>4</sub>               | CF <sub>4</sub>                    | 6,500        | 7,390        | 6,630        |
| C <sub>2</sub> F <sub>6</sub> | C <sub>2</sub> F <sub>6</sub>      | 9,200        | 12,200       | 11,100       |
| SF <sub>6</sub>               | SF <sub>6</sub>                    | 23,900       | 22,800       | 23,500       |

\* The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. The indirect effect due to the production of CO<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.

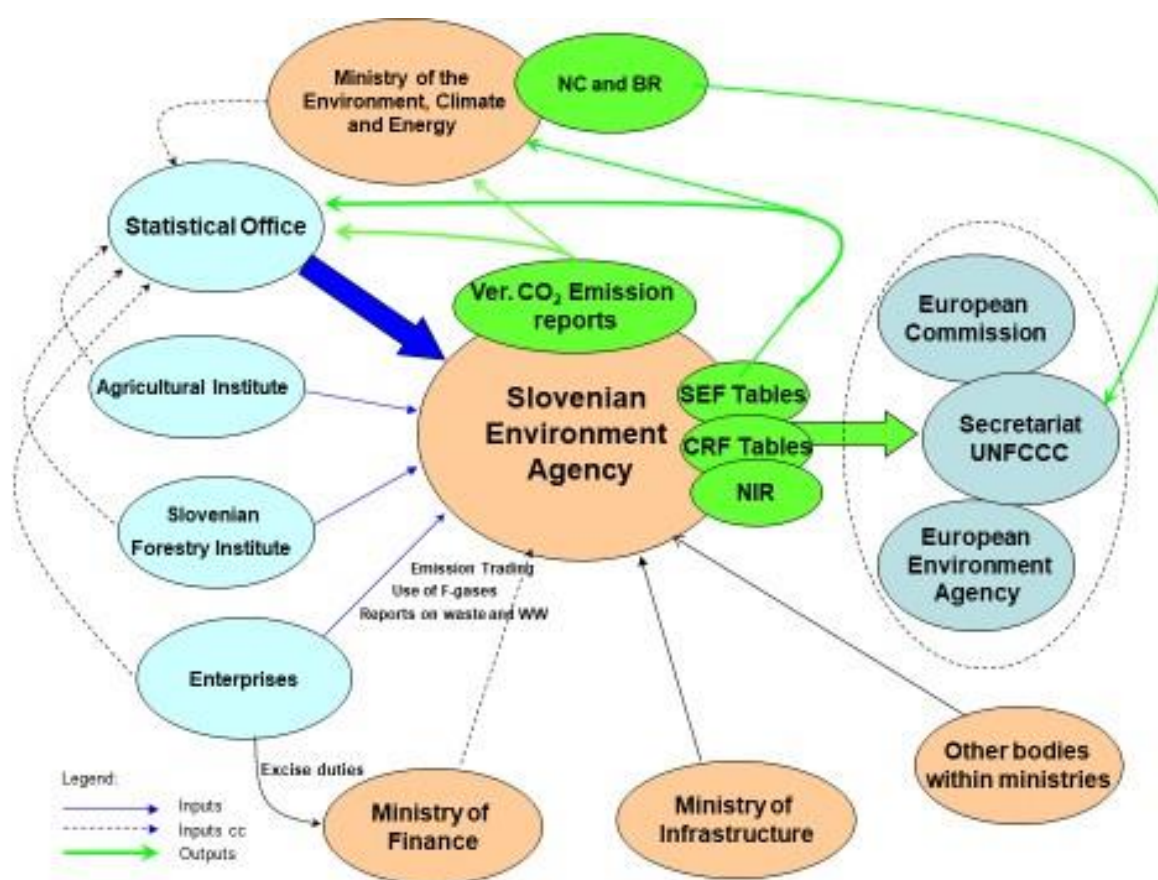


Figure 1.2.1: Data flows in the Slovenian Inventory System

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 NID have shortened with the entry of Slovenia into the EU, since inventories and part of the NID for the year before last must be made by 15<sup>th</sup> of January, and with corrections and final submission of the NID 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:<br>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</li> <li>• Eurocontrol</li> <li>• Slovenian Maritime Administration</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> <li>• The Fisheries Research Institute of Slovenia</li> </ul>  |
|   | 5 Other                                     | <ul style="list-style-type: none"> <li>• Slovenian Army and Police</li> </ul>   |
| 1.B Energy:<br>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>  |
| CRT 2 – Industrial Processes and Product Use    | CRT 2A – Mineral Products                   | <ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency</li> </ul>   |
|   | CRT 2B – Chemical Industry                  | <ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> </ul>   |
|   | CRT 2C – Metal Production                   | <ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia:</li> <li>• Slovenian Environment Agency</li> </ul>   |
|   | CRT 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>   |
|   | CRT 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> |
|   | CRT 2G – Other product                      | <ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia</li> <li>• Slovenian Environment Agency</li> </ul>  |
| CRT 3 – Agriculture                             |   | <ul style="list-style-type: none"> <li>• Statistical Office of the Republic of Slovenia</li> <li>• Agricultural Institute of Slovenia</li> </ul>  |
| CRT 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>  |
| CRT 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.

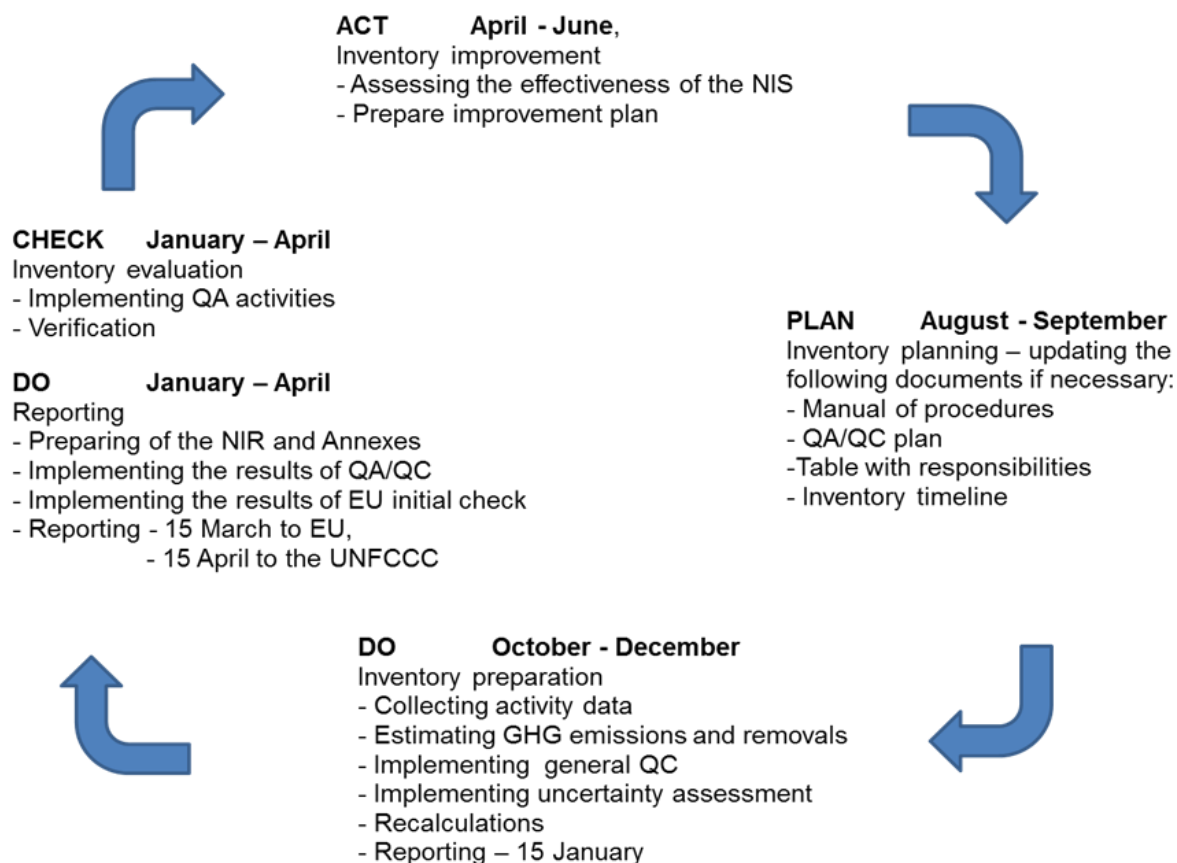


Figure 1.2.2: The inventory cycle.

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

### Public Availability of the Inventory

The inventories are publicly available on the web at a time of submission. Short after the final submission the estimates are presented in a more simple way with a table similar to Table 2.2.1 from the NID on the web page for Environmental indicators. It is very common

that yearly submission of GHG inventory is followed by a press conference, where our last estimates are presented in connection with our emission reduction goals.

Web page address: <https://www.gov.si teme/emisijske-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 and will be including also in the new ETF tool.

**Check of uncertainty estimates**

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

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

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

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

### **Check of NID**

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

### **Checks of Documentation and archiving**

QA/QC checks of documentation and archiving procedures:

- Check that inventory data, supporting data and inventory records are archived and stored to facilitate detailed review.
- Check that all supporting documentation on QA/QC procedures is archived
- Check that results of QC analysis and uncertainty estimates are archived
- Check that there is detailed internal documentation to support the estimates and enable duplication of emissions estimates.
- Check that documentation of the database is adequate and archived.
- Check that bibliographical data references are properly cited in the internal documentation and archived.
- Check that inventory improvements plan is updated 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 NID (Agriculture, LULUCF). Data based on agricultural statistics are mainly from SORS and the Agricultural Institute and data based on forest statistics are produced by the Slovenian Forestry Institute and SORS. All data have been checked.

The Statistical Office of Slovenia (SORS) is our main data provider. In 2005, the European Statistics Code of Practice was adopted, bringing considerable changes to the SORS QA/QC system. The main pillars (factors) of quality are defined and thoroughly described in the Medium-term Programme of Statistical Surveys 2018-2022.

<https://www.stat.si/StatWeb/File/DocSysFile/9809/MTPSS%202018-2022-eng.pdf>

## **EU expert review of GHG emissions**

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

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

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

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

## **1.3 Inventory preparation, and data collection, processing and storage**

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

| GREENHOUSE GAS SOURCE<br>AND SINK<br>CATEGORIES | CO <sub>2</sub>       |                     | CH <sub>4</sub>      |                     | N <sub>2</sub> O  |              |
|---|-----------------------|---------------------|----------------------|---------------------|-------------------|--------------|
|   | Method<br>applied     | EF                  | Method<br>applied    | EF                  | Method<br>applied | EF           |
| <b>1. Energy</b>                                | <b>T1, T2,T3, M</b>   | <b>CS, D, M, PS</b> | <b>T1, T2, T3, M</b> | <b>CS, D, M, PS</b> | <b>T1, M</b>      | <b>D, M</b>  |
| A. Fuel combustion                              | T1, T2,T3, M          | CS, D, M, PS        | T1, T2, M            | CS, D, M            | T1, M             | D, M         |
| 1. Energy industries                            | T1, T2, T3            | CS, D, PS           | T1                   | D                   | T1                | D            |
| 2. Manufacturing ind. and const.                | T1, T2, T3            | CS, D, PS           | T1                   | D                   | T1                | D            |
| 3. Transport                                    | T1, T2, M             | CS, D, M            | T1, M                | D, M                | T1, M             | D, M         |
| 4. Other sectors                                | T1, T2                | CS, D               | T1, T2               | CS, D               | T1                | D            |
| 5. Other  | T1                    | D                   | T1                   | D                   | T1                | D            |
| B. Fugitive emissions from fuels                | T1, T3                | D, PS               | T1, T2, T3           | CS, D, PS           | T1                | D            |
| 1. Solid fuels                                  | T1, T3                | D, PS               | T2, T3               | CS, D, PS           |                   |              |
| 2. Oil and natural gas                          | T1                    | D                   | T1                   | D                   | T1                | D            |
| <b>2. Industrial Processes</b>                  | <b>T1, T2, T3, M</b>  | <b>CS, D, M, PS</b> |                      |                     | <b>D</b>          | <b>D</b>     |
| A. Mineral Products                             | T2, T3                | D, PS               |                      |                     |                   |              |
| B. Chemical Industry                            | T2, T3                | CS, D               |                      |                     |                   |              |
| C. Metal Production                             | T1, T2, T3            | D, PS               |                      |                     |                   |              |
| D. Non-Energy Product                           | T1, M                 | D, M                |                      |                     |                   |              |
| F. Substitutes for ODS                          |                       |                     |                      |                     |                   |              |
| G. Other product man. and use                   |                       |                     |                      |                     | 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                           |                       |                     |                      |                     | T1, T2            | D            |
| G. Liming                                       | T1                    | D                   |                      |                     |                   |              |
| H. Urea application                             | T1                    | D                   |                      |                     |                   |              |
| I. Other C-containing fertilizers               | T1                    | D                   |                      |                     |                   |              |
| <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</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               |                      |                     | D, T1             | D            |
| C. Grassland                                    | D,T1,T2,T3            | CS, D               |                      |                     | D, T1             | D            |
| D. Wetlands                                     | D,T1,T2               | CS, D               |                      |                     |                   |              |
| E. Settlements                                  | D, T2                 | CS, D               |                      |                     | D, T1             | D            |
| F. Other Land                                   | D, T2                 | CS, D               |                      |                     | D, T1             | D            |
| G. HWP  | D, T2                 | D                   |                      |                     | 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                         |                       |                     | T2                   | CS, D               |                   |              |
| B. Biological Treatment                         |                       |                     | T1                   | D                   | T1                | D            |
| C. Incineration                                 | T1                    | D                   | T1                   | D                   | T1                | D            |
| D. Waste-water Treatment                        |                       |                     | T1                   | CS, D               | T1                | D            |

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

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, LPG, 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. Considering SF<sub>6</sub> emissions, the release of this gas from gas-insulated switchgear for electricity is the main source while other sources are also included like a linear particle accelerators and electronic microscopes.



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 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 2023. The level assessment was undertaken for 1986 and 2023, and the trend assessment was performed for 2023. 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, 28 categories were selected as keys in 2023 according to the level assessment, and additional 8 were chosen as key categories according to the trend assessment only. As many as 20 categories are key sources according to level and trend KC analysis.

The most of the 36 key categories are from Energy sector (15): 11 categories are CO<sub>2</sub> emissions from fuel combustion, one is CH<sub>4</sub> emissions from biomass and solid fuel combustion in the residential sector, remaining three are CO<sub>2</sub> and CH<sub>4</sub> fugitive emissions

from Coal mining and handling and CO<sub>2</sub> emissions due to the SO<sub>2</sub> scrubbing. The second most important sector is LULUCF with 8 key categories, six KCs are in the industrial processes, four in the Agriculture sector, where 2 are related to methane emissions and 2 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 N<sub>2</sub>O emissions from N<sub>2</sub>O product use is defined to be KC according to the level.

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

| IPCC Category   | Gas              | with LULUCF | w/o LULUCF additional |
|---|------------------|-------------|-----------------------|
| 1.A.1 Energy Industries, Gaseous Fuels                                  | CO <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           |                       |
| 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, Gasoline                                   | CO <sub>2</sub>  | L, 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           |                       |
| 1.B.1.a Fugitive Emissions, Coal Mining and Handling                    | CH <sub>4</sub>  | L, T        |                       |
| 1.B.1.a Fugitive Emissions, Coal Mining and Handling                    | CO <sub>2</sub>  | T           |                       |
| 1.B.1.a Fugitive Emissions, Other                                       | CO <sub>2</sub>  | T           |                       |
| 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.C.3 Industrial processes, Iron and Steel                              | CO <sub>2</sub>  | T           |                       |
| 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 <sub>sub</sub>      |
| 3.A Agriculture, Enteric Fermentation                                   | CH <sub>4</sub>  | L, T        |                       |
| 3.B Agriculture, Manure Management                                      | CH <sub>4</sub>  | L, T        |                       |
| 3.D.1 Agriculture, Direct N <sub>2</sub> O Emissions from Managed Soils | N <sub>2</sub> O | L           |                       |
| 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.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>  | L, 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           |                       |
| 5.A.1 Waste, Managed waste disposal sites                               | CH <sub>4</sub>  | L, T        |                       |
| 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           |                       |

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 as well as in the present submission. 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.

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

**Table 1.5.2: Methodologies used for key categories according to the level in 2023**

| 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                      |
| 2.A.1 Industrial processes, Cement Production                  | CO <sub>2</sub>  | Tier 3          | PS                      |
| 2.G.3 Industrial processes, N <sub>2</sub> O from product use  | N <sub>2</sub> O | Tier 1          | D                       |
| 2.F.1 Industrial processes, Refrigeration and AC Equipment     | HFC              | Tier 2          | CS, 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.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.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.C.2 LULUCF, Land converted to Grassland                      | CO <sub>2</sub>  | D, Tier 1 - 2   | 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 2023**

| IPCC Category  | Gas             | Methodology    | EF and other parameters |
|--|-----------------|----------------|-------------------------|
| 1.A.1 Energy Industries, Liquid Fuels                | CO <sub>2</sub> | Tier 1         | D                       |
| 1.B.1.a Fugitive Emissions, Coal Mining and Handling | CO <sub>2</sub> | Tier 3         | PS                      |
| 1.B.1.c Fugitive Emissions, Other                    | CO <sub>2</sub> | Tier 1         | D                       |
| 2.B.6 Industrial processes, Iron and steel           | CO <sub>2</sub> | Tier 3         | PS                      |
| 2.C.3 Industrial processes, Lime production          | CO <sub>2</sub> | Tier 1, Tier 3 | D, PS                   |
| 2.C.3 Industrial processes, Aluminium Production     | CO <sub>2</sub> | Tier 3         | PS                      |
| 2.C.3 Industrial processes, Aluminium Production     | PFC             | Tier 3         | PS                      |
| 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 2023 by sectors.**

|                                    | 1986          | 2023          |
|------------------------------------|---------------|---------------|
| 1A Energy                          | 5.19%         | 2.21%         |
| 1B Fugitive                        | 38.77%        | 35.35%        |
| 2 Industrial Processes/Product use | 41.51%        | 10.50%        |
| 3 Agriculture                      | 42.88%        | 46.18%        |
| 4 LULUCF                           | 26.58%        | 29.36%        |
| 5 Waste                            | 55.38%        | 59.43%        |
| <b>TOTAL COMBINED UNCERTAINTY</b>  | <b>12.07%</b> | <b>14.41%</b> |
| <b>w/o LULUCF</b>                  | <b>6.99%</b>  | <b>5.68%</b>  |

A total trend uncertainty (2023/1986) is 26.95% and without LULUCF it is 2.01% w/o.

Uncertainty in 2023 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 2023. 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 2023 as in 1986.

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

More detailed data on uncertainties are included in the excel file SVN\_2025\_Art12\_AnnexX\_Uncertainty v2.

## 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 (CRT 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 CRT for which "NA" is applicable are shaded so they do not need to be filled in.

C (confidential)

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

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

## 2 TRENDS IN GREENHOUSE GAS EMISSIONS

### 2.1 Description and Interpretation of Emission Trends for Aggregated GHG emissions

Total emissions of GHG in 2023, sinks not considered, amounted to 14,804 kt CO<sub>2</sub> eq, which represents a 33.9% decrease of emissions compared to the year 1986. In the period 1986-1991, a reduction of emissions was recorded due to the economic conditions at that time and the fact that the Republic of Slovenia was gaining its independence. In the period 1992-1997, a strong increase of emissions was recorded, which was a consequence of increasing economic growth and revival of industrial production. In the second half of that period, the increased emissions were a consequence of "gasoline tourism" (25% of the total sale of motor fuels in the Republic of Slovenia), since the prices of motor fuels in the Republic of Slovenia were appreciably lower than in the neighbouring countries.

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

In 2009, emissions from fuel used and from industrial processes started to decrease due to the global financial crisis. In 2010 and 2011, emissions stayed almost the same as in 2009, while since 2012 a further decrease has been observed. In 2020 a strong decline in emissions happened due to the Covid-19 measures, while in 2022 after increase of emissions in 2021 by 0.8% emissions decrease by 2.9% and in 2023 by 4.8%.

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

CO<sub>2</sub> emissions in 2023 represented 81.1% 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 28.4% in 2023. CH<sub>4</sub> emissions represented 12.4% of total emissions in 2023 and were by 37.1% lower than in 1986. N<sub>2</sub>O emissions represented 4.3% of total emissions and were by 13.8% lower than N<sub>2</sub>O emissions in 1986. F-gases represented 2.1% 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 until 2019 and since then emissions of F-gasses are more or less constant.



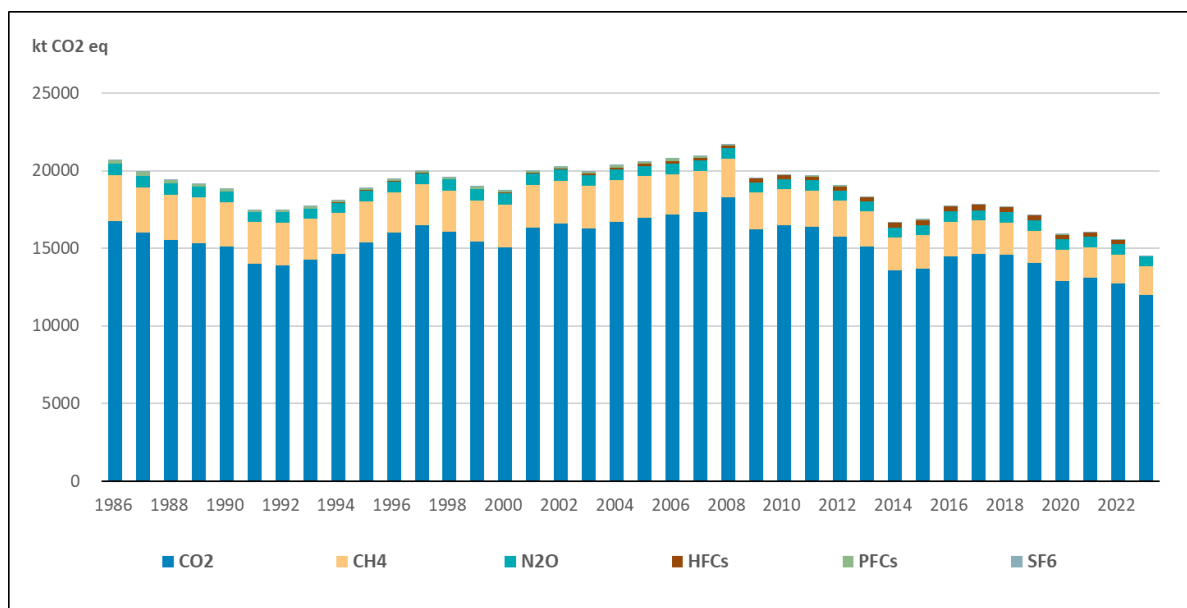


Figure 2.2.1: GHG Emissions in Slovenia by gas.

## 2.2 Description and Interpretation of Emission Trends by Sector

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

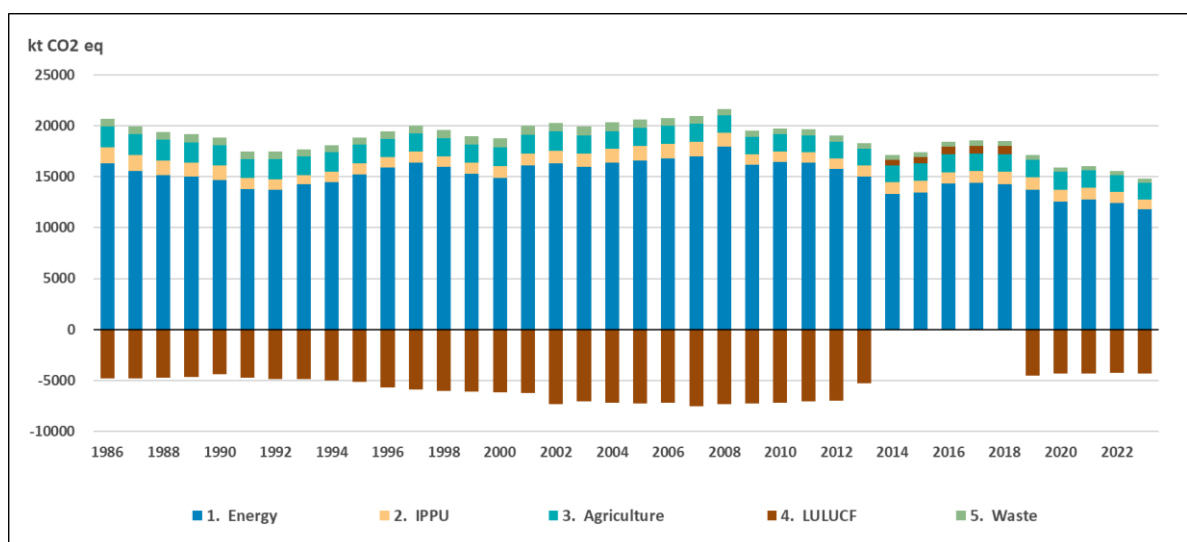


Figure 2.3.1: GHG Emissions in Slovenia by sector

By far the most important sector is Energy, which in 2023 accounted for 79.6% of total GHG emissions. In this sector emissions have decreased by 27.8%, compared to the 1986. Within this sector, in the period 1986–2023, GHG emissions from the Energy Industry, as the

biggest sub-sector in the base year, decreased by 51.6%. In the period 1999–2007, steep growth (+27%) has been recorded due to the increased consumption of electrical energy.

Undoubtedly the greatest increase in GHG emissions was observed in the transport sector, by as much as 200% until 2008, due to the increase in road transportation, while emissions from other kinds of traffic slightly declined. In 2009 GHG emissions from transport decreased by 16.3% compared to 2008. Since then emissions fluctuate from year to year but have never reached the 2008 peak. Due to the Covid-19 “lock down” in 2020 emissions in the transport sector decreased by 18.7% compared to the previous year, while in 2021 emissions are almost back on the pre-Covid level and in 2022 emissions increased by 11.3% compared to 2021 and are 182.5% higher as in the base year. However in 2023 emission decrease by 7.4% 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 construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2023 emissions from this sector decreased by 63.2%.

In the CRT category Other sectors, which accounts for 10.7% of emissions, emissions from the households prevails. Mainly due to increasing use of biomass for heating, better insulation of buildings and warmer winters, the GHG emissions from this sector decreased by 51.7% since 1986.

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

Fugitive emissions in the Republic of Slovenia are also of minor importance thus they represent only 2.5% of emissions in the sector and have decreased by 52.5% compare to emissions in 1986 by 51.7%.

Emissions from Industrial processes and product use (CRT sector 2) in Slovenia account for 6.8% of the total national GHG emissions, excluding LULUCF. They amounted to 1,586 kt CO<sub>2</sub> equivalents in 1986 and 1,006 kt CO<sub>2</sub> equivalents in 2023. The most important GHG of this sector was carbon dioxide, with 63.7% of emissions from this category, followed by HFCs with 29.5%, N<sub>2</sub>O with 5.1%, SF<sub>6</sub> with 1.7%, and PFCs with 0.1%. The main source of emissions is mineral industry with 52.4% of emissions, followed by consumption of F-gases (product uses as substitutes for ODS) with 29.5%. Significantly smaller are the contributions from other product manufacture and use (6.8%), metal industry (5.1%), and chemical industry (5.8%), while use of non-energy products from fuels and solvent contributes 1.5% to the total emissions from this sector.

Since 1986, GHG emissions from Industrial Processes at first fell sharply to reach their lowest value in 1993, but then started to rise again and were in 2007 6.0% above 1986 level. Due

to the global financial crises and lower industrial production, emissions in 2009 were 28.2% below the 1986 emissions but in the period 2010 – 2019 slowly increased by 24.5% while in 2020 decreased by 4.3% due to the epidemics and continue to decrease also in the following years.

In Agriculture as the second most important sector, emissions in 2023 amounted to 1,632 Gg CO<sub>2</sub> eq, which represents 11% of all emissions. Agriculture represents the main source of methane and N<sub>2</sub>O emissions, namely 63.6% of all methane emissions and 66.6% of all N<sub>2</sub>O emissions. In the agricultural sector, CH<sub>4</sub> emissions accounted for 71.6% of emissions and N<sub>2</sub>O emissions accounted for 25.9% of emissions, while CO<sub>2</sub> emissions accounted for 2.5% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2023, emissions were 20.5% below the emissions in the base year.

The most important sub-sector represented emissions from enteric fermentation, which contributed 59.8% of all emissions from agriculture, followed by emissions from agricultural soils, with 22.4%; the rest is contributed by emissions of methane and N<sub>2</sub>O from animal manure (15.2%) while CO<sub>2</sub> emissions due to the liming and application of urea and other C-containing fertilizers represented only 2.5% of emissions in this sector (Figure 5.1.1).

In 2023, the LULUCF sector acted as a CO<sub>2</sub> sink of -4,291 Gg CO<sub>2</sub> eq. The most important category is forest land, which accounts for 96.7% of the sector's total net removals. 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 largely improved but the net GHG sinks in 2023 were still by 18.8% lower than in the year 2013.

In 2023, emissions from the Waste sector amounted to 377 Gg CO<sub>2</sub> eq, or 2.5 per cent of the total GHG emissions. Since 1986 emissions decreased by 45.9 per cent. The key driver for the decline of emissions is the decrease of biodegradable part of the municipal waste deposited on the SWD sites and increase of gas recovery on the SWD sites and in the wastewater treatment plants. (Figure 7.1.1).

Methane emissions from the Waste sector are the second largest source of methane and represents 17.4% of the all methane emissions in Slovenia in 2023. The fraction of methane emissions in this sector amounts to 85.2%, while the remaining part represent N<sub>2</sub>O (10.4%) and CO<sub>2</sub> emissions (4.5%). Solid waste handling contributes 45.7% to the total emissions from this sector, wastewater handling 45.1%, composting 4.7%, and incineration of waste 4.5%. Emissions from solid waste disposal started to decline in 2005 and since then emissions decreased by 68.4% due to the strong decrease of deposited biodegradable part of municipal waste and gas recovery. Emissions from waste waters were by 53.8% 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 1986-2023.**

|   | 1986   | 1990   | 2000   | 2005   | 2010   | 2015   | 2020   | 2022   | 2023   | Change LY<br>to BY (%) | Change LY<br>to PY (%) |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|------------------------|------------------------|
| 1. Energy                                 | 15,900 | 14,466 | 12,564 | 13,380 | 12,570 | 17,430 | 11,567 | 11,339 | 10,513 | -33.9                  | -7.3                   |
| A. Fuel Combustion                        | 16,321 | 14,708 | 14,880 | 16,610 | 16,460 | 13,475 | 12,582 | 12,422 | 11,790 | -27.8                  | -5.1                   |
| 1. Energy Industries                      | 15,672 | 14,147 | 14,365 | 16,041 | 15,897 | 13,074 | 12,171 | 12,114 | 11,456 | -26.9                  | -5.4                   |
| 2. Man. Industries and Construction       | 6,840  | 6,374  | 5,593  | 6,449  | 6,347  | 4,567  | 4,517  | 3,420  | 3,310  | -51.6                  | -3.2                   |
| 3. Transport                              | 4,126  | 3,096  | 2,294  | 2,466  | 1,934  | 1,611  | 1,713  | 1,620  | 1,517  | -63.2                  | -6.4                   |
| 4. Other Sectors                          | 2,051  | 2,737  | 3,676  | 4,402  | 5,300  | 5,354  | 4,575  | 5,793  | 5,364  | 161.5                  | -7.4                   |
| 5. Other                                  | 2,614  | 1,907  | 2,798  | 2,721  | 2,314  | 1,538  | 1,363  | 1,276  | 1,261  | -51.7                  | -1.2                   |
| B. Fugitive Emissions from Fuels          | 41     | 32     | 3      | 3      | 3      | 4      | 3      | 5      | 4      | -89.2                  | -4.6                   |
| 1. Solid Fuels                            | 649    | 561    | 515    | 570    | 563    | 401    | 411    | 308    | 334    | -48.5                  | 8.4                    |
| 2. Oil and Natural Gas and other...       | 602    | 505    | 461    | 511    | 510    | 361    | 367    | 267    | 295    | -51.0                  | 10.4                   |
| 2. Industrial Processes                   | 1,586  | 1,368  | 1,141  | 1,395  | 987    | 1,108  | 1,154  | 1,095  | 1,006  | -36.6                  | -8.2                   |
| A. Mineral Industry                       | 744    | 694    | 598    | 636    | 479    | 452    | 560    | 574    | 527    | -29.2                  | -8.3                   |
| B. Chemical Industry                      | 98     | 88     | 114    | 138    | 90     | 60     | 62     | 65     | 48     | -51.3                  | -26.1                  |
| C. Metal Industry                         | 656    | 530    | 321    | 410    | 126    | 207    | 143    | 89     | 51     | -92.2                  | -42.5                  |
| D. Non-energy products                    | 8      | 8      | 14     | 25     | 15     | 26     | 31     | 15     | 15     | 81.8                   | 1.3                    |
| E. Electronics industry                   | NO     | NO     | NO     | NO     | NO     | NO     | NO     | NO     | NO     | –                      | –                      |
| F. Product uses as ODS substitutes        | NO     | NO     | 41     | 130    | 233    | 312    | 282    | 286    | 297    | –                      | 3.6                    |
| G. Other product manufacture and use      | 80     | 47     | 52     | 56     | 44     | 51     | 76     | 66     | 68     | -14.8                  | 3.0                    |
| H. Other                                  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | –                      | –                      |
| 3. Agriculture                            | 2,053  | 1,983  | 1,873  | 1,763  | 1,705  | 1,736  | 1,727  | 1,660  | 1,632  | -20.5                  | -1.7                   |
| A. Enteric Fermentation                   | 1,119  | 1,067  | 1,061  | 1,020  | 1,004  | 1,038  | 1,039  | 998    | 976    | -12.8                  | -2.2                   |
| B. Manure Management                      | 449    | 453    | 342    | 316    | 287    | 282    | 265    | 251    | 249    | -44.6                  | -1.0                   |
| C. Rice Cultivation                       | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | –                      | –                      |
| D. Agricultural Soils                     | 428    | 407    | 436    | 398    | 386    | 391    | 393    | 378    | 366    | -14.5                  | -3.2                   |
| E. Prescribed Burning of Savannahs        | NA     | NA     | NA     | NA     | NA     | NA     | NA     | NA     | NA     | –                      | –                      |
| F. Field Burning of Agricultural Residues | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | NA,NO  | –                      | –                      |
| G. Liming                                 | 44     | 44     | 17     | 14     | 13     | 11     | 14     | 21     | 29     | -34.7                  | 36.6                   |
| H. Urea applications                      | 9      | 9      | 12     | 12     | 11     | 9      | 12     | 8      | 8      | -9.6                   | -2.1                   |
| I. Other carbon-containing fertilizers    | 4      | 4      | 4      | 4      | 4      | 5      | 4      | 3      | 4      | -5.5                   | 15.7                   |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

|   | 1986   | 1990   | 2000   | 2005   | 2010   | 2015 | 2020   | 2022   | 2023   | Change LY<br>to BY (%) | Change LY<br>to PY (%) |
|---|--------|--------|--------|--------|--------|------|--------|--------|--------|------------------------|------------------------|
| 4. Land Use, Land-Use Change and Forestry | -4,793 | -4,818 | -6,043 | -7,266 | -7,145 | 624  | -4,241 | -4,028 | -4,148 | -13.5                  | 3.0                    |
| A. Forest Land                            | 253    | 256    | 122    | 142    | 133    | 173  | 136    | 129    | 128    | -49.3                  | -0.6                   |
| B. Cropland                               | -271   | -245   | -713   | -533   | -489   | -410 | -356   | -266   | -244   | -10.1                  | -8.6                   |
| C. Grassland                              | 42     | 43     | 32     | 30     | 46     | 13   | 42     | 46     | 48     | 13.7                   | 4.0                    |
| D. Wetlands                               | 454    | 455    | 498    | 579    | 409    | 306  | 219    | 201    | 191    | -57.8                  | -4.9                   |
| E. Settlements                            | 14     | 15     | 8      | 16     | 20     | 4    | 4      | 4      | 4      | -73.3                  | -8.1                   |
| F. Other Land                             | -457   | -67    | -85    | -185   | -129   | -129 | -142   | -305   | -271   | -40.8                  | -11.2                  |
| G. Harvested wood products                | -4,793 | -4,818 | -6,043 | -7,266 | -7,145 | 624  | -4,241 | -4,028 | -4,148 | -13.5                  | 3.0                    |
| H. Other                                  | NO     | NO     | NO     | NO     | NO     | NO   | NO     | NO     | NO     | –                      | –                      |
| 6. Waste                                  | 697    | 769    | 850    | 828    | 574    | 532  | 440    | 380    | 377    | -45.9                  | -0.8                   |
| A. Solid Waste Disposal                   | 327    | 418    | 532    | 546    | 335    | 286  | 219    | 176    | 172    | -47.4                  | -2.5                   |
| B. Biological treatment of solid waste    | NA,NO  | NA,NO  | NA,NO  | 3      | 5      | 13   | 20     | 19     | 18     | –                      | -6.4                   |
| C. Incineration and open burning of waste | 2      | 2      | 3      | 3      | 7      | 27   | 20     | 14     | 17     | 744.2                  | 20.4                   |
| D. Waste water treatment and discharge    | 368    | 350    | 315    | 276    | 227    | 205  | 182    | 170    | 170    | -53.8                  | -0.1                   |
| E. Other                                  | NO     | NO     | NO     | NO     | NO     | NO   | NO     | NO     | NO     | –                      | –                      |
| 6. Other                                  | NO     | NO     | NO     | NO     | NO     | NO   | NO     | NO     | NO     | –                      | –                      |

## Memo Items.

|  |        |        |        |        |        |        |        |        |        |       |        |
|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|
| International Bunkers                              | 59     | 49     | 69     | 130    | 133    | 283    | 408    | 62     | 54     | -7.2  | -11.7  |
| Aviation   | 59     | 49     | 69     | 61     | 73     | 75     | 26     | 62     | 54     | -7.2  | -11.7  |
| Navigation   | NO,NA  | NO,NA  | NO,NA  | 69     | 60     | 208    | 382    | NO     | NO     | –     | –      |
| Multilateral Operations                            | NO     | NO     | 1      | 0      | 0      | 1      | 0      | 1      | 1      | –     | -10.44 |
| CO <sub>2</sub> Emissions from Biomass             | 2,763  | 2,581  | 2,576  | 3,315  | 3,308  | 3,207  | 2,958  | 2,874  | 2,823  | 2.2   | -1.8   |
| Long term storage of C in waste disposal sites     | 771    | 1,084  | 2,037  | 2,587  | 3,063  | 3,247  | 3,249  | 3,249  | 3,249  | 321.2 | 0.0    |
|  |        |        |        |        |        |        |        |        |        |       |        |
| Total CO <sub>2</sub> Eq. Emissions without LULUCF | 20,657 | 18,828 | 18,744 | 20,596 | 19,726 | 16,850 | 15,903 | 15,558 | 14,804 | -28.3 | -4.8   |
| Total CO <sub>2</sub> Eq. Emissions with LULUCF    | 15,900 | 14,466 | 12,564 | 13,380 | 12,570 | 17,430 | 11,567 | 11,339 | 10,513 | -33.9 | -7.3   |



## 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 2023 41% of the Slovenian emissions of NO<sub>x</sub>. The total emissions have decreased by 68% from 1990 to 2023. 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 2023 by 74%. 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 2023 was emissions from non-energy products from fuels and solvent use, followed by small combustion. Emissions of NMVOC have decreased from 1990 to 2023 by 57%. 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 2023, the total emission decreased by 9%. This enormous reduction is largely due to installation of desulphurisation process in the plant, use of fuels with lower content of sulphur in public power and district heating plants, introduction of liquid fuels with lower content of sulphur and substitution of high-sulphur solid and liquid fuels to low-sulphur fuels such as natural gas.

In the Table 2.3.1, emissions of pollutants reported under Directive 2016/2284 (NECD) are presented. The data are slightly different from the data reported in the CRT tables because emissions from international aviation are not included in the national total in GHG inventory.

**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 | 2023 | Change |
|-----------------|-------|-------|-------|-------|-------|-------|------|------|--------|
| NO <sub>x</sub> | 75.3  | 75.2  | 58.7  | 55.0  | 47.7  | 35.1  | 25.5 | 23.8 | -68.4  |
| CO              | 291.2 | 280.9 | 204.5 | 182.0 | 142.6 | 121.2 | 88.6 | 75.1 | -74.2  |
| NMVOC           | 65.2  | 62.7  | 55.0  | 47.9  | 39.4  | 32.4  | 32.2 | 27.8 | -57.4  |
| SO <sub>2</sub> | 202.8 | 124.5 | 93.1  | 39.7  | 10.3  | 5.4   | 3.9  | 2.6  | -98.7  |

### 3 ENERGY (CRT sector 1)

#### 3.1 Overview over the Sector

The energy sector is the most important sector of GHG emissions in the Republic of Slovenia, since it accounted for 79.6% of overall CO<sub>2</sub> eq. emissions (w/o considering LULUCF) in 2023. Emissions from this sector arise from fuel combustion, accounting for 97.2% emissions from the energy sector, and as fugitive emissions from fuels, accounting for 2.8% of emissions (Figure 3.1.1).

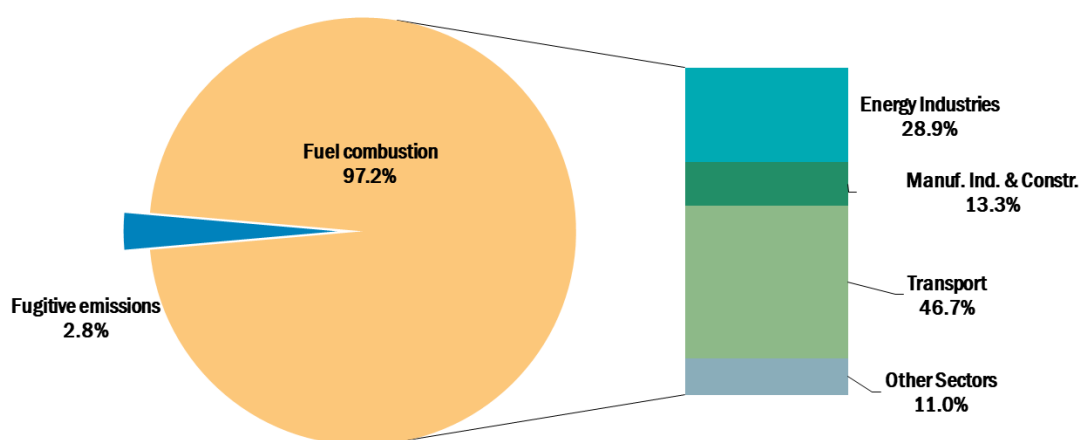


Figure 3.1.1: Emissions of GHG in Energy Sector by categories in 2023

Emissions from Energy sector are presented on the Table 3.1.1. Compared to 2022, GHG emissions decreased by 7.3% in 2023 and were by 33.9% 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 2023, 5.3 TWh (i.e. 35.2%) of electrical energy was produced in the Krško Nuclear Power Plant, 5.3 TWh (i.e. 34.8%) in public hydroelectric power plants, 3.5 TWh in thermal power plants (i.e. 23.4%), while the remaining 1 TWh (i.e. 6.5%) was produced using solar and wind energy. The structure changes slightly from year to year, depending mostly on the changes in the hydrology of Slovenian rivers. Within this sector, in the period 1986–2023, GHG emissions from the Energy Industry, as the second biggest sub-sector, decreased by 51.6%.

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 2023 with share of 45.5%. For traffic, virtually all emissions are accounted for by road traffic and within this category the



growth of the fraction of emissions from goods transport is particularly noticeable, since the goods transport in transit through Slovenia has been, annually increasing by more than 10% since 2000. Due to the recession, the emissions in 2009 decreased drastically and since then emissions have fluctuated from year to year but have never reached the 2008 level again. In 2020 due to the Covid-19 measures emissions from transport was by 18.7% lower as in the previous year but as much as 172.6% higher as in 1986. In 2021 emissions from this sector increased by 13.8% and in 2022 they increased further by 11.3%. However in 2023 emission decrease by 7.4% compared to the previous year. In the period 1986 to 2023 transport emissions increased by 161.5%.

There was an appreciable reduction of GHGs from Manufacturing industry between 1986 and 2001 (-50.3%). After 2001, a stabilisation of emissions was observed until 2008. Due to the global financial crisis, emissions from Manufacturing industry and construction decreased in 2009 by 15.6%. In the following years the emissions have further decreased and altogether in the 2015 due to the economic crises emissions from manufacturing industries and construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2023 emissions from this sector decreased by 63.2%.

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

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

**Table 3.1.1: Emissions from Energy sector by sources in kt CO<sub>2</sub> eq.**

|                              | 1986   | 1990   | 2000   | 2005   | 2010   | 2015   | 2020   | 2022   | 2023   |
|------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b>1. Energy</b>             | 16,321 | 14,708 | 14,880 | 16,610 | 16,460 | 13,475 | 12,582 | 12,422 | 11,790 |
| <b>A. Fuel Combustion</b>    | 15,672 | 14,147 | 14,365 | 16,041 | 15,897 | 13,074 | 12,171 | 12,114 | 11,456 |
| 1. Energy Industries         | 6,840  | 6,374  | 5,593  | 6,449  | 6,347  | 4,567  | 4,517  | 3,420  | 3,310  |
| 2. Man. Ind. and Const.      | 4,126  | 3,096  | 2,294  | 2,466  | 1,934  | 1,611  | 1,713  | 1,620  | 1,517  |
| 3. Transport                 | 2,051  | 2,737  | 3,676  | 4,402  | 5,300  | 5,354  | 4,575  | 5,793  | 5,364  |
| 4. Other Sectors             | 2,614  | 1,907  | 2,798  | 2,721  | 2,314  | 1,538  | 1,363  | 1,276  | 1,261  |
| 5. Other                     | 41     | 32     | 3      | 3      | 3      | 4      | 3      | 5      | 4      |
| <b>B. Fugitive Emissions</b> | 649    | 561    | 515    | 570    | 563    | 401    | 411    | 308    | 334    |
| 1. Solid Fuels               | 602    | 505    | 461    | 511    | 510    | 361    | 367    | 267    | 295    |
| 2. Oil and Natural Gas       | 47     | 56     | 54     | 59     | 54     | 40     | 44     | 41     | 39     |

Fugitive emissions in the Republic of Slovenia are also of minor importance thus they represent only 2.5% of emissions in the sector and have decreased by 52.5% compare to emissions in 1986 by 51.7%. The biggest fraction (73.4%) of GHG emissions from this sector are emissions of carbon dioxide and methane from mining of coal in underground mines, while remaining emissions are emissions of CO<sub>2</sub> due to the SO<sub>2</sub> scrubbing (13.3%) and emissions from oil and natural gas (11.7%). 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 (CRT 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 primary taken from the SORS but since 2005 they were replaced by EU-ETS data when they differ. Additional data on the energy use of some types of waste (waste tyres, oils and solvents) were also acquired from the verified EU-ETS reports.

The European Union Emissions Trading System (EU-ETS) has been established in 2003. It includes heavy energy-consuming installations in power generation and manufacturing. The activities covered are energy activities, the production and processing of ferrous metals, aluminium, the mineral industry and some other production activities. In 2023 EU-ETS is covering 69% of all stationary combustion activities, and 63% of IPPU emissions. As much as 95% of emissions from Energy industries have been included in the EU-ETS in 2023.

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.

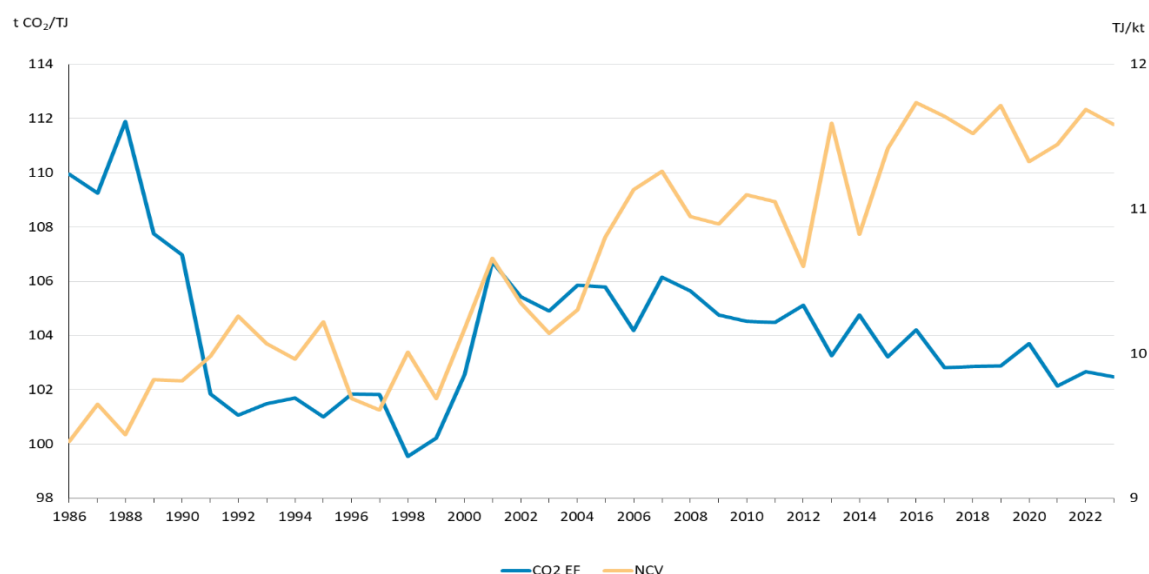
Emissions from the standard liquid fuels are mostly calculated with default CO<sub>2</sub> EFs while in road transport CO<sub>2</sub> EFs from COPERT 5 model are used. We are aware that not using the CS EF for the key categories is not in line with the IPCC methodology. To help many EU countries with the same problem the European Commission has started the project to help MS in developing CS EF. Initially, we expected that this project will resulted in a set of CS EFs used by EU Member States and instructions for their use in the other countries, where CS EFs are not available. However in the end this not happened. The result of the project are the instructions that every MS should determine their own EF. They suggest to analyse carbon content in fuel samples collected under the Fuel Quality Directive (FQD). However this approach is not suitable for us, because samples which are collected under the FQD are not available for further use because they are not archived. The expert from the main company which prepare reports for FQD are of the opinion that fuel should be sampled separately for this purpose. There is also no accredited laboratory in Slovenia to determine C content in the liquid fuels. At this moment we do not yet know exactly how and when we will be able to start with this contract.

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

### **Country specific CO<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 1986-2023.**

**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 | 102.14 | 102.67 | 102.47 |        |        |

### **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 energetski izrabi zemeljskega plina).

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

For the present submission we have obtained data on the chemical composition of natural gas used in Slovenia for the period after 1996. The data are available for the years 2002, 2005, 2009, 2013, and yearly since 2015. Following the methodology described in the study mentioned above CO<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 and in t CO<sub>2</sub>/1000 Sm<sup>3</sup>.**

| 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 |
| 1.866  | 1.866  | 1.899  | 1.900  | 1.900  | 1.900  | 1.900  | 1.909  | 1.899  | 1.900  |
| 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 | 56.022 |
| 1.900  | 1.884  | 1.888  | 1.892  | 1.896  | 1.900  | 1.904  | 1.906  | 1.909  | 1.912  |
| 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   |
| 55.910 | 55.821 | 55.753 | 55.620 | 55.487 | 55.357 | 55.225 | 55.187 | 55.102 | 55.273 |
| 1.912  | 1.913  | 1.915  | 1.914  | 1.913  | 1.913  | 1.912  | 1.915  | 1.915  | 1.924  |
| 2016   | 2017   | 2018   | 2019   | 2020   | 2021   | 2022   | 2023   | 2024   | 2025   |
| 55.379 | 55.486 | 55.335 | 55.376 | 55.346 | 55.440 | 55.477 | 55.740 |        |        |
| 1.930  | 1.930  | 1.927  | 1.930  | 1.929  | 1.932  | 1.952  | 1.979  |        |        |

**Country specific CO<sub>2</sub> EF for LPG**

In accordance with business practice in ensuring the appropriate quality of LPG, the requirements defined in the internal specifications for LPG – propane-butane mixture and LPG – propane and the national standard SIST 1030 are taken into account in the procurement procedures. The specifications or the said standard determine the properties of LPG, within which the requirement regarding the composition is also defined. The main components of liquefied petroleum gas are propane and butane in various proportions. The ratio of propane and butane in LPG – propane-butane mixture is max. 65% (m/m) butane and max. 35% (m/m) propane. The propane content in LPG-propane is min. 95% (m/m). Individual LPG deliveries may of course differ in terms of composition, but exclusively within the upper or lower permitted limits of the specified specifications.

Based on data from LPG distributors on NCV, which is 46,05 MJ/t and is used for the entire period also in the national statistics, CS EF has been determined in the way, that CO<sub>2</sub> EF in kg CO<sub>2</sub>/ kg LPG is the same as IPCC default e.g. 2.98 kg CO<sub>2</sub>/kg LPG. This EF is calculated with default NCV 47.3 MJ/t and default EF 63.1 kg CO<sub>2</sub>/MJ. In our case NCV is 46.05 MJ/t and the corresponding CS EF is 64.7 kg CO<sub>2</sub>/MJ.

**Oxidation factor**

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

**Sources of data**

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

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

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

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

### **SORS data**

E1L-YY-arso – fuel consumption in public power plants

E2L-YY-arso – fuel consumption in auto producers

E2LP-YY-arso – fuel consumption in cogeneration plants

E3L-YY-arso – fuel consumption in public heat

epel\_arsoYY\_NACE2008.xls – fuel consumption in mining, manufacturing industry and construction

ZBIRNA E8-E12 ARSO YYYY.xls – data on energy balance

### **Joint questionnaires:**

ENERGY\_NTGAS\_A\_SI\_YYYY - gaseous fuel

ENERGY\_PETRO\_A\_SI\_YYYY - liquid fuel

ENERGY\_RENEW\_A\_SI\_YYYY - other fuel

ENERGY\_SOLID\_A\_SI\_YYYY - solid fuel

### **Other data providers**

SEA - Individual data and verifying reports from ETS and internal reports from verifiers

Eurocontrol – data on domestic and international flights

Ministry of Infrastructure – fleet composition

Slovenian Maritime Administration – fuel used for domestic navigation

Plinovodi – fuel used for natural gas transport and composition of natural gas

The Fisheries Research Institute of Slovenia – fuel used for fishing

Slovenian Army and Police – consumption of jet kerosene

IJS/CEU – biomass consumption in different types of stoves in residential sector

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

The total difference of CO<sub>2</sub> emissions between the sectoral approach and the reference approach in 2023 amounted to 0.3 per cent related to the energy consumption (Table 3.2.3) and to 0.04 per cent related to the CO<sub>2</sub> emissions (Table 3.2.4).

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

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

| Fuels        | 1986        | 1990         | 2000        | 2005         | 2010         | 2015        | 2020        | 2022         | 2023        |
|--------------|-------------|--------------|-------------|--------------|--------------|-------------|-------------|--------------|-------------|
| Liquid       | 3.16        | 2.12         | 2.34        | -0.51        | 0.57         | 0.15        | 0.14        | -0.01        | 0.32        |
| Solid        | 3.22        | 0.08         | 0.01        | -1.30        | -0.83        | -0.03       | 1.06        | -0.23        | 0.50        |
| Gaseous      | -4.04       | -8.25        | 0.33        | 0.61         | -0.08        | 0.01        | 0.01        | -0.80        | 0.00        |
| Other fossil | -100        | -100         | -90.91      | 16.46        | -43.54       | 5.02        | -0.46       | 2.75         | 0.74        |
| <b>Total</b> | <b>2.05</b> | <b>-0.62</b> | <b>1.18</b> | <b>-0.58</b> | <b>-0.28</b> | <b>0.12</b> | <b>0.35</b> | <b>-0.16</b> | <b>0.30</b> |

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

| Fuels        | 1986        | 1990         | 2000        | 2005         | 2010         | 2015         | 2020        | 2022         | 2023        |
|--------------|-------------|--------------|-------------|--------------|--------------|--------------|-------------|--------------|-------------|
| Liquid       | 1.73        | 1.13         | 1.71        | -0.75        | 0.40         | -0.07        | 0.04        | -0.16        | 0.10        |
| Solid        | 3.12        | 0.06         | -0.31       | -1.68        | -1.47        | -0.25        | 0.82        | -0.49        | -0.04       |
| Gaseous      | -3.98       | -8.21        | 0.42        | 0.68         | -0.01        | 0.07         | -0.06       | -0.75        | 0.05        |
| Other fossil | -100        | -100         | -90.91      | -3.53        | -43.70       | 5.02         | -1.61       | 0.87         | -1.34       |
| <b>Total</b> | <b>1.93</b> | <b>-0.60</b> | <b>0.65</b> | <b>-1.06</b> | <b>-0.68</b> | <b>-0.07</b> | <b>0.30</b> | <b>-0.32</b> | <b>0.04</b> |

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

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

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

### 3.2.2 International Bunker Fuels

#### International navigation

Slovenia has only one international port "Luka Koper", but in the period 1986-2004 no ships were refuelled in that port (mostly the ships were refuelled in the international waters by Italian ships under Panama flags). Since 2005, a small amount of heavy fuel oil has been reported as fuel sold to the international marine bunkers for the first time. Since then the

amount of fuel used for this purpose has gradually increased. In 2020 and 2021 emissions decreased due to the Covid-19 pandemic. Since 2022 no fuel is used for this purpose.

Method: Tier 1

Source for AD (amount of heavy fuel oil and diesel oil and corresponding NCVs): SORS.

Source for EFs: default values from 2006 IPCC Guidelines, Vol. 2. Table 3.5.2 and 3.5.3

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

**Table 3.2.5: International Navigation Bunkers – fuel used in TJ and GHG emissions in kt CO<sub>2</sub> eq.**

|                              | 2005 | 2010 | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  | 2022 | 2023 |
|------------------------------|------|------|-------|-------|-------|-------|-------|-------|------|------|
| <b>fuel in TJ</b>            | 880  | 768  | 2,668 | 5,122 | 6,456 | 9,429 | 7,974 | 4,904 | NO   | NO   |
| <b>kt CO<sub>2</sub> eq.</b> | 69   | 60   | 208   | 400   | 504   | 734   | 619   | 382   | NO   | NO   |

### **International aviation**

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

**Table 3.2.6: Consumption of jet kerosene in 2023 in different CRT categories.**

| <b>Jet kerosene</b>           | <b>amount</b> | <b>unit</b> | <b>amount</b> | <b>unit</b> |
|-------------------------------|---------------|-------------|---------------|-------------|
| 1A3a Domestic navigation      | 33            | t           | 1             | TJ          |
| 1A5b Military use of fuel     | 1,426         | t           | 63            | TJ          |
| Memo – international aviation | 17,317        | t           | 754           | TJ          |
| Memo – multilateral operation | 186           | t           | 8             | TJ          |
| <b>Total</b>                  | <b>18,962</b> | <b>t</b>    | <b>826</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 CRT categories in 2010 is presented in the Table 3.2.6.

Because of negligible quantities of emissions, the entire consumption of aviation gasoline for piston engine aircraft was considered to be used for the domestic aviation, since it was



assumed that this was fuel for a small aircrafts, which fly mostly between smaller regional airports in Slovenia.

Method: Tier 1

Source for AD: SORS, Slovenian Army and Police, Eurocontrol

Source for EFs: default values from 2006 IPCC Guidelines, Vol.2, Table 3.6.4 and 3.6.5

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

**Table 3.2.7: International Aviation Bunkers – fuel used in TJ and GHG emissions in kt CO<sub>2</sub> eq.**

|                              | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------------|------|------|------|------|------|------|------|------|------|
| <b>fuel in TJ</b>            | 812  | 684  | 962  | 852  | 1017 | 1037 | 363  | 854  | 754  |
| <b>kt CO<sub>2</sub> eq.</b> | 59   | 49   | 69   | 61   | 73   | 75   | 26   | 62   | 54   |

### **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 | 2020 | 2022 | 2023 |
|------------------------------|------|------|------|------|------|------|------|------|
| <b>fuel in TJ</b>            | 3    | 7    | 6    | 5    | 7    | 6    | 9    | 8    |
| <b>kt CO<sub>2</sub> eq.</b> | 0.2  | 0.5  | 0.4  | 0.4  | 0.5  | 0.4  | 0.6  | 0.6  |

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

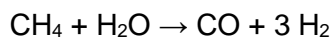


**Figure 3.2.2: Methanol production in Nafta-Petrochem Lendava.**

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.

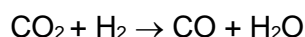
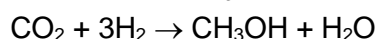
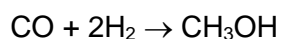
Natural gas was entirely used as the raw material for transformation into methanol. In every cycle only a fifth of it is transformed to the product, while the remaining natural gas is returned into the process. The schematic diagram of the process is shown in the Figure 3.2.3.

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.

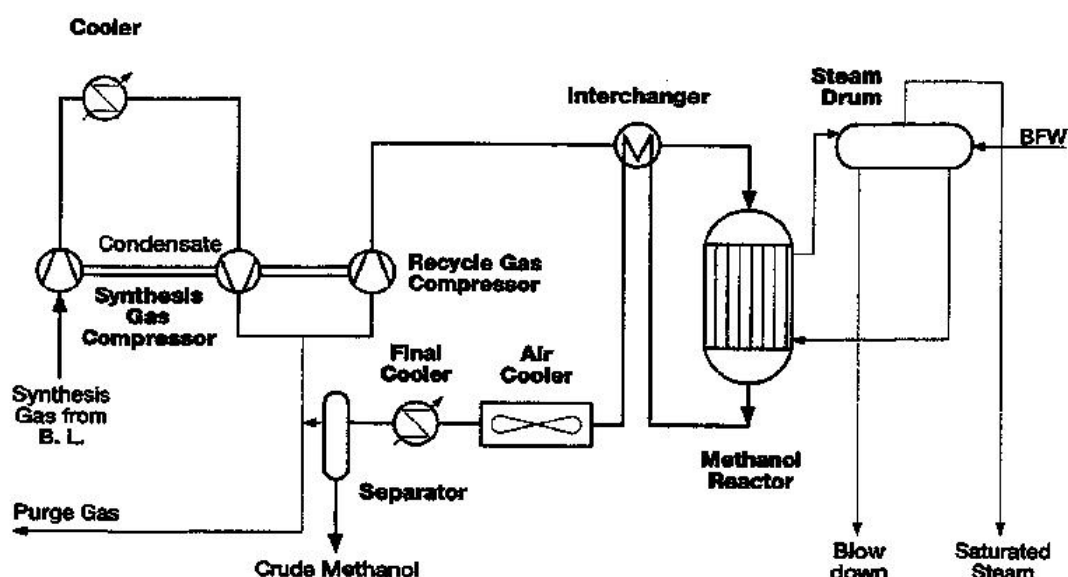


Figure 3.2.3: Schematic diagram of methanol production.

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   | 2000   | 2005   | 2010   | 2015   | 2020   | 2022   | 2023   |
|--------------------------|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Natural Gas              | 1000 m <sup>3</sup> | 67666  | 69524  | 136740 | 164407 | 97004  | 6176   | 6522   | 6471   | 5393   |
| Carbon EF                | t C/TJ              | 15.195 | 15.195 | 15.172 | 15.29  | 15.144 | 15.311 | 15.105 | 15.141 | 15.213 |
| Excluded CO <sub>2</sub> | kt                  | 125.4  | 131.2  | 257.7  | 297.0  | 185.7  | 11.8   | 12.3   | 12.6   | 10.7   |

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   | 2015  | 2020  | 2022  | 2023  |
|---------------------|----------------------|---------|--------|-------|-------|-------|-------|
| Methanol prod.      | 1000 Sm <sup>3</sup> | 145,903 | 89,475 | 0     | 0     | 0     | 0     |
| Other org. chem.    | 1000 Sm <sup>3</sup> | 410     | 0      | 0     | 0     | 0     | 0     |
| Inorganic chem.     | 1000 Sm <sup>3</sup> | 8,314   | 7,465  | 5,765 | 6,521 | 6,471 | 5,393 |
| Rubber and Plastics | 1000 Sm <sup>3</sup> | 590     | 61     | 0     | 0     | 0     | 0     |
| Other               | 1000 Sm <sup>3</sup> | 0       | 0      | 411   | 2     | 0     | 0     |
| Total               | 1000 Sm <sup>3</sup> | 155,217 | 97,001 | 6,176 | 6,523 | 6,471 | 5,393 |
| Total               | TJ                   | 5,297   | 3,345  | 215   | 227   | 228   | 191   |

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 | 2000  | 2005  | 2010  | 2015  | 2020  | 2022 | 2023  |
|----------------------|------|------|------|-------|-------|-------|-------|-------|------|-------|
| Apparent consumption | kt   | 6.59 | 7.20 | 11.00 | 28.00 | 12.00 | 27.00 | 37.28 | 9.61 | 10.82 |
| Road transport       | kt   | 0.03 | 0.03 | 0.02  | 0.01  | 0.02  | 0.02  | 0.02  | 0.03 | 0.02  |
| IPPU                 | kt   | 6.56 | 7.17 | 10.98 | 27.90 | 11.98 | 26.98 | 37.26 | 9.58 | 10.80 |

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

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

A small portion of collected waste oils has also been incinerated (procedure R9) or reformed and then reused (procedure D10). We reported these emissions in waste sector under waste

incineration in submission 2010 for the first time. No other use of lubricants as a fuel has been recorded in Slovenia until now.

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

Stored CO<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 CRT tables. In 2022, a small amount of fuel oil, LPG, other kerosene, and white spirit was used, mostly for production of lacquers, paintings and other coatings. The same is valid also for bitumen which is used for road paving and for production of roofing material and during this process no GHG emissions are occurring.

### 3.2.4 Energy industries (CRT 1A1)

#### 3.2.4.1 Category description

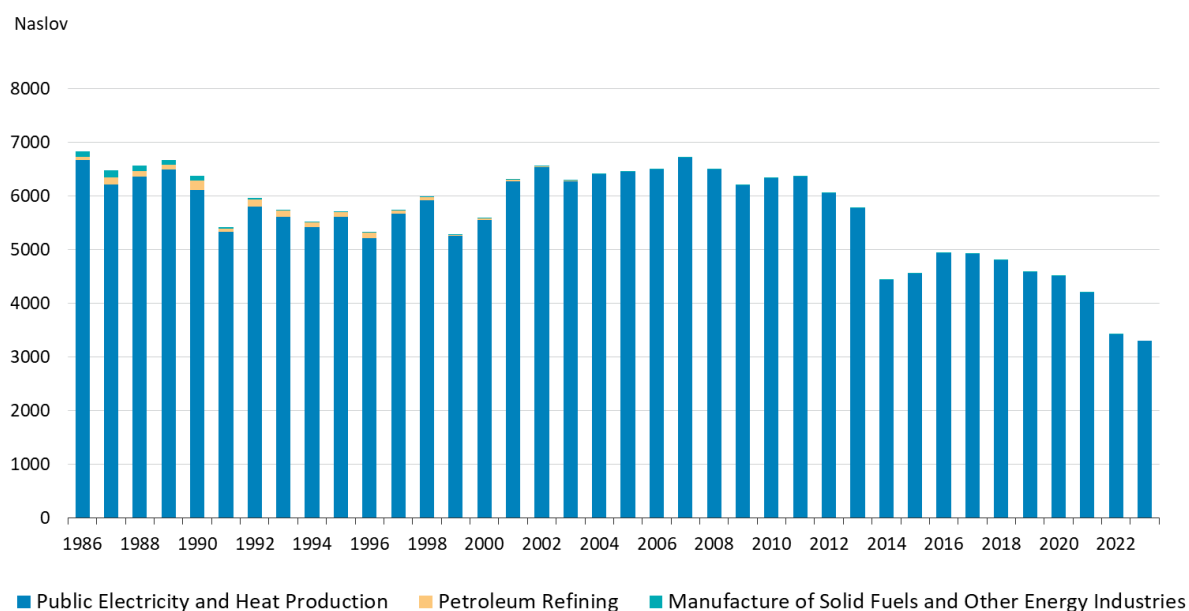
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

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

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

**Table 3.2.12: Method, EF used, and key categories indications for the year 2023 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,T2           | CS,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 100% share in 2023. 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  | 2000  | 2005  | 2010  | 2015  | 2020  | 2022  | 2023  |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <b>1. Energy Industries</b>                        | 6,840 | 6,374 | 5,593 | 6,449 | 6,347 | 4,567 | 4,517 | 3,420 | 3,310 |
| a. Public Electricity and Heat Production          | 6,670 | 6,121 | 5,561 | 6,448 | 6,332 | 4,561 | 4,517 | 3,419 | 3,310 |
| b. Petroleum Refining                              | 63    | 171   | 32    | 0     | 0     | 0     | 0     | 0     | 0     |
| c. Manufacture of Solid Fuels and Oth. Energy Ind. | 106   | 82    | 0.4   | 2     | 15    | 6     | 0     | 0     | 0     |

### 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 NID.

#### **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<br>(Velenje) | Sub-<br>bituminous<br>Coal -<br>domestic | Sub-<br>bituminous<br>Coal -<br>imported | Bitumin-<br>ous<br>Coal | Gas<br>Oil | Residual<br>Fuel Oil | LPG    | Natural<br>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 | 34.127         | 12.170 |
| 2006 | 11.132               | 10.880                                   | 18.874                                   |                         | 42.600     | 41.420               | 46.050 | 34.198         | 9.764  |
| 2007 | 11.259               | 11.763                                   | 18.275                                   |                         | 42.600     | 41.420               | 46.050 | 34.269         | 9.141  |
| 2008 | 10.949               | 11.654                                   | 17.714                                   |                         | 42.600     | 41.420               | 46.050 | 34.340         | 11.512 |
| 2009 | 10.894               | 11.094                                   | 17.872                                   | 28.612                  | 42.600     | 41.420               | 46.050 | 34.411         | 11.128 |
| 2010 | 11.097               | 12.815                                   | 18.130                                   | 28.271                  | 42.600     | 41.420               | 46.050 | 34.481         | 9.871  |
| 2011 | 11.051               | 11.935                                   | 18.428                                   | 28.251                  | 42.600     | 41.420               | 46.050 | 34.552         | 10.267 |
| 2012 | 10.604               | 11.778                                   | 18.524                                   | 26.140                  | 42.600     | 41.420               | 46.050 | 34.623         | 10.560 |
| 2013 | 11.591               | 11.946                                   | 18.457                                   | 25.180                  | 42.600     | 41.420               | 46.050 | 34.694         | 10.262 |
| 2014 | 10.823               | 11.727                                   | 18.655                                   | 26.590                  | 42.600     | 41.420               | 46.050 | 34.758         | 10.510 |
| 2015 | 11.418               | -  | 18.629                                   | 25.800                  | 42.600     | -                    | 46.050 | 34.805         | 10.474 |
| 2016 | 11.733               | -  | 18.595                                   | 25.898                  | 42.600     | -                    | 46.050 | 34.851         | 10.519 |
| 2017 | 11.640               | -  | 18.230                                   | 26.293                  | 42.600     | -                    | 46.050 | 34.789         | 10.706 |
| 2018 | 11.521               | -  | 18.238                                   | 25.800                  | 42.600     | -                    | 46.050 | 34.820         | 10.583 |
| 2019 | 11.716               | -  | 18.247                                   | 25.800                  | 42.600     | -                    | 46.050 | 34.851         | 10.502 |
| 2020 | 11.329               | -  | 17.929                                   | 25.800                  | 42.600     | -                    | 46.050 | 34.850         | 10.608 |
| 2021 | 11.447               | -  | 17.881                                   | -                       | 42.600     | -                    | 46.050 | 34.855         | 10.083 |
| 2022 | 11.689               | -  | 18.033                                   | -                       | 42.600     | -                    | 46.050 | 35.184         | 9.770  |
| 2023 | 11.586               | -  | 17.843                                   | -                       | 42.600     | -                    | 46.050 | 35.506         | 10.802 |



### **Emission factors**

For coal, LPG, 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 1986-2023 are presented.

**Table 3.2.15: EFs used for the period 1986-2023**

|                          | 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 | NID, Tables: 3.2.1, 3.2.17-20 | 74.1    | 77.4              | 64.7   | NID, 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 (CRT 1A1a)**

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

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

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

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

**Solid fuels**

Since 2005 all public power plants are included into ETS and therefore plant specific CO<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 |
|                         | 2021   | 2022   | 2023   | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  |
| <b>Oxidation factor</b> | 0.9974 | 0.9954 | 0.9967 |       |       |       |       |       |       |       |

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  | 97.383 | 96.928 | 96.953 |        |

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

**Table 3.2.21: Plant specific CO<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   | 2015-2020 |
|----------------|-----------------------|--------|--------|--------|--------|--------|--------|-----------|
| 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 (CRT 1A1b)**

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

### **Activity data**

Data on the consumption of fuels in this sector for the period 1986-2004 have been collected in LEG – Annual Energy Statistics of the Energy Sector of the Republic of Slovenia:

for the period 1986-1996 under „Oil Industry”

From 1997 – 2004 under „DF–Production of coke, refined petroleum products and nuclear fuel”

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

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

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

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

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

#### **Activity data**

The consumptions according to individual energy products are collected in the LEG tables as follows:

For the period 1986-1996 under „Coal-mining”

From 1997 onwards under „CA–Production of energy commodities”

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

Since 2004, data are available in the excel files from SORS (E\_PE-M YYYY.xls).

In the period 2004 -2007 according to the old SKD classification the following SKD categories have been included in this CRT category:

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

Since 2008, the new SKD\_2008 classification has been used and the following categories have been included in this CRT category:

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

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

### **3.2.4.3 Uncertainty and time–series consistency**

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

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

**Table 3.2.22: Uncertainties of activity data and emission factors as used in the 2025 submission for the base year and the last reporting year.**

|         | 1986 |                    |                    |                     | 2023 |                    |                    |                     |
|---------|------|--------------------|--------------------|---------------------|------|--------------------|--------------------|---------------------|
|         | 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 2005-2022.**

|                    | <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.2 Energy industries, Gaseous fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O have been recalculated for the period 2005-2022 due to the use of NCV values for natural gas from natural gas provider instead of SORS data. In addition CO<sub>2</sub> EF have been also slightly improved. Until 2021 recalculations was very minor.

#### 1.A.1.a Public electricity and heat production, Liquid fuels, CO<sub>2</sub>

In present submission we have started to use country specific CO<sub>2</sub> EF for LPG instead of default value. Recalculation of emissions affected all years in the period 1986-2022, if the LPG has been used. For category 1A1a Public electricity and heat production these years were 1997- 2006 and 2010 – 2022.

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

No improvement is planned for this category.

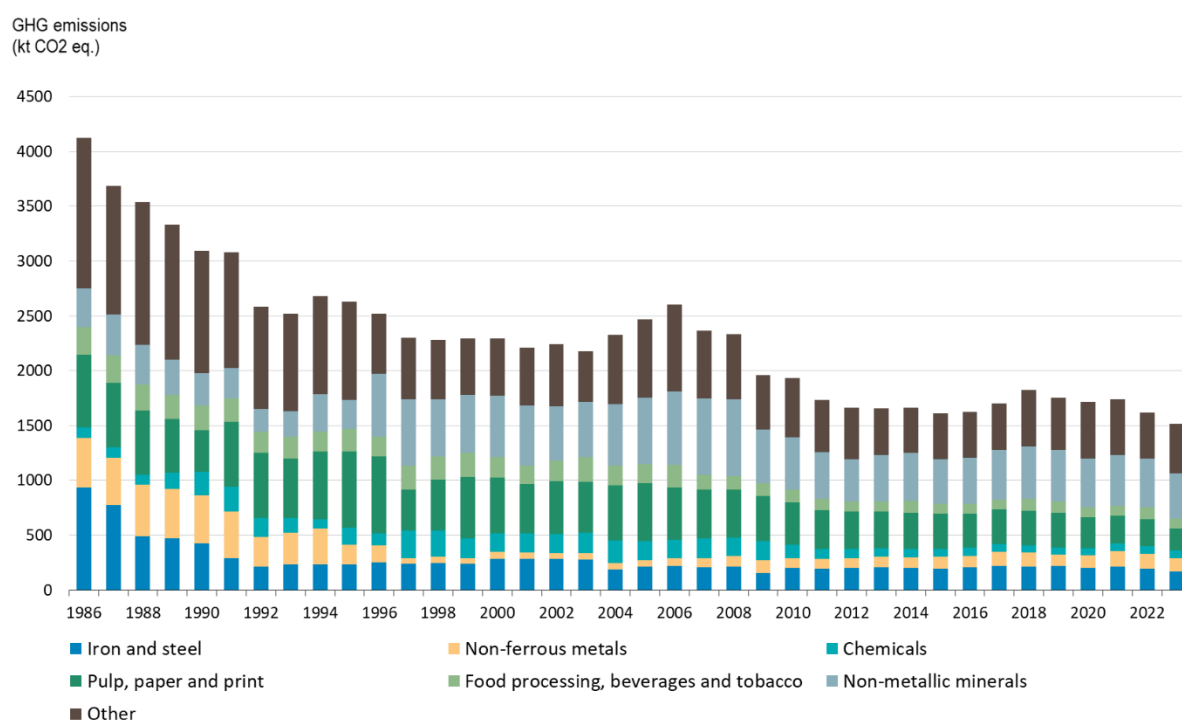
## 3.2.5 Manufacturing Industries and Construction (CRT 1A2)

### 3.2.5.1 Category description

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

**Table 3.2.24: Method, EF used and key categories indications for the year 2023.**

|           | 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,T2           | CS,D  | L, T         | T1              | D  | -            | T1               | D  | -            |
| gaseous   | T2              | CS    | L            | 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

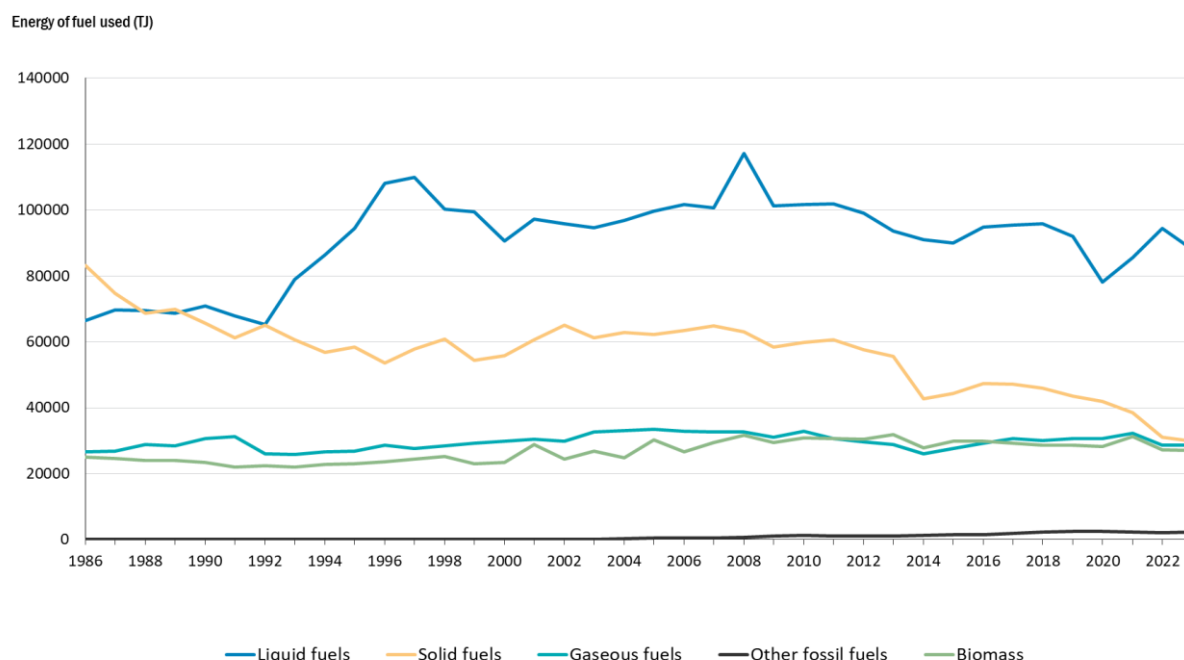


the global financial crisis, emissions from Manufacturing industry and construction decreased in 2009 by 15.6%. In the following years the emissions have further decreased and altogether in the 2015 due to the economic crises emissions from manufacturing industries and construction were lower by 31.3% from emissions in 2008. Due to the economic recovery in the last years emissions started to increase again until 2018 and since then stabilisation of emissions is observed. However in 2022 emissions decreased by 7.3%. In the period 1986 to 2023 emissions from this sector decreased by 63.2%.

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

|  | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|--|------|------|------|------|------|------|------|------|------|
| <b>2. Manufacturing Ind. and Constr.</b> | 4126 | 3096 | 2294 | 2466 | 1934 | 1611 | 1713 | 1620 | 1517 |
| <b>a. Iron and Steel</b>                 | 937  | 424  | 284  | 211  | 201  | 196  | 199  | 194  | 168  |
| <b>b. Non-Ferrous Metals</b>             | 449  | 442  | 63   | 62   | 90   | 107  | 118  | 133  | 121  |
| <b>c. Chemicals</b>                      | 100  | 211  | 171  | 173  | 121  | 74   | 67   | 75   | 71   |
| <b>d. Pulp, Paper and Print</b>          | 662  | 383  | 509  | 528  | 390  | 318  | 279  | 244  | 200  |
| <b>e. Food Processing, Bev. and Tob.</b> | 251  | 222  | 183  | 175  | 112  | 91   | 92   | 107  | 92   |
| <b>f. Non-metallic minerals</b>          | 355  | 298  | 561  | 604  | 478  | 406  | 440  | 445  | 413  |
| <b>g. Other - stationary</b>             | 1214 | 982  | 366  | 565  | 434  | 336  | 414  | 304  | 349  |
| <b>g. Other – off road</b>               | 157  | 134  | 157  | 147  | 107  | 84   | 102  | 119  | 103  |

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 CRT**

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

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

#### **PERIOD 1997-2003**

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

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

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

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

#### YEARS 2004 - 2007

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

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

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

YEARS since 2008

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

| CRT category   | Description  |
|--|--|
| 1.A.2.a<br>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<br>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<br>Chemicals                                 | C 20 Manufacture of chemicals and chemical products  |
| 1.A.2.d<br>Pulp, Paper and Print                     | C 17 Manufacture of paper and paper products   |
|  | C 18 Printing and reproduction of recorded media   |
| 1.A.2.e<br>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<br>Non-metallic Minerals                     | C 23 Manufacture of other non-metallic mineral products  |
| 1.A.2.g.vii<br>Off road vehicles and other machinery | F Construction (only gasoline and diesel fuel)<br>B and C – only consumption of gasoline and gas/diesel oil                          |
| 1.A.2.g.viii<br>Other                                | B07, B08, B09 except B09.1 – Mining and quarrying  |
|  | C 13 Manufacture of textiles   |
|  | C 14 Manufacture of wearing apparel  |
|  | C 15 Manufacture of leather and related products   |
|  | C 16 Manufacture of wood and of products of wood and cork, except furniture, manufacture of articles of straw and plaiting materials |
|  | C 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations  |
|  | C 22 Manufacture of rubber and plastic products  |
|  | C 25 Manufacture of metallic products  |
|  | C 26 Production of electrical and optical equipment  |
|  | C 27 Production of electrical equipment  |
|  | C 28 Production of machines and devices  |
|  | C 29 Production of vehicles  |
|  | C 30 Production of vessels   |
|  | C 31 Production of furniture   |
|  | C 32 Other manufacturing   |
|  | C 33 Repair and installation of machinery and equipment  |
|  | F Construction (all other fuels except diesel and gasoline)  |

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

### **Net calorific values**

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

| Year | Lignite – domestic (Velenje) | Sub-bituminous Coal - domestic | Lignite - imported | Sub-bituminous Coal - imported | Other Bituminous Coal | Anthracite | Coke   | Petroleum coke |
|------|------------------------------|--------------------------------|--------------------|--------------------------------|-----------------------|------------|--------|----------------|
|      | TJ/kt                        | TJ/kt                          | TJ/kt              | TJ/kt                          | TJ/kt                 | TJ/kt      | TJ/kt  | TJ/kt          |
| 1986 | 9.390                        | 11.880                         |                    |                                | 27.57                 | 29.25      | 29.30  | 31.000         |
| 1987 | 9.650                        | 11.820                         |                    |                                | 27.57                 | 29.25      | 29.30  | 31.000         |
| 1988 | 9.440                        | 12.000                         |                    |                                | 27.57                 | 29.25      | 29.30  | 31.000         |
| 1989 | 9.820                        | 12.050                         |                    |                                | 27.57                 | 29.25      | 29.30  | 31.000         |
| 1990 | 9.810                        | 12.760                         |                    |                                | 27.57                 | 29.25      | 29.30  | 31.000         |
| 1991 | 9.980                        | 12.879                         |                    |                                | 25.00                 | 29.25      | 29.30  | 31.000         |
| 1992 | 10.260                       | 12.589                         |                    |                                | 25.00                 | 29.25      | 29.30  | 31.000         |
| 1993 | 10.070                       | 13.351                         |                    |                                | 25.00                 | 29.25      | 29.30  | 31.000         |
| 1994 | 9.960                        | 12.666                         |                    |                                | 25.00                 | 29.25      | 29.30  | 31.000         |
| 1995 | 10.220                       |                                |                    | 17.404                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 1996 | 9.690                        |                                |                    | 16.353                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 1997 | 9.610                        |                                |                    | 17.712                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 1998 | 10.010                       |                                |                    | 20.664                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 1999 | 9.690                        |                                |                    | 20.806                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 2000 | 10.170                       |                                |                    | 20.782                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 2001 | 10.660                       |                                |                    | 20.947                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 2002 | 10.350                       |                                |                    | 21.000                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 2003 | 10.138                       |                                |                    | 21.570                         | 25.00                 | 29.31      | 29.31  | 31.000         |
| 2004 | 10.301                       |                                |                    | 19.908                         |                       | 29.40      | 28.49  | 29.927         |
| 2005 |                              |                                |                    | 20.381                         | 25.15                 |            | 27.90  | 29.927         |
| 2006 |                              |                                |                    | 20.108                         | 25.77                 |            | 29.44  | 32.223         |
| 2007 |                              |                                |                    | 20.387                         | 24.46                 |            | 29.37  | 31.949         |
| 2008 |                              |                                |                    | 18.623                         | 24.31                 |            | 29.87  | 31.949         |
| 2009 |                              |                                | 10.078             | 17.972                         | 23.896                |            | 29.67  | 32.498         |
| 2010 |                              |                                | 9.763              | 16.325                         | 25.290                |            | 29.42  | 30.644         |
| 2011 |                              |                                | 10.717             | 15.138                         | 25.422                |            | 29.62  | 31.684         |
| 2012 |                              |                                | 10.159             | 18.847                         | 25.409                |            | 29.41  | 31.813         |
| 2013 |                              |                                | 10.085             | 19.224                         | 26.264                |            | 29.59  | 31.721         |
| 2014 |                              |                                | 9.837              | 19.047                         | 24.915                |            | 29.605 | 31.602         |
| 2015 |                              |                                | 9.885              | 18.890                         | 25.000                |            | 28.859 | 31.663         |
| 2016 |                              |                                | 9.327              | 19.194                         | 25.000                |            | 29.568 | 31.236         |
| 2017 |                              |                                |                    | 19.473                         | 25.000                |            | 29.609 | 31.264         |
| 2018 |                              |                                |                    | 18.839                         | 25.000                |            | 29.624 | 31.405         |
| 2019 |                              |                                |                    | 17.085                         | 24.599                |            | 30.483 | 31.348         |
| 2020 |                              |                                |                    | 17.666                         | 24.755                |            | 29.328 | 31.105         |
| 2021 |                              |                                |                    | 17.796                         | 25.001                |            | 29.355 | 31.090         |
| 2022 |                              |                                |                    | 17.818                         | 28.210                |            | 29.866 | 31.136         |
| 2023 |                              |                                |                    | 17.300                         | 27.545                |            | 29.349 | 31.249         |

**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 | 34.127      | 12.24 |
| 2006 | 42.60   | 41.42             | 42.70  | 43.08    | 46.05 | 34.198      | 12.18 |
| 2007 | 42.60   | 41.42             | 42.70  | 43.08    | 46.05 | 34.269      | 11.44 |
| 2008 | 42.60   | 41.42             | 42.70  | 43.85    | 46.05 | 34.340      | 11.18 |
| 2009 | 42.60   | 41.42             | 42.70  | 43.85    | 46.05 | 34.411      | 10.96 |
| 2010 | 42.60   | 41.42             | 42.70  | 43.85    | 46.05 | 34.481      | 10.77 |
| 2011 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.552      | 10.79 |
| 2012 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.623      | 10.41 |
| 2013 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.694      | 10.58 |
| 2014 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.758      | 11.57 |
| 2015 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.805      | 11.46 |
| 2016 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.851      | 11.10 |
| 2017 | 42.60   | 41.42             | 42.60  | 43.85    | 46.05 | 34.789      | 11.46 |
| 2018 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 34.820      | 11.55 |
| 2019 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 34.851      | 11.58 |
| 2020 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 34.850      | 11.59 |
| 2021 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 34.855      | 10.27 |
| 2022 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 35.184      | 11.20 |
| 2023 | 42.60   |                   | 42.60  | 43.85    | 46.05 | 35.506      | 11.20 |

Table 3.2.30 presents the net calorific values (NCV) which have been used for solid fuels and petroleum coke combusted in the manufacturing industries. In the past they have been mostly taken from SORS while since 2005 the ETS data are used, if available. The plant specific data for 2023 for solid fuels are presented in the Table 3.2.32. The values for liquid

fuels excluding petrol coke and for natural gas and biomass have been taken from SORS for the entire period (Table 3.2.31).

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

| Industry              | Unit  | Sub-bituminous Coal - imported | Other Bituminous Coal | Coke   | Petroleum coke |
|-----------------------|-------|--------------------------------|-----------------------|--------|----------------|
| Iron and steel        | TJ/kt |                                |                       | 29.866 |                |
| Non-Ferrous metals    | TJ/kt |                                | 27.545                |        |                |
| Chemicals             | TJ/kt |                                |                       |        | 33.178         |
| Pulp, Paper and Print | TJ/kt | 17.300                         |                       |        | 33.178         |
| Non-metallic minerals | TJ/kt |                                |                       | 29.300 | 31.220         |

### **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 2023 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 and petroleum coke in manufacturing industry in 2023.**

|                       | Unit | Sub-bituminous<br>Coal - imported | Other<br>Bituminous<br>Coal | Petroleum<br>Coke |
|-----------------------|------|-----------------------------------|-----------------------------|-------------------|
| Pulp, Paper and Print | t/TJ | 100.297                           | -                           | 80.849            |
| Non-metallic minerals | t/TJ |                                   | -                           | 95.705            |

**Other fuels**

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

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

|       | waste<br>industrial<br>oils | waste<br>cooking<br>fat | Waste<br>solvents | waste<br>tyres | other<br>waste | waste<br>biomass | waste<br>cooking<br>oils | Black<br>liquor | Fibrous<br>sludge |
|-------|-----------------------------|-------------------------|-------------------|----------------|----------------|------------------|--------------------------|-----------------|-------------------|
| until | TJ/kt                       | TJ/kt                   | TJ/kt             | TJ/kt          | TJ/kt          | TJ/kt            | TJ/kt                    | TJ/kt           | TJ/kt             |
| 2000  | 37.00                       |                         |                   | 27.21          | 11.00          |                  |                          | 6.4             |                   |
| 2001  | 37.00                       | 39.20                   |                   | 27.21          | 11.00          |                  |                          | 6.4             |                   |
| 2002  | 37.00                       | 39.20                   |                   | 27.21          | 11.00          |                  |                          | 6.4             |                   |
| 2003  | 37.00                       | 39.20                   |                   | 27.21          | 11.00          |                  |                          | 6.4             |                   |
| 2004  | 41.90                       | 40.41                   |                   | 27.21          |                |                  | 40.00                    | 6.4             |                   |
| 2005  | 34.64                       | 39.20                   |                   | 27.21          |                | 15.00            |                          | 6.43            |                   |
| 2006  | 34.53                       | 39.20                   | 25.00             | 27.21          |                | 15.00            |                          | 6.07            |                   |
| 2007  | 33.76                       | 39.95                   | 25.00             | 27.21          |                | 15.00            |                          |                 |                   |
| 2008  | 34.48                       | 39.81                   | 25.00             | 27.21          | 17.52          | 16.11            |                          |                 | 4.48              |
| 2009  | 37.65                       | 39.81                   | 25.00             | 27.19          | 26.67          | 15.14            |                          |                 | 3.88              |
| 2010  | 36.95                       | 39.20                   | 25.00             | 27.23          | 22.34          | 15.36            |                          |                 | 3.92              |
| 2011  | 36.25                       | 39.20                   | 25.00             | 27.26          | 19.52          | 13.78            |                          |                 | 3.86              |
| 2012  | 37.09                       | 39.20                   | 25.00             | 27.21          | 20.25          | 13.50            |                          |                 | 3.82              |
| 2013  | 37.13                       | 39.20                   | 25.00             | 27.21          | 19.44          | 12.74            |                          |                 | 3.55              |
| 2014  | 33.03                       | 39.20                   | 25.00             | 27.20          | 18.87          | 11.72            |                          |                 | 3.47              |
| 2015  | 35.495                      | 39.20                   | 25.00             | 27.20          | 19.32          | 12.14            |                          |                 | 3.55              |
| 2016  | 36.544                      | 39.20                   | 25.00             | 27.20          | 18.19          | 10.23            |                          |                 | 3.61              |
| 2017  | 35.342                      | 39.20                   | 25.00             | 27.20          | 16.90          | 12.79            |                          |                 | 3.48              |
| 2018  | 37.000                      |                         | 25.00             | 27.20          | 18.33          | 8.36             |                          |                 | 3.52              |
| 2019  | 37.373                      |                         | 25.00             | 27.20          | 19.11          | 15.0             |                          |                 | 3.56              |
| 2020  | 38.173                      |                         | 25.00             | 27.20          | 16.52          | 15.0             |                          |                 | 3.24              |
| 2021  | 39.319                      |                         | 25.00             | 27.20          | 16.24          | 15.0             |                          |                 | 3.34              |
| 2022  | 39.503                      |                         | 25.00             | 27.20          | 16.43          | 15.0             |                          |                 | 3.28              |
| 2023  |                             |                         | 25.00             | 27.20          | 16.02          | 15.0             |                          |                 | 3.63              |



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 |
|                       | 2021  | 2022  | 2023  |       |       |       |       |       |       |       |       |
| t CO <sub>2</sub> /TJ | 48.97 | 50.92 | 50.20 |       |       |       |       |       |       |       |       |

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   | 2021   | 2022   |
|--------------------|-----------------------|-------|-------|-------|-------|-------|-------|--------|--------|--------|
| 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 | 75.013 | 75.196 |

There was no combustion of waste oil in the cement plant in 2023.

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

In accordance with IPCC 2006 GL the item Industry reports the consumption of fuels in the group of industrial power plants (auto producers – enterprises that generate electric energy

for internal consumption and/or heat for sale) as well as other consumption in industry (except in production processes) .

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

#### Period 1986-2000

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

##### ➤ Lignite

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

##### ➤ Brown Coal

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

##### ➤ Residual Fuel Oil

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

##### ➤ Gas Oil and Natural Gas

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

#### Period 2000-2022

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

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

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

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

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

| Year                | Diesel  | Motor gasoline |
|---------------------|---------|----------------|
|                     | t/TJ    | t/TJ           |
| CO <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 2025 submission for the base year and the last reporting year in per cents**

|         | 1986 |                    |                    |                     | 2023 |                    |                    |                     |
|---------|------|--------------------|--------------------|---------------------|------|--------------------|--------------------|---------------------|
|         | 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, Gaseous fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O have been recalculated for the period 2005-2022 due to the use of NCV values for natural gas from natural gas provider instead of SORS data. In addition CO<sub>2</sub> EF have been also slightly improved. Until 2021 recalculations was very minor.

##### 1.A.2 Manufacturing industries, Liquid fuels, CO<sub>2</sub>,

In present submission we have started to use country specific CO<sub>2</sub> EF for LPG instead of default data. Recalculation of emissions affected all years in the period 1986-2022.

##### 1.A.2.b Non-ferrous Metals, Solid Fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions for the year 1993 have been slightly changed due to the error in NCV used for domestic brown coal. The calorific value is now in line with domestic brown coal used in the other industrial sectors.

##### 1.A.2.c Chemicals, Liquid Fuels, 1.A.2.d Pulp and Paper, Liquid Fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions for the years 2005 and 2007 have been slightly changed due to the error in NCV used for gas diesel oil and residual fuel oil in the previous submission. The calorific value is now in line with other industrial sectors.

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

No improvement is planned for these categories.

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

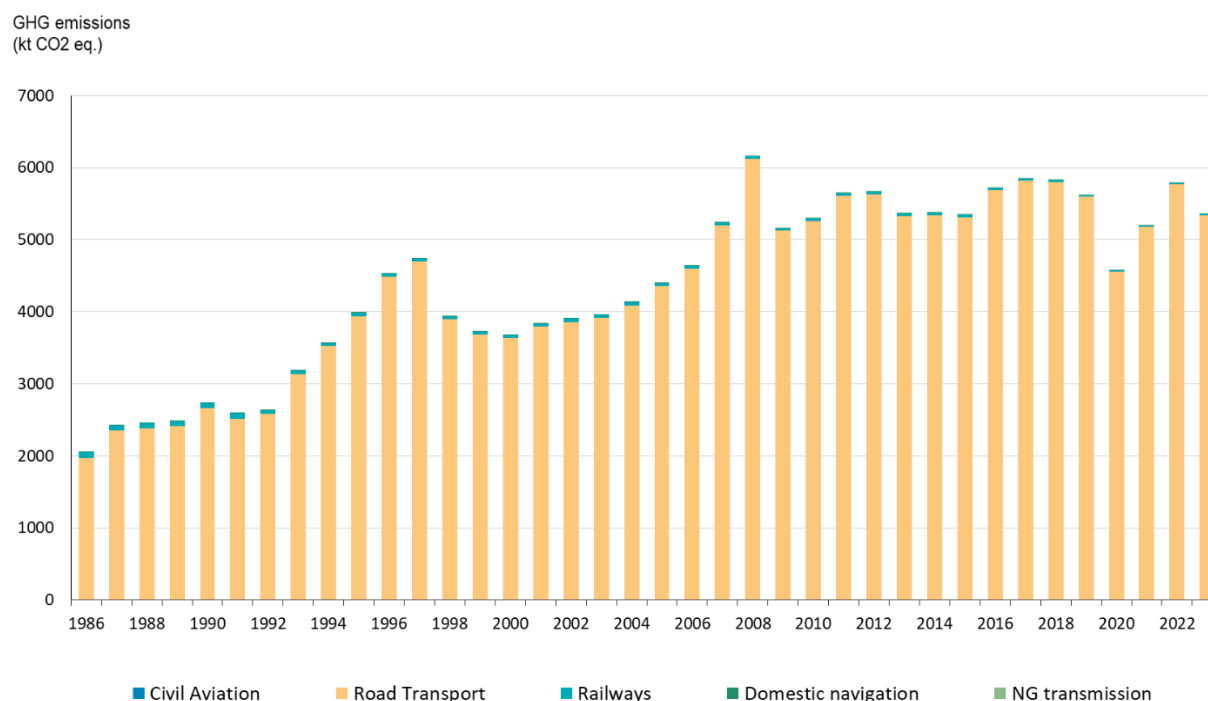
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

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

**Table 3.2.41: Method, EFs used for key categories for the year 2023 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 | -            |
| Gasoline       | Model           | Model | L,T          | Model           | Model | -            | Model            | Model | -            |

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, while in 2021 emissions are almost back on the pre-Covid level and in 2022 emissions increased by 11.3% compared to 2021 and are 182.5% higher as in the base year. However in 2023 emission decrease by 7.4% compared to the previous year.

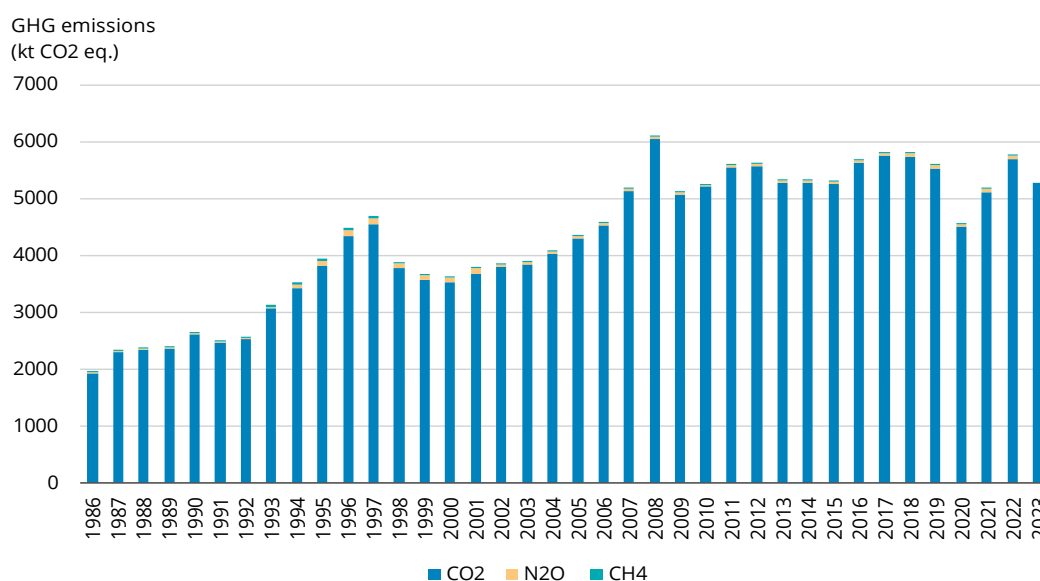
**Table 3.2.42: GHG emissions from Transport in kt CO<sub>2</sub> eq.**

|                        | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------|------|------|------|------|------|------|------|------|------|
| 3. Transport           | 2051 | 2737 | 3676 | 4402 | 5300 | 5354 | 4575 | 5793 | 5364 |
| a. Civil Aviation      | 1    | 1    | 3    | 3    | 2    | 2    | 2    | 2    | 1    |
| b. Road Transportation | 1974 | 2664 | 3631 | 4357 | 5260 | 5308 | 4554 | 5768 | 5339 |
| c. Railways            | 76   | 72   | 42   | 41   | 33   | 41   | 19   | 23   | 24   |
| d. Domestic navigation | 0.01 | 0.01 | 0.01 | 0.03 | 0.04 | 0.04 | 0.09 | 0.05 | 0.01 |
| e. NG transmission     | 0    | 0    | 0    | 0    | 4    | 3    | 1    | 0.5  | 0.1  |

### 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.

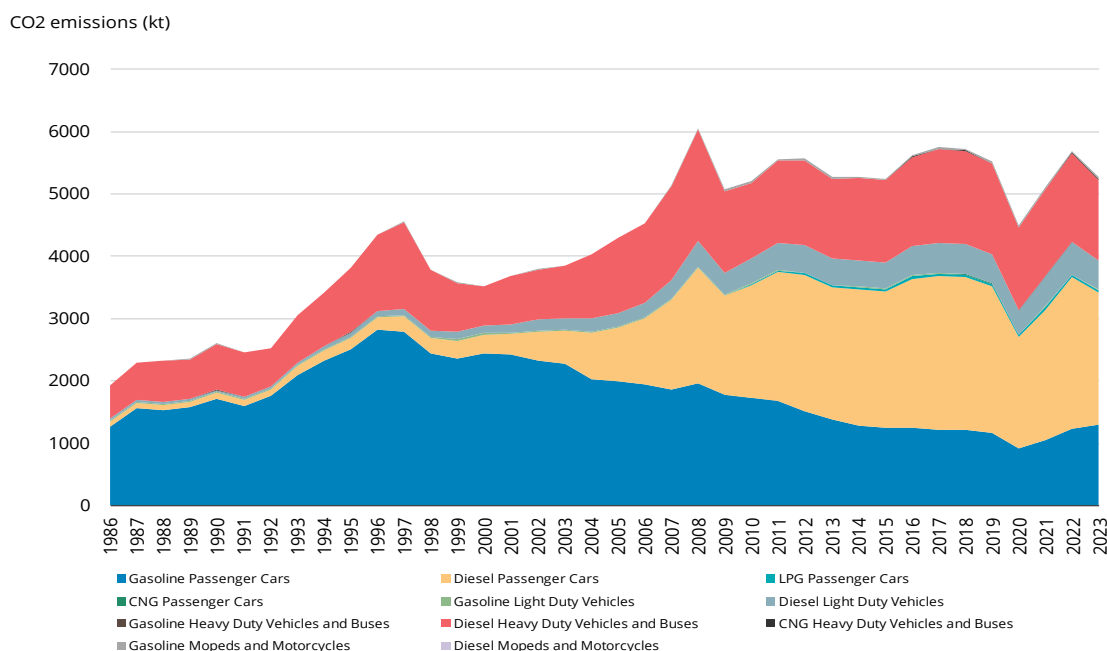


**Figure 3.2.8: CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> emissions for road transport 1986–2023.**

From 1986 to 2023 the road transport emissions of CO<sub>2</sub> and N<sub>2</sub>O increased by 173% and 164%, respectively. Emissions of CH<sub>4</sub> have decreased by 82%. Due to the world economic crises and consecutively smaller fuel consumption emissions of all GHG considerably decreased in 2009. Another huge drop in all GHG emissions occurred in 2020 due to the Covid-19 pandemic crisis. Lockdown measures and reduced mobility caused a drastic decline in emissions. In 2021 the sale of fuel was on the rise again and consequently, emissions increased. The impact of measures for handling the Covid-19 pandemic was just temporary. The same trend was observed in 2022 as well. In 2023 emissions decreased due to lower sales of diesel fuel.

Referring to the fifth IPCC assessment report, 1 g CH<sub>4</sub> and 1 g N<sub>2</sub>O have the greenhouse effect of 28 and 265 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).

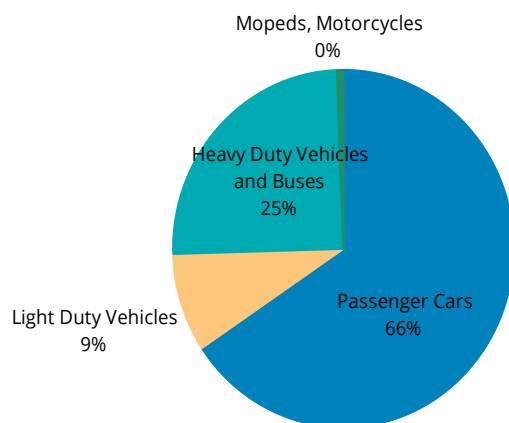
Due to the direct dependency of CO<sub>2</sub> emissions on fuel consumption, the total growth in CO<sub>2</sub> emissions reflects the trend of increased fuel consumption till 2008. In 2009 and 2020 significant drops in CO<sub>2</sub> emissions occurred due to the smaller fuel consumption due to the economic crisis and a Covid-19 pandemic crisis. In 2021 a drastic increase in CO<sub>2</sub> emissions is shown due to the release of Covid-19 measures. The same trend was observed also in 2022. In 2023 emissions decreased due to lower sales of diesel fuel. As shown in Figures 3.2.9 and 3.2.10, the most important emission source for road transport is passenger cars, followed by heavy duty vehicles and buses, light duty vehicles and mopeds and motorcycles in decreasing order. In 2023, the emission shares were about 66, 25, 9 and below 1 %, respectively.



**Figure 3.2.9: CO<sub>2</sub> emissions (kt) per vehicle type for road transport 1986–2023.**

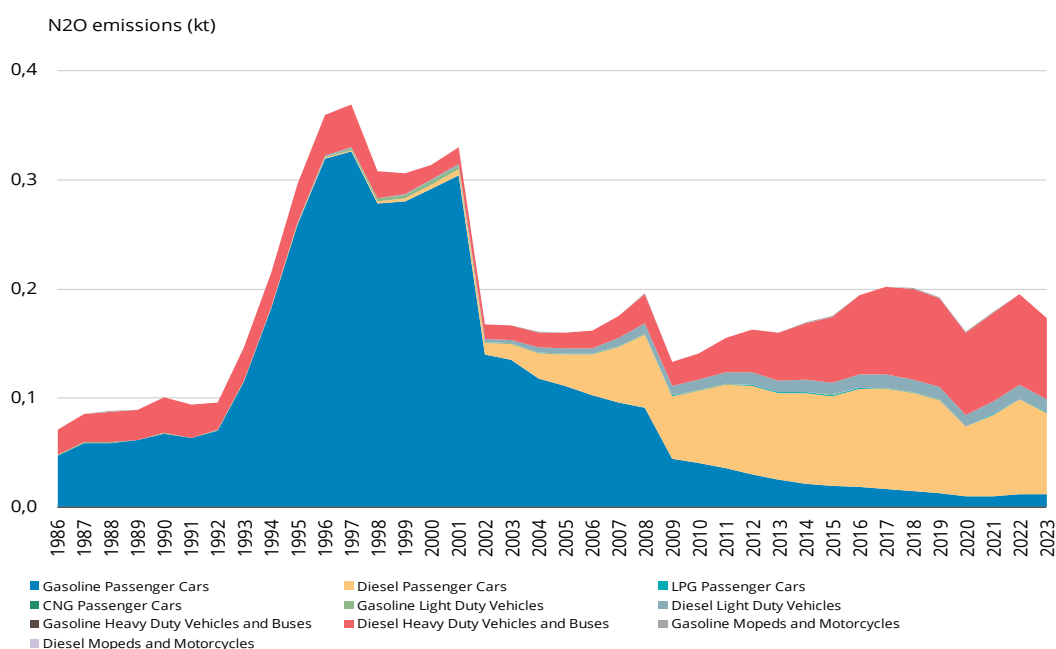
CO<sub>2</sub> emissions of passenger cars were gradually increasing from 1991 to 1996 mainly due to the fuel being sold to foreigners as a consequence of the lower fuel prices in Slovenia.

From 2000 onwards an extensive switch from petrol powered to diesel powered cars could be observed. In 2019 diesel cars prevailed petrol cars. The better energy efficiency of diesel cars and a general improvement in fuel efficiency for all new vehicles diminished a considerable increase in fuel consumption which led to a slower increase of CO<sub>2</sub> emissions in this period.



**Figure 3.2.10: CO<sub>2</sub> emission share per vehicle type for road transport for 2023.**

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 2023 CO<sub>2</sub> emissions from lube oil in two-stroke engines represent only 0.001% of total CO<sub>2</sub> emissions from road transportation.



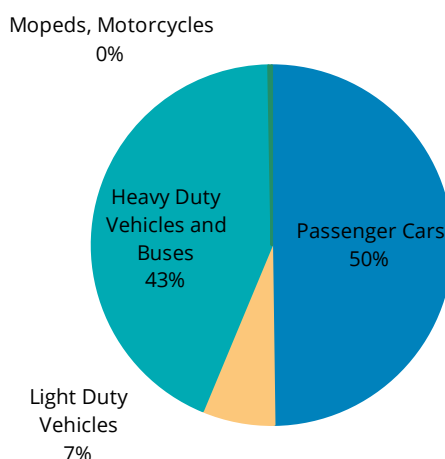
**Figure 3.2.11: N<sub>2</sub>O emissions (kt) per vehicle type for road transport 1986–2023.**



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.

An undesirable environmental side effect of the introduction of catalyst cars is the increase in the emissions of N<sub>2</sub>O. N<sub>2</sub>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 N<sub>2</sub>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 N<sub>2</sub>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.

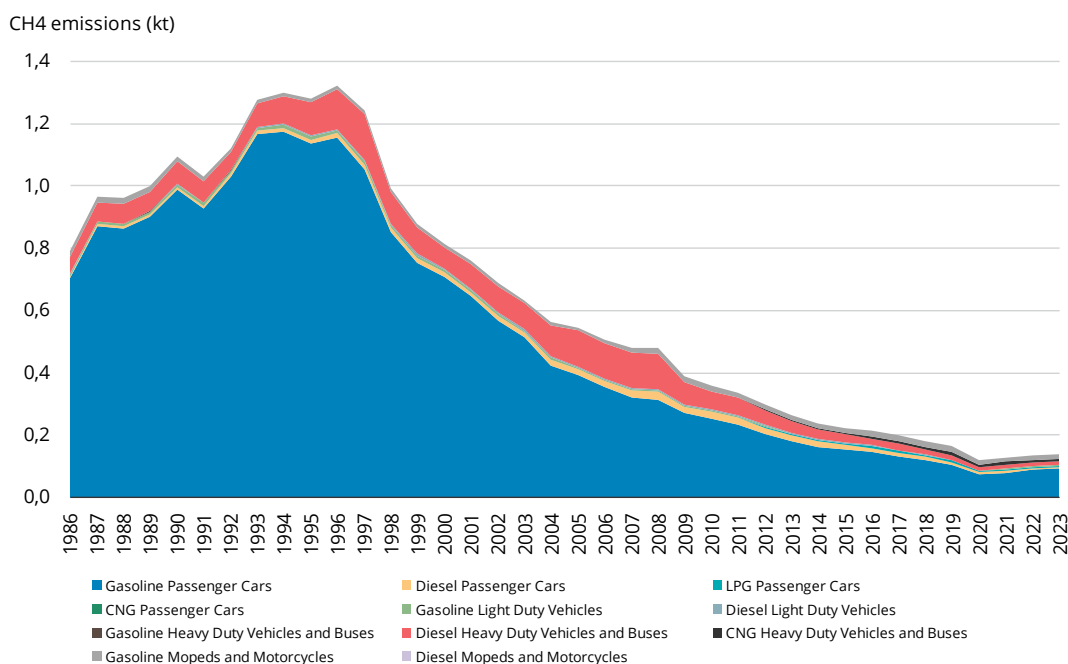
In 2023 emission shares for passenger cars were 50% and heavy duty vehicles and buses 43%. Light duty vehicles contributed 7% to the total road transport N<sub>2</sub>O. N<sub>2</sub>O emissions from mopeds and motorcycles are negligible (Figures 3.2.11 and 3.2.12).



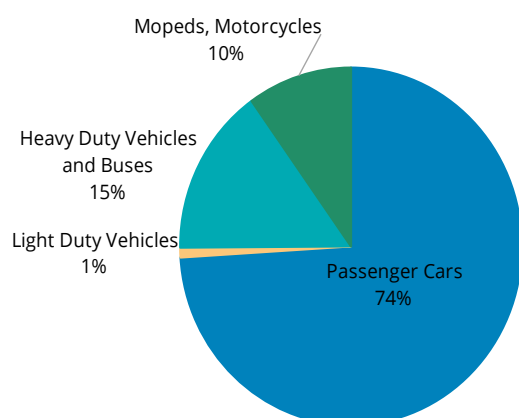
**Figure 3.2.12: N<sub>2</sub>O emission share per vehicle type for road transport for 2023.**

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 2023 emission shares for CH<sub>4</sub> were about 74, 15, 10 and 1% for passenger cars, heavy duty vehicles and buses, mopeds and motorcycles and light duty vehicles, respectively (Figures 3.2.13 and 3.2.14).



**Figure 3.2.13: CH<sub>4</sub> emissions (kt) per vehicle type for road transport 1986–2023.**



**Figure 3.2.14: CH<sub>4</sub> emission share per vehicle type for road transport for 2023.**

### **Methodological issues**

COPERT 5 (version 5.8.1) methodology has been used for the calculation of the national greenhouse gas emissions from road transport for the entire 1986-2023 period. The methodology is fully incorporated in the computer software program COPERT 5 (version 5.8.1) which facilitates its application. The actual calculations have been therefore performed by using this computer software.

COPERT 5 estimates the emissions of greenhouse gas emissions (CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>) as well as all major air pollutants (SO<sub>x</sub>, NO<sub>x</sub>, CO, NMVOC, NH<sub>3</sub>, particulate matter, persistent organic

pollutants and heavy metals) by the different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles and buses, mopeds and motorcycles). The emissions estimated are divided among the three sources: emissions produced during thermally stabilized engine operation (hot emissions), emissions occurring during engine start from ambient temperature (cold-start and warming-up effects) and NMVOC emissions due to a fuel evaporation. The total emissions are calculated as a product of the activity data provided by the user and speed-dependent emission factors calculated by the software.

COPERT 5 also provides CO<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. The COPERT methodology is fully consistent with the Road Transport chapter of the EMEP/EEA air pollutant emission inventory guidebook. The use of a software tool to calculate road transport emissions allows for a transparent and standardized, hence consistent and comparable data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and the EU legislation.

The applied methodology is fully described in the following literature:

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

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

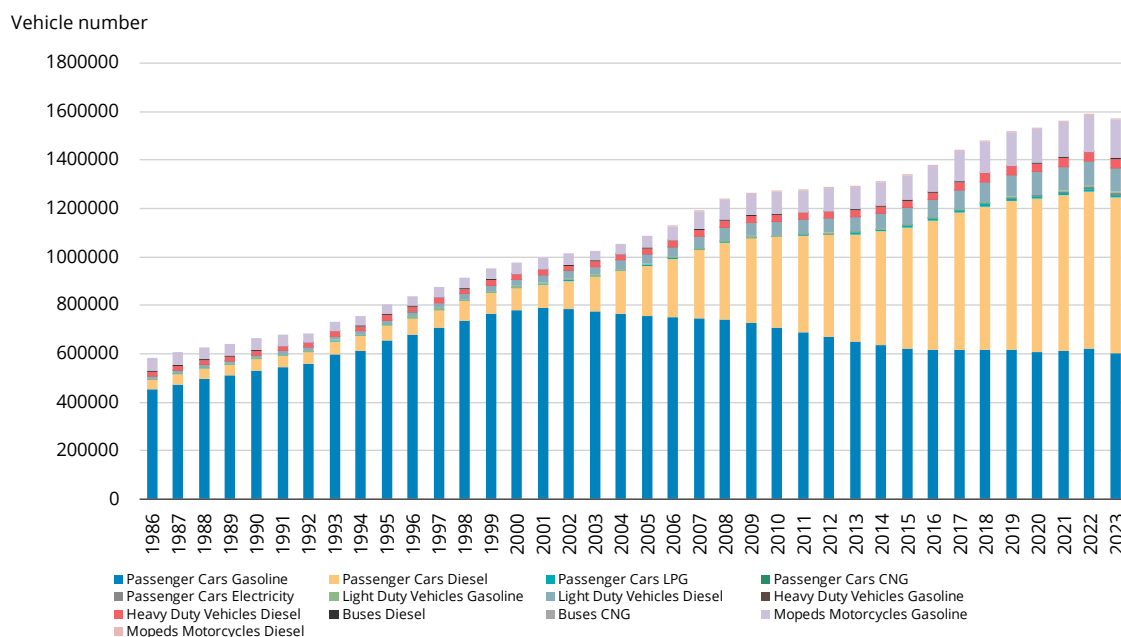
### **Activity data**

#### **Vehicle fleet**

The COPERT 5 methodology requires detailed knowledge of the structure of the vehicle fleet composition. The vehicle numbers per all vehicle classes for the period 1986–2023 are shown in Annex 3: Road transport: Fleet data (number of vehicles) 1986–2023.

The fleet composition for the years 1992–2023 was taken from the official database of registered motor and trailer vehicles in the Republic of Slovenia. Until 2009 data were provided by the Ministry of the Interior. Since 2010, those data have been collected by the Ministry of Infrastructure of the Republic of Slovenia. Since no database exists on licensed motor and trailer vehicles in the Republic of Slovenia for the years 1986–1991, an expert

estimate has been made on the basis of the annual Statistical Yearbooks, published by the Statistical Office of the Republic of Slovenia (SORS).



**Figure 3.2.15: Vehicle fleet 1986–2023.**

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

### Mileage

Annual mileage (km/year) for each vehicle category for 2015–2023 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 1986–2023.

### 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 1986–2023.

### Fuel Consumption

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

Figure 3.2.16 shows the total fuel consumption in road transport. Diesel, gasoline, LPG, CNG and electricity have been used as fuels in road transportation. The fuel consumption began to grow markedly during the years 1991–1997 due to fuel being sold to foreigners as a consequence of the lower fuel prices in Slovenia. During the years 2000–2008 an extensive growth in usage of diesel fuel can be observed. The transit of heavy duty trucks has been an important factor for the increase in diesel consumption. In the year 2005, the sale of diesel exceeded the sale of gasoline. In 2009, a significant decline in gasoline and diesel consumption appeared. In comparison with the year 2008, consumption of gasoline dropped by 9% and diesel by 20%. The lower consumption of fuel was due to the world economic crisis. Another huge drop in fuel consumption is seen in 2020. In comparison with the year 2019, consumption of gasoline dropped by 21% and diesel by 18%. Lower fuel consumption was due to reduced mobility as a consequence of the Covid-19 pandemic lockdown measures. In 2021 the sale of fuel was on the rise again due to the release of Covid-19 measures. The same trend was observed also in 2022. In 2023 emissions decreased due to lower sales of diesel fuel. In 2023, the fuel use shares for diesel and gasoline were about 76% and 23%, respectively. The share of LPG was about 0.6% and CNG only 0.3%. Consumption of LPG was reported for the first time in 2006. It has been used by passenger cars. CNG was reported for the first time in 2012 and has been applied by passenger cars and busses. Electric passenger cars were introduced in 2010.

Fuel consumption (TJ)

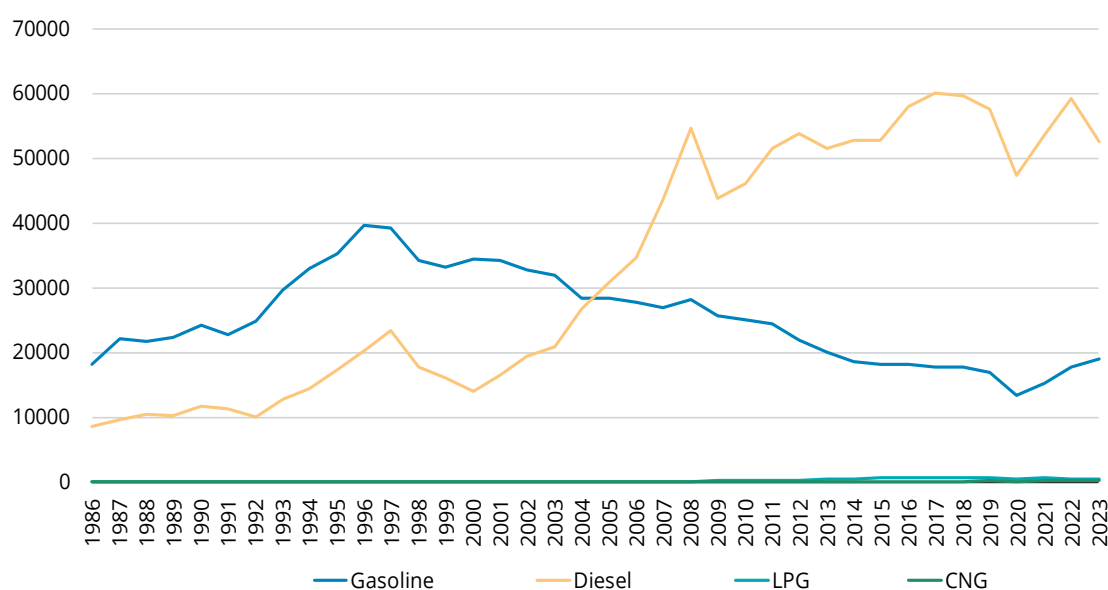
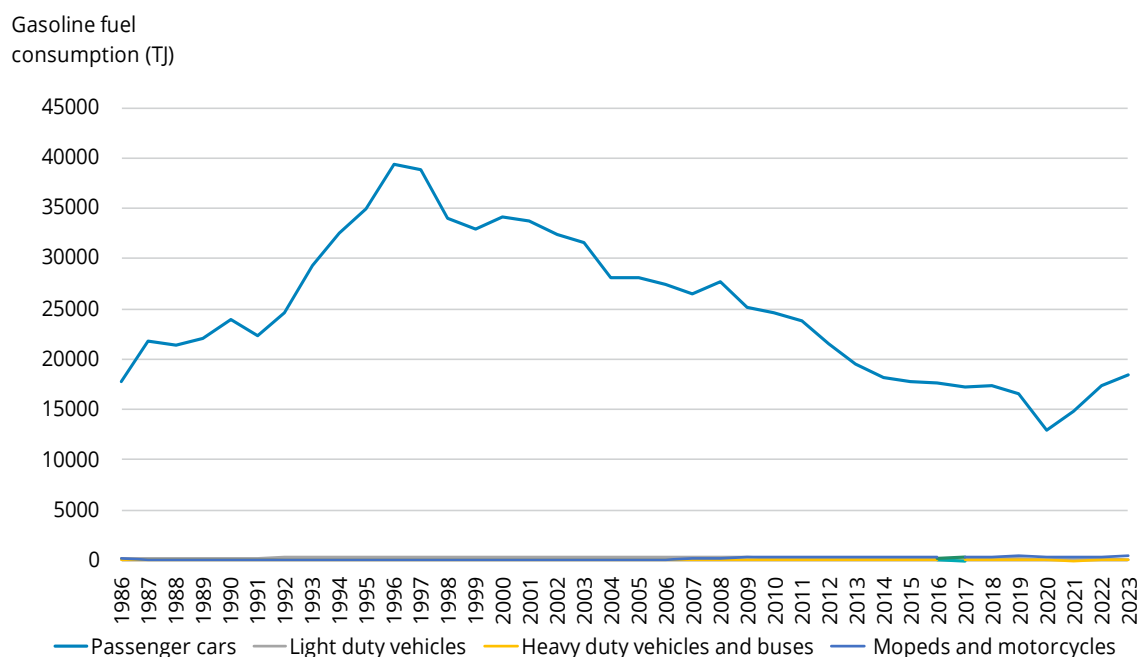
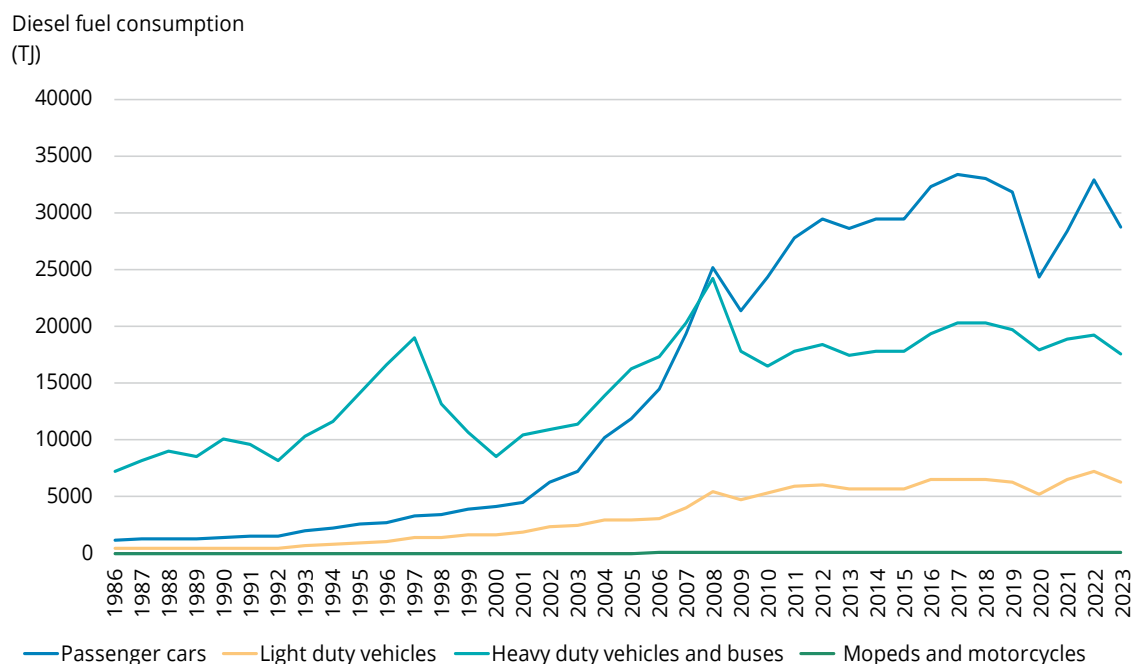


Figure 3.2.16: Fuel consumption in road transport for 1986–2023.



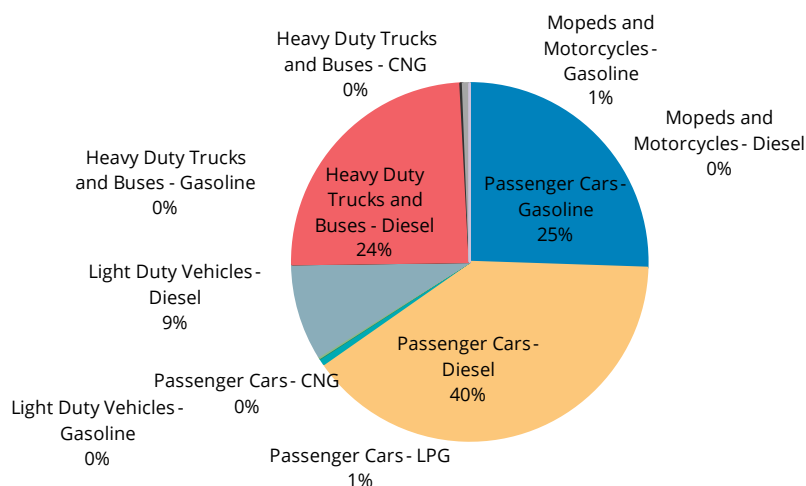
**Figure 3.2.17: Gasoline fuel consumption per vehicle type for road transport 1986–2023.**

As shown in Figures 3.2.17 and 3.2.18, the passenger cars represent the most fuel-consuming vehicle category, followed by heavy duty vehicles and buses, light duty vehicles, mopeds and motorcycles, in decreasing order. Passenger cars dominate the overall gasoline consumption trend. The development in diesel fuel consumption in recent years is characterised by an increasing fuel use for diesel passenger cars and heavy duty trucks, while the fuel use for light duty vehicles and mopeds and motorcycles is less distinctive. To meet the data quality objective of transparency, the fuel consumption by types of vehicles is shown in Annex 3: Road transport: Fuel Consumption by types of vehicles 1986–2023.



**Figure 3.2.18: Diesel fuel consumption per vehicle type for road transport 1986–2023.**

In 2023 the fuel consumption shares for diesel passenger cars, gasoline passenger cars, diesel heavy duty vehicles and buses were about 40, 25 and 24%, respectively (Figure 3.2.19).



**Figure 3.2.19: Fuel consumption share per vehicle type for road transport in 2023.**

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

Fuel Characteristics

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

**Table 3.2.43: Levels of lead content in gasoline.**

| Fuel              | Period    | Lead [g/l] |
|-------------------|-----------|------------|
| Gasoline Leaded   | 1986-1994 | 0.6        |
|                   | 1995      | 0.4        |
|                   | 1996-2001 | 0.15       |
| Gasoline Unleaded | 1986-1994 | 0.026      |
|                   | 1995-2001 | 0.013      |
|                   | 2002-2023 | 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          |
|                   | 2009-2023 | 0.001          |
| Diesel            | 1986-1994 | 1              |
|                   | 1995      | 0.25           |
|                   | 1996-2001 | 0.20           |
|                   | 2002-2004 | 0.035          |
|                   | 2005-2008 | 0.005          |
|                   | 2009-2023 | 0.001          |

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



Monthly minimum and maximum air temperatures

The meteorological data necessary for 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 5.8.1) program.

***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 2025 submission for the base year and the last reporting year in per cents.**

|            | 1986 and 2023 |                    |                    |                     |
|------------|---------------|--------------------|--------------------|---------------------|
|            | 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                  |

### **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 5.8.1) was used for emissions calculation for 2025 submission.

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

GHG emissions arising from biofuels were thoroughly examined as well. In contrast with COPERT 4, COPERT 5 enables disaggregation of the emissions from biomass among different vehicle types. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions reported in the CRT 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.

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

**Table 3.2.46: A comparison of CO<sub>2</sub> emissions factors for gasoline and diesel.**

|              | <b>gasoline</b>                | <b>diesel</b>                   |
|--------------|--------------------------------|---------------------------------|
|              | <b>g CO<sub>2</sub>/g fuel</b> | <b>g CO<sub>2</sub>/ g fuel</b> |
| Italy        | 3.152                          | 3.150                           |
| Austria      | 3.153                          | 3.153                           |
| Slovenia     | 3.096                          | 3.151                           |
| IPCC default | 3.070                          | 3.186                           |

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

However, NCVs for gasoline and diesel are not available in the NIRs of Italy and Austria, because they are not used for emission calculation. They are using EFs in g CO<sub>2</sub>/ g fuel and the same is valid also for Slovenian inventory. NCVs are used only to calculate energy of fuel for CRT reporting. The new NCVs will have no impact on GHG emissions from the road transport, and will not trigger any recalculations.

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

Recalculation of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions for the period 2000-2022 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.8.1) was used for emissions calculation.

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

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

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

#### 3.2.6.2.1 Category description

This chapter presents emissions of greenhouse gases in:

- Domestic Aviation (CRT 1A3a)
- Railways (CRT 1A3c)
- Domestic Navigation (CRT 1A3d)
- Other Transportation / Pipeline Transport (CRT 1A3e.i)

#### Domestic aviation

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

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

**Table 3.2.47: GHG Emissions from domestic aviation in the period 1986-2023.**

|                              | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------------|------|------|------|------|------|------|------|------|------|
| <b>Av. gasoline in TJ</b>    | 9    | 15   | 40   | 24   | 23   | 20   | 19   | 23   | 16   |
| <b>Jet kerosene in TJ</b>    | NO   | NO   | NO   | 15   | 4    | 8    | 3    | 1    | 1    |
| <b>Gg CO<sub>2</sub> eq.</b> | 0.6  | 1.1  | 2.8  | 2.7  | 2.0  | 2.0  | 1.6  | 1.7  | 1.2  |

#### 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. Since 2020 the steam locomotive has not been used any more. Fuel in TJ and GHG emissions from the railways are presented in table 3.2.48.

There was a strong increase in diesel consumption in 2014. The reason for this increase is a 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 3.2.48: GHG Emissions from railways in the period 1986-2023.**

|                              | 1986 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------------|------|------|------|------|------|------|------|------|------|------|
| <b>fuel in TJ</b>            | 931  | 879  | 588  | 514  | 505  | 403  | 498  | 231  | 286  | 288  |
| <b>Gg CO<sub>2</sub> eq.</b> | 76   | 72   | 48   | 42   | 41   | 33   | 41   | 19   | 23   | 24   |

#### Domestic navigation

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

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

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

#### Other transportation

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

**Table 3.2.49: GHG Emissions from compressor station in the period 1986-2023.**

|                              | 1986 - 2001 | 2002 - 2007 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------------|-------------|-------------|------|------|------|------|------|
| <b>fuel in TJ</b>            | NO          | IE          | 79   | 53   | 16   | 8    | 1    |
| <b>Gg CO<sub>2</sub> eq.</b> | NO          | IE          | 4.4  | 2.9  | 0.9  | 0.4  | 0.1  |

#### **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 2023 inventory are presented in table 3.2.50.

**Table 3.2.50: NCVs for fuel used in all other transportation in 2023.**

|     | Unit  | Aviation<br>Gasoline | Jet<br>kerosene | Gas/Diesel<br>Oil | Coal | Gasoline | Natural gas |
|-----|---|----------------------|-----------------|-------------------|------|----------|-------------|
| NCV | TJ/kt or TJ/<br>10 <sup>6</sup> Sm <sup>3</sup> | 43.54                | 43.54           | 42.6              | NO   | 43.85    | 35.506      |

### **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 3.2.51).

**Table 3.2.51: EFs for fuel used in all other transportations in the period 1986-2023.**

|                     | Unit                                  | Aviation<br>Gasoline | Jet<br>kerosene      | Gas/Diesel<br>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                | 0.05                 | 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<br>3.6.4 | IPCC, Table<br>3.6.4 | IPCC, Table<br>3.4.1              | IPCC, Table<br>2.2   | IPCC, Table<br>3.6.4 | CS                 |
| Source              | CH <sub>4</sub> ,<br>N <sub>2</sub> O | IPCC, Table<br>3.6.5 | IPCC, Table<br>3.6.5 | IPCC, Table<br>3.4.1 and<br>3.3.1 | IPCC, Table<br>3.4.1 | IPCC, Table<br>3.3.1 | IPCC, Table<br>2.4 |

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

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

#### **3.2.6.2.3 Uncertainty and time –series consistency**

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

**Table 3.2.52: Uncertainties of activity data and emission factors as used in the 2025 submission for the base year and the last reporting year in per cents.**

|                     | 1986 and 2023 |                    |                    |                     |
|---------------------|---------------|--------------------|--------------------|---------------------|
|                     | 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                 |

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

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

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

#### **3.2.6.2.5 Category-specific recalculations**

##### 1.A.3.e Other transportations, Gaseous fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O have been recalculated for the period 2008-2022 due to the use of NCV values for natural gas from natural gas provider instead of SORS data. In addition CO<sub>2</sub> EF have been also slightly improved. Until 2021 recalculations were very minor.

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

No improvement is planned for this category.

### 3.2.7 Other Sectors (CRT 1A4)

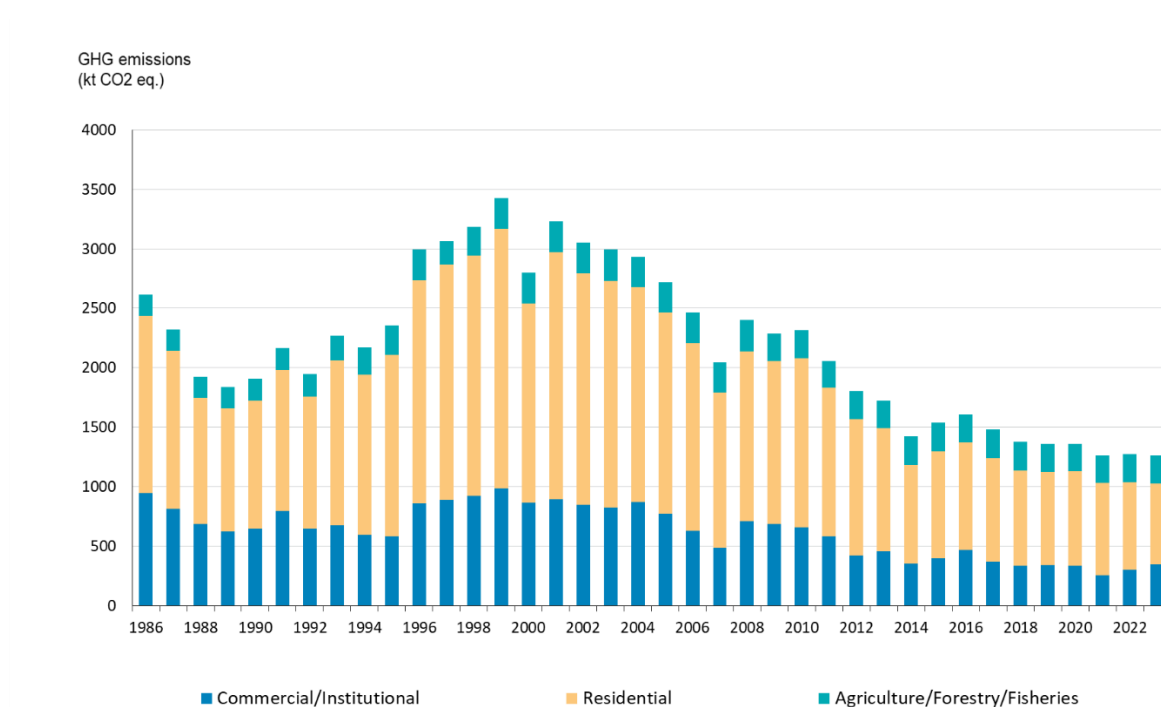
This chapter presents the consumption of fuels and emissions of greenhouse gases in:

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

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

|         | CO <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            | T1              | D  | -            | T1               | D  | -            |
| Biomass | T1              | D  | -            | T2              | CS | L            | T1               | D  | -            |

In this sector CO<sub>2</sub> emissions due to the use of gaseous fuel is a key category according to the level and trend,. CO<sub>2</sub> emissions from liquid fuel is a key category according to the level and, methane emissions from the biomass combustion in residential sector is a key category according to the level. Since 2022 a solid fuel has not been used in this sector. The GHG emissions are presented in the Table 3.2.54 and on the Figure 3.2.20.



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



**Table 3.2.54: GHG emissions from Other Sectors in kt CO<sub>2</sub> eq.**

|  | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|--|------|------|------|------|------|------|------|------|------|
| <b>4. Other Sectors</b>                  | 2614 | 1907 | 2798 | 2721 | 2314 | 1538 | 1363 | 1276 | 1261 |
| <b>a. Commercial/Institutional</b>       | 947  | 648  | 866  | 776  | 656  | 397  | 338  | 299  | 349  |
| <b>b. Residential</b>                    | 1488 | 1076 | 1673 | 1688 | 1424 | 900  | 793  | 741  | 676  |
| <b>c. Agriculture/Forestry/Fisheries</b> | 179  | 183  | 259  | 257  | 234  | 241  | 232  | 236  | 237  |

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

#### **3.2.7.1.1 Category description**

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

#### **3.2.7.1.2 Methodology issues**

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

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

#### **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. In accordance with IPCC 2006 GL (Vol.2, Box 2.1 Autoproducers), emissions from combustion of landfill gas and gas from WW treatment

plants which is used for electricity production are included under 1A4a Commercial use and not under 1A1a.

### **Net calorific values**

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

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

| Year | Lignite<br>(Velenje) | Sub-<br>bituminous<br>Coal -<br>domestic | Sub-<br>bituminous<br>Coal -<br>imported | Fuel Oil | Residual<br>Fuel Oil | LPG    | Natural<br>Gas | Wood<br>and<br>Other<br>Biomass |
|------|----------------------|--|--|----------|----------------------|--------|----------------|---------------------------------|
|      | TJ/kt                | TJ/kt                                    | TJ/kt                                    | TJ/kt    | TJ/kt                | TJ/kt  | TJ/Mm3         | TJ/kt                           |
| 1986 | 9.390                | 11.880                                   |  | 41.82    | 39.74                | 46.00  | 33.500         | 14                              |
| 1987 | 9,650                | 11.820                                   |  | 41,78    | 39.80                | 46.00  | 33.500         | 14                              |
| 1988 | 9,440                | 12.000                                   |  | 41,71    | 39.80                | 46.00  | 34.080         | 14                              |
| 1989 | 9,820                | 12,050                                   |  | 41,85    | 39.90                | 46.00  | 34.100         | 14                              |
| 1990 | 9.810                | 12.760                                   |  | 41.87    | 39.80                | 46.00  | 34.100         | 14                              |
| 1991 | 9.980                | 12.879                                   |  | 41.88    | 39.80                | 46.00  | 34.100         | 14                              |
| 1992 | 10.260               | 12.589                                   |  | 41.90    | 39.90                | 46.00  | 34.100         | 14                              |
| 1993 | 10.070               | 13.351                                   |  | 41.90    | 39.80                | 46.00  | 34.100         | 14                              |
| 1994 | 9.960                | 12.666                                   |  | 41.90    | 39.86                | 46.00  | 34.100         | 14                              |
| 1995 | 10.220               |  | 17.404                                   | 41.90    | 40.00                | 46.00  | 34.100         | 14                              |
| 1996 | 9.690                |  | 16.353                                   | 41.90    | 40.00                | 46.00  | 34.100         | 14                              |
| 1997 | 9.610                |  | 18.203                                   | 41.90    | 40.00                | 46.05  | 34.080         | 14                              |
| 1998 | 10.010               |  | 18.531                                   | 41.90    | 40.00                | 46.05  | 34.080         | 14                              |
| 1999 | 9.690                |  | 18.563                                   | 41.90    | 40.00                | 46.05  | 34.080         | 14                              |
| 2000 | 10.170               |  | 17.983                                   | 41.90    | 40.00                | 46.05  | 34.080         | 13.97                           |
| 2001 | 10.660               |  | 18.834                                   | 41.90    | 40.00                | 46.05  | 34.080         | 13.95                           |
| 2002 | 10.350               |  | 19.000                                   | 41.90    | 40.00                | 46.05  | 34.080         | 13.95                           |
| 2003 | 10.138               |  | 19.000                                   | 41.90    |                      | 46.05  | 34.080         | 13.98                           |
| 2004 | 10.301               |  | 19.000                                   | 41.90    |                      | 46.05  | 34.080         | 14.02                           |
| 2005 | 10.803               |  | 17.000                                   | 42.60    |                      | 46.05  | 34.127         | 14.05                           |
| 2006 |                      |  | 17.318                                   | 41.90    |                      | 46.05  | 34.198         | 14.11                           |
| 2007 |                      |  | 16.863                                   | 42.60    |                      | 46.05  | 34.269         | 14.15                           |
| 2008 |                      |  | 16.407                                   | 42.60    |                      | 46.05  | 34.340         | 14.19                           |
| 2009 |                      |  | 15.952                                   | 42.60    |                      | 46.05  | 34.411         | 14.74                           |
| 2010 |                      |  | 16.155                                   | 42.60    |                      | 46.05  | 34.481         | 14,75                           |
| 2011 |                      |  | 15.985                                   | 42.60    |                      | 46.05  | 34.552         | 14,77                           |
| 2012 |                      |  | 16.032                                   | 42.60    |                      | 46.05  | 34.623         | 14,80                           |
| 2013 |                      |  | 16.457                                   | 42.60    |                      | 46.05  | 34.694         | 14.81                           |
| 2014 |                      |  | 15.734                                   | 42.60    |                      | 46.05  | 34.758         | 14.81                           |
| 2015 |                      |  | 16.360                                   | 42.60    |                      | 46.05  | 34.805         | 14.81                           |
| 2016 |                      |  | 16.575                                   | 42.60    |                      | 46.05  | 34.851         | 14.82                           |
| 2017 |                      |  | 16.000                                   | 42.60    |                      | 46.05  | 34.789         | 14.82                           |
| 2018 |                      |  | 17.647                                   | 42.600   |                      | 46.050 | 34.820         | 14.83                           |
| 2019 |                      |  | 18.282                                   | 42.60    |                      | 46.050 | 34.851         | 14.84                           |
| 2020 |                      |  | 18.198                                   | 42.60    |                      | 46.050 | 34.850         | 14.84                           |
| 2021 |                      |  | 18.256                                   | 42.60    |                      | 46.050 | 34.855         | 14.84                           |
| 2022 |                      |  | -  | 42.60    |                      | 46.050 | 35.184         | 14.85                           |
| 2023 |                      |  |  | 42.60    |                      | 46.050 | 35.506         | 14.85                           |

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

### **Emission factors**

Emission factors are mainly taken from the 2006 IPCC Guidelines, Vol. 2 Table 2.4 and Table 2.5. with the following exceptions. Country specific CO<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 3.2.56-58.

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

|                     | Unit | Lignite<br>(Velenje) | Sub-<br>bituminous<br>Coal -<br>domestic | Fuel<br>Oil | Residual<br>Fuel<br>Oil | LPG    | Natural<br>Gas | Wood<br>and other<br>solid<br>biomass | Gaseous<br>biomass |
|---------------------|------|----------------------|--|-------------|-------------------------|--------|----------------|---------------------------------------|--------------------|
| CO <sub>2</sub> EF  | t/TJ | Table<br>3.2.1       | 101                                      | 74.0        | 77.1                    | 64.7   | Table<br>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 3.2.57: EFs for the fuel used in Residential Sector if different from Commercial.**

|                    | Unit | Lignite<br>(Velenje) | Sub-<br>bituminous<br>Coal -<br>domestic | Wood<br>biomass |
|--------------------|------|----------------------|--|-----------------|
| CH <sub>4</sub> EF | t/TJ | 0.3                  | 0.3                                      | Table 3.2.58    |

**Table 3.2.58: 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  | 0.2811 | 0.2783 | 0.2777 | 0.2692 | 0.2723 |
| 2016   | 2017   | 2018   | 2019   | 2020    | 2021   | 2022   | 2023   | 2024   | 2025   |
| 0.2737 | 0.2728 | 0.2659 | 0.2591 | 0.2478  | 0.2512 | 0.2389 | 0.2258 |        |        |

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 3.2.59.

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 – 2022, while for years before data was estimated taking into account, that in 1986 only conventional boilers and stoves have existed.

**Table 3.2.59: 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<br>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 3.2.60.

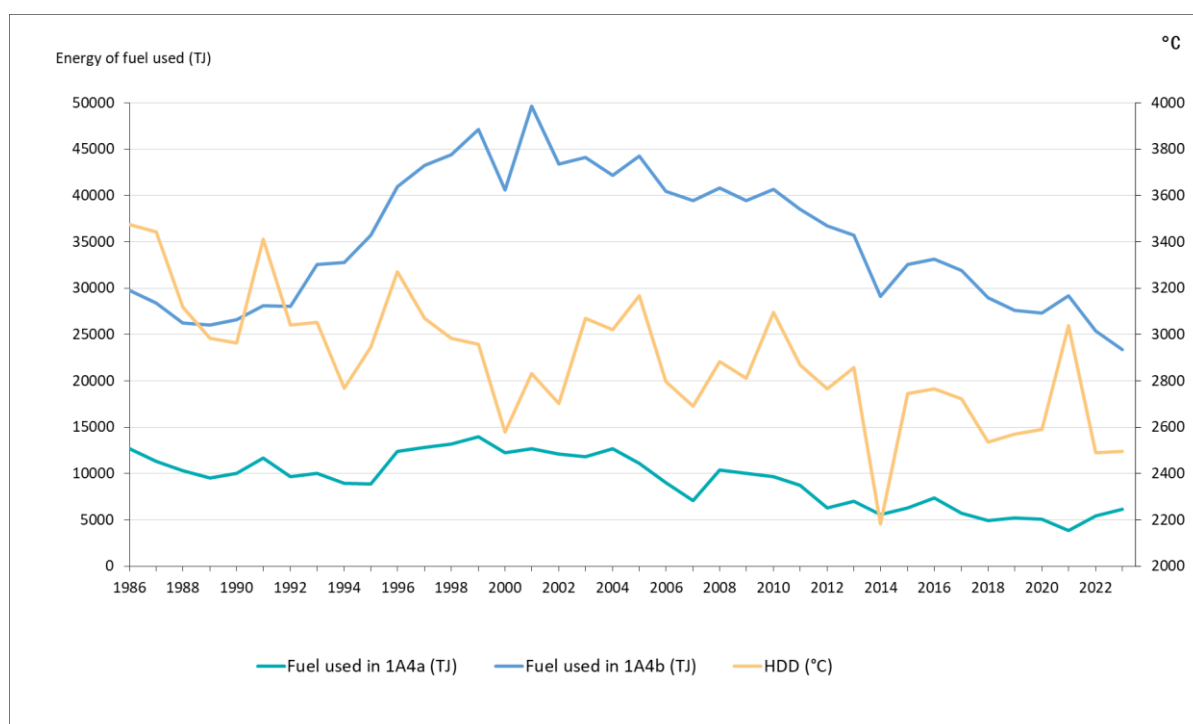
**Table 3.2.60: Uncertainties of activity data and emission factors as used in the 2025 submission for the base year and the last reporting year in per cents.**

|         | 1986 and 2023 |                    |                    |                     |
|---------|---------------|--------------------|--------------------|---------------------|
|         | 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                 |

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

#### 3.2.7.1.4 Category-specific QA/QC and verification

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

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

In addition every year the energy of fuel consumption in the commercial/institutional and residential sectors is compared with the value of Heating Degree Days (HDD). HDD is a

measurement designed to quantify the demand for energy needed to heat a building. The heating requirements for a given building at a specific location are considered to be directly proportional to the number of HDD at that location. By default, the duration is limited to days when the outdoor temperature (threshold) is lower than 12 ° C. For a given place, therefore, we take the average outdoor temperature during the heating season and subtract it from the agreed 20 ° C and multiply it by the number of heating days. This comparison is presented on the Figure 3.2.21.

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

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

1.A.4.a and b. Commercial / Institutional and Residential, Gaseous Fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O  
Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O have been recalculated for the period 2005-2022 due to the use of NCV values for natural gas from natural gas provider instead of SORS data. In addition CO<sub>2</sub> EF have been also slightly improved. Until 2021 recalculations was very minor.

1.A.4.a and b. Commercial / Institutional and Residential, Liquid Fuels, CO<sub>2</sub>  
In addition we started to use country specific CO<sub>2</sub> EF for LPG instead of default value. Recalculation of emissions affected all years in the period 1986-2022.

1.A.4.b Residential, Biomass, CH<sub>4</sub>

CS CH<sub>4</sub> EF was corrected due to the slightly changed data on share of different types of stove and boilers for combustion of wood and CH<sub>4</sub> emissions have been recalculated accordingly for the period 2016-2022. Corresponding emissions increased by 2.5%.

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

No improvements are planned for this category.

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

#### 3.2.7.2.1 Category description

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

#### 3.2.7.2.2 Methodology issues

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

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

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

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

|  | 1986           | 1990          | 1995          | 2000          |
|--|----------------|---------------|---------------|---------------|
| Cultivated Land in State owned Agriculture ent. (1000 ha)                  | 70             | 77            | 62            | 31            |
| Total Cultivated Land (1000 ha)  | 647            | 653           | 634           | 509           |
| Consumption of Gasoline in State owned Agriculture ent. (1000 t)           | 1.3            | 1.1           | 0.7           | 0.4           |
| Consumption of Gasoline per ha of Cultivated Land (t/1000 ha)              | 18.6           | 14.1          | 10.5          | 7.1           |
| <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 3.2.62. Since 2001 data on fuel are available from SORS.

For the state-owned sector, data are available for the consumption of fuel and cut, for the private sector only data on cut are available. Firstly; the consumption per m<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.

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

|  | 1986          | 1990          | 1995         | 2000         |
|--|---------------|---------------|--------------|--------------|
| Consumption of Fuel in State owned Forest (1000 t)                     | 6.902         | 5.922         | 3.680        | 2.808        |
| Cut in State owned Forest (1000 m <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> |

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

**Table 3.2.64: Consumption of diesel in Fishing**

|                                       | 1986-1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|---------------------------------------|-----------|------|------|------|------|------|------|------|
| Consumption of Diesel in Fishing (kt) | 203       | 270  | 355  | 511  | 202  | 200  | 200  | 220  |

### **Net calorific values**

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

### **Emission factors**

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

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

|                          | Diesel  | Motor gasoline |
|--------------------------|---------|----------------|
|                          | t/TJ    | t/TJ           |
| <b>CO<sub>2</sub> EF</b> | 74.1    | 69.3           |
| <b>CH<sub>4</sub> EF</b> | 0.00415 | 0.08           |
| <b>N<sub>2</sub>O EF</b> | 0.0286  | 0.002          |

### ***3.2.7.2.3 Uncertainty and time –series consistency***

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



**Table 3.2.66: Uncertainties of activity data and emission factors as used in the 2025 submission for the base year and the last reporting year in per cents.**

|        | 1986 and 2023 |                    |                    |                     |
|--------|---------------|--------------------|--------------------|---------------------|
|        | 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**

No recalculations have been performed for this category.

#### **3.2.7.2.6 Category-specific planned improvements**

No improvement is planned for this category.

### 3.2.8 Other (CRT 1A5)

#### 3.2.8.1.1 Category description

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

- Other mobile (CRT 1A5b)

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

**Table 3.2.67: GHG Emissions in the period 1986-2023.**

|                              | 1986 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|------------------------------|------|------|------|------|------|------|------|------|------|------|
| <b>fuel in TJ</b>            | 575  | 444  | 19   | 43   | 46   | 40   | 51   | 44   | 65   | 62   |
| <b>Gg CO<sub>2</sub> eq.</b> | 41   | 32   | 1.4  | 3.1  | 3.3  | 2.9  | 3.7  | 3.2  | 4.7  | 4.6  |

#### 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 3.2.67.

**Table 3.2.68: 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 3.2.68).

**Table 3.2.69: Uncertainties of activity data and emission factors as used in the 2025 submission for the base year and the last reporting year in per cents.**

|        | 1986 |                    |                    |                     | 2023 |                    |                    |                     |
|--------|------|--------------------|--------------------|---------------------|------|--------------------|--------------------|---------------------|
|        | 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, (CRT 1.B)

This chapter presents the fugitive emissions of greenhouse gases from:

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

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

Emissions of CO<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.

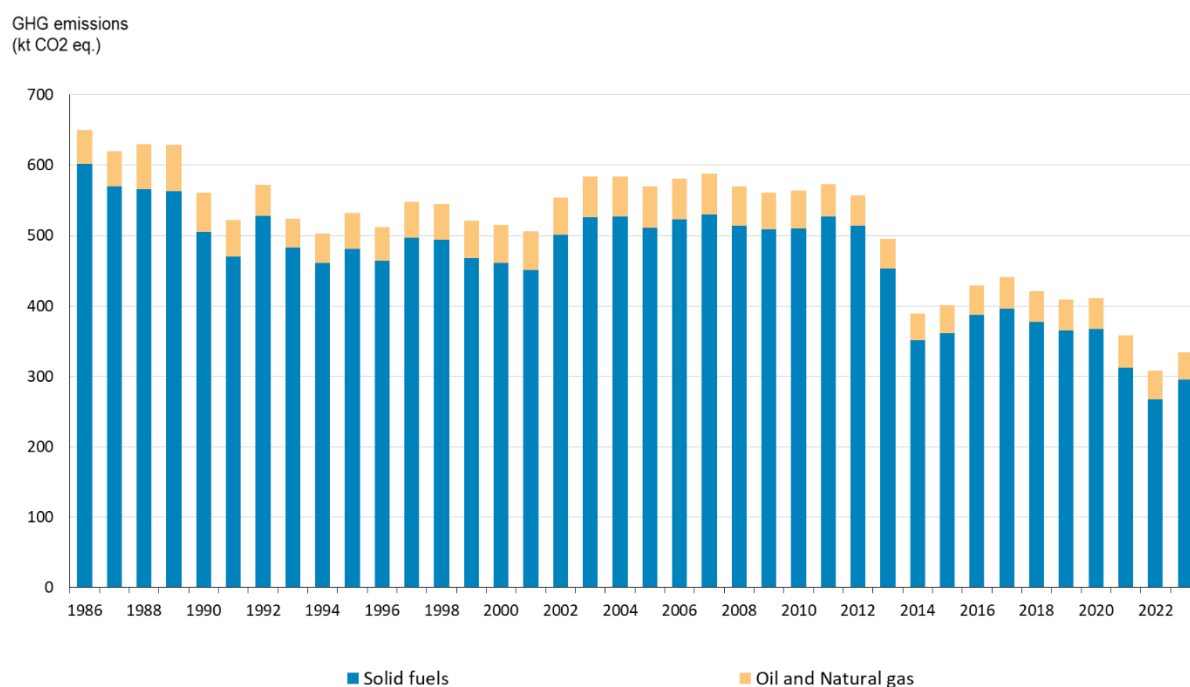
**Table 3.3.1: Method, EF used and key categories indications for the year 2022 in the Fugitive emissions sectors.**

|                           | 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 | T                | T2, T3          | D, PS | L,T          | NO               | NO | NA           |
| SO <sub>2</sub> scrubbing | T3              | PS | L <sub>sub</sub> | 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       | 2000       | 2005       | 2010       | 2015       | 2020       | 2022       | 2023       |
|---------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| <b>Total</b>              | <b>649</b> | <b>561</b> | <b>515</b> | <b>570</b> | <b>563</b> | <b>401</b> | <b>411</b> | <b>308</b> | <b>334</b> |
| Solid Fuels               | 602        | 505        | 461        | 511        | 510        | 361        | 367        | 267        | 265        |
| Oil and Natural gas       | 47         | 56         | 54         | 59         | 54         | 40         | 44         | 41         | 39         |



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

Fugitive emissions in the Republic of Slovenia are also of minor importance thus they represent only 2.5% of emissions in the sector and have decreased by 52.5% compare to emissions in 1986 by 51.7%. The biggest fraction (73.4%) of GHG emissions from this sector are emissions of carbon dioxide and methane from mining of coal in underground mines, while remaining emissions are emissions of CO<sub>2</sub> due to the SO<sub>2</sub> scrubbing (13.3%) and emissions from oil and natural gas (11.7%). 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.

### 3.3.1 Solid Fuels (CRT 1.B.1)

#### 3.3.1.1 Category description

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

- 1.B.1.a.i Coal mining and handling / Underground mines
  - Mining activities
  - Post-mining activities
  - Abandoned underground mines
- 1.B.1.c Other
  - SO<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 – 2023 in kt CO<sub>2</sub> eq.**

|  | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|--|------|------|------|------|------|------|------|------|------|
| <b>Mining (CH<sub>4</sub>)</b>               | 116  | 59   | 224  | 233  | 234  | 178  | 179  | 133  | 145  |
| <b>Mining (CO<sub>2</sub>)</b>               | 123  | 101  | 81   | 83   | 82   | 61   | 62   | 46   | 50   |
| <b>Post-Mining (CH<sub>4</sub>)</b>          | 363  | 344  | 112  | 107  | 99   | 59   | 60   | 44   | 48   |
| <b>Abandoned coal mines (CH<sub>4</sub>)</b> | 0.2  | 0.4  | 8    | 4    | 3    | 7    | 4    | 4    | 4    |
| <b>Total</b>                                 | 602  | 505  | 424  | 428  | 418  | 306  | 304  | 226  | 246  |

**Table 3.3.4: Emission of CO<sub>2</sub> from SO<sub>2</sub> scrubbing 1986 – 2022 in kt CO<sub>2</sub>.**

|                                 | 1986-1991 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022 | 2023 |
|---------------------------------|-----------|------|------|------|------|------|------|------|------|
| <b>SO<sub>2</sub> scrubbing</b> | NO        | 30.0 | 36.7 | 82.3 | 91.5 | 55.3 | 63.4 | 41.0 | 48.9 |

#### 3.3.1.2 Methodology issues

##### Mining and post mining

*Methane emissions (t) = (EF<sub>1</sub>+ EF<sub>2</sub>) \* excavated coal (t) \* 0.67(kg/m<sup>3</sup>)*

*CO<sub>2</sub> emissions (t) = EF<sub>3</sub> (m<sup>3</sup> CO<sub>2</sub>/t) \* excavated coal (t) \* 1.84(kg/m<sup>3</sup>)*

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)

$EF_3$  = 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 – 2023**

| Pit                               | 1986         | 1990         | 1995         | 2000         | 2005         | 2010         | 2015         | 2020         | 2023         | Closed in |
|-----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-----------|
| Velenje                           | 5,001        | 4,210        | 3,917        | 3,743        | 3,945        | 4,011        | 3,168        | 3,175        | 2,571        |           |
| 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>3,175</b> | <b>2,358</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 – 2023 (m<sup>3</sup> CH<sub>4</sub>/t coal)**

| Pit                 | 1986 | 1990              | 1995  | 1997-2023                |
|---------------------|------|-------------------|-------|--------------------------|
| 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 – 2023 (m<sup>3</sup> CH<sub>4</sub>/t coal)**

| Pit                 | 1986 | 1990              | 1995 | 1997-2023                |
|---------------------|------|-------------------|------|--------------------------|
| 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 – 2023 (m<sup>3</sup> CO<sub>2</sub>/t coal)**

| Pit                 | 1986-2023 |
|---------------------|-----------|
| 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 2023.**

| 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   | 10                          | 0.270 |
| Zagorje           | brown        | 0.39   | 26                          | 0.125 |
| Senovo            | brown        | 0.07   | 26                          | 0.117 |
| Kanižarica        | brown        | 0.04   | 28                          | 0.117 |
| Laško             | brown        | 0.01   | 34                          | 0.098 |
| Šega              | brown        | 0.01   | 60                          | 0.058 |
| Krmelj            | brown        | 0.043  | 61                          | 0.057 |
| Leše              | brown        | 0.006  | 87                          | 0.041 |

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

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

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

a and b are constants determining the declining curve

T = years elapsed since abandonment and inventory year

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

### **SO<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 2005–2022 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 2025 submission for the base year and the last reporting year.**

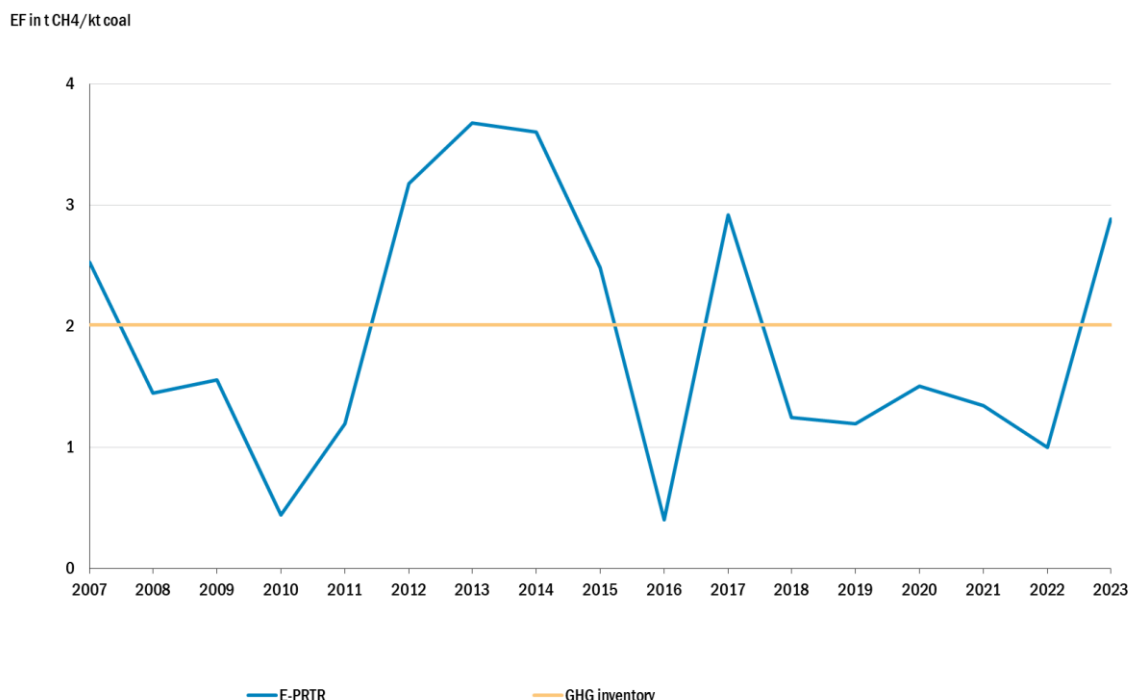
|                                   | 1986 |                    |                    |                     | 2023 |                    |                    |                     |
|-----------------------------------|------|--------------------|--------------------|---------------------|------|--------------------|--------------------|---------------------|
|                                   | 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 category many years until 2021, but in 2022 was not KC any more. Due to the fact, that AD are obtained from the verified ETS reports, additional QA is not necessary. We have compared the final CO<sub>2</sub> emissions from ETS report and from GHG inventory and the difference in 2022 was 0.06%. The reason is a different EFs used: in ETS the EF factors are rounded and are 440 instead of 439.71 kg CO<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 (CRT 1.B.2)

#### 3.3.2.1 Category description

Fugitive emissions of GHG from Oil and Natural Gas in the period 1986-2022 are presented in the Table 3.3.12. Methane emissions from the production of crude oil and refined petroleum products were insignificant in the period 1986-2002 and have not occurred since 2003. There was also one oil refinery in Slovenia which was closed in 2002. Since then no oil is refined in the country. According to the 2006 IPCC GL fugitive CH<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 – 2023 (kt CO<sub>2</sub> eq.)**

|              |              | 1986    | 1990    | 2000    | 2005    | 2010    | 2015    | 2020    | 2023    |
|--------------|--------------|---------|---------|---------|---------|---------|---------|---------|---------|
| OIL          | Production   | 0.00005 | 0.00005 | 0.00001 | 0.00001 | 0.00000 | 0.00001 | 0.00000 | 0,00000 |
|              | Transport    | 0.032   | 0.025   | 0.059   | 0.065   | 0.062   | 0.060   | 0.061   | 0,055   |
|              | Refining     | 0.382   | 0.382   | 0.104   | NO      | NO      | NO      | NO      | NO      |
|              | Venting      | 0.073   | 0.071   | 0.016   | 0.008   | 0.007   | 0.007   | 0.007   | 0.004   |
|              | Flaring      | 0.150   | 0.146   | 0.033   | 0.017   | 0.014   | 0.015   | 0.014   | 0.008   |
| NATURAL GAS  | Production   | 2.517   | 8.068   | 1.084   | 0.159   | 0.251   | 0.113   | 0.201   | 0,168   |
|              | Transmission | 11.177  | 11.989  | 12.656  | 14.172  | 12.519  | 8.676   | 9.460   | 8.348   |
|              | Distribution | 25.655  | 27.519  | 31.283  | 35.201  | 32.681  | 25.174  | 27.872  | 24.988  |
|              | Venting      | 7.454   | 7.995   | 8.440   | 9.451   | 8.349   | 5.786   | 6.309   | 5.567   |
|              | Flaring      | 0.011   | 0.034   | 0.010   | 0.005   | 0.008   | 0.004   | 0.007   | 0,005   |
| <b>TOTAL</b> |              | 47,449  | 56.229  | 53.685  | 59.053  | 53.870  | 39.813  | 43.910  | 39.132  |

Natural gas transmission and distribution is the main source of emissions in this category while fugitive emissions from natural gas production are less important. The gasification of Slovenia began in the early 1970s and in 1978 the newly constructed pipeline system enabled the transportation of Russian natural gas for Croatia and delivered gas to the first two consumers in Slovenia. Today, the total length of the gas pipeline transport network in Slovenia is 1,200 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. Due to Russian aggression against Ukraine, a direct import of Russian gas was not allowed in 2023.

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**

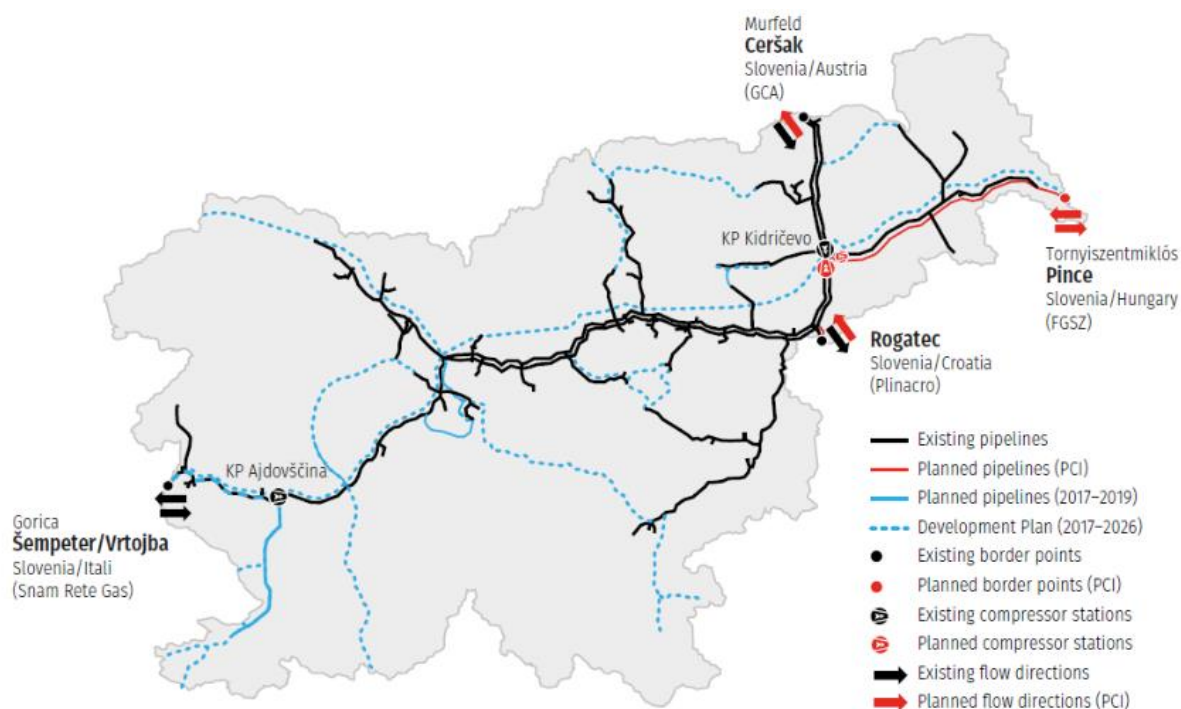
The data on the amount of crude oil produced and refined and LPG consumed have been obtained from SORS. As all data are available in tonnes the following densities have been used to transform ton to m<sup>3</sup>: crude oil: 0.85 t/m<sup>3</sup> and LPG: 0.58 t/m<sup>3</sup>.

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 | 2000 | 2005 | 2010  | 2015  | 2020  | 2023  |
|------------------------------------|------|------|------|------|-------|-------|-------|-------|
| <b>Length (km)</b>                 | 740  | 784  | 948  | 960  | 1,018 | 1,155 | 1,177 | 1,200 |
| <b>Built before 1992</b>           | 100% | 100% | 83%  | 82%  | 78%   | 68%   | 67%   | 66%   |
| <b>Built between 1992 and 2004</b> |      |      | 17%  | 18%  | 17%   | 15%   | 14%   | 14%   |
| <b>Built since 2005</b>            |      |      |      |      | 6%    | 17%   | 18%   | 20%   |



Source: Plinovodi

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

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

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

|                                    | 1986 | 1990 | 2000  | 2005  | 2010  | 2015  | 2020  | 2023  |
|------------------------------------|------|------|-------|-------|-------|-------|-------|-------|
| <b>Length (km)</b>                 | 401  | 514  | 2,079 | 3,413 | 4,246 | 4,633 | 4,953 | 5,121 |
| <b>Built before 1992</b>           | 100% | 100% | 26%   | 16%   | 13%   | 12%   | 11%   | 11%   |
| <b>Built between 1992 and 2004</b> |      |      | 74%   | 75%   | 60%   | 55%   | 52%   | 50%   |
| <b>Built since 2005</b>            |      |      |       | 9%    | 27%   | 33%   | 37%   | 39%   |

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 CRT 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     | 2005-2023            |
|----------------|-----------|----------------------|----------------------|---------------|----------------------|
| 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 2025 submission for the base year and the last reporting year in per cents.**

|                     | 1986 and 2023 |                    |                    |                     |
|---------------------|---------------|--------------------|--------------------|---------------------|
|                     | 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><br>(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 NID (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 25 years and all old steel and cast iron pipes were replaced with the new PE or PVC pipes with very low leakages. In addition, the reasons for low emissions is also the strict EU legislation in this field which requires good maintenance and, last but not least, the high price of natural gas, which is almost entirely imported.

#### **3.3.2.5 Category-specific recalculations**

No recalculations have been performed for this category.

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

No improvement is planned for this category.

### **3.4 CO<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 (CRT sector 2)

### 4.1 Overview of Sector

This chapter presents the processes emissions of greenhouse gases in:

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

and emissions due to the product use:

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

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

Industrial activities unrelated to energy produce various GHG emissions. The emission sources are the industrial production processes in which raw materials are chemically or physically transformed. In this transformation, many different GHGs can be released, such as CO<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.

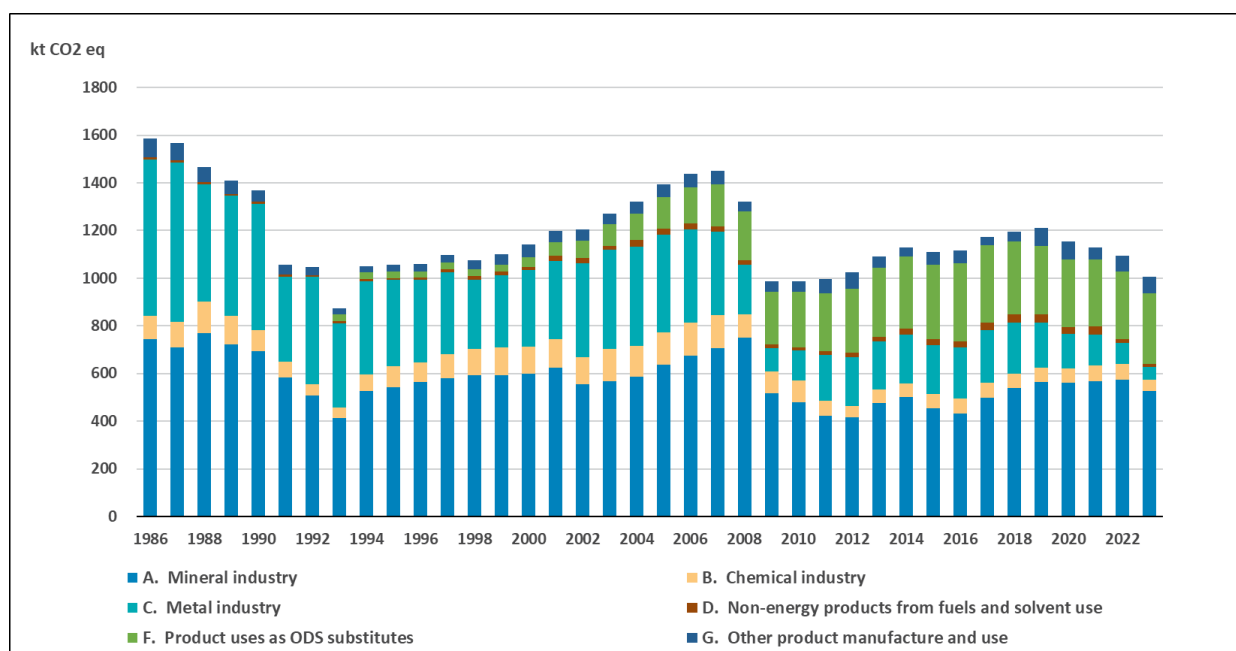
**Table 4.1.1: Method, EF used and key categories indications for the year 2023 in the IPPU sector.**

|  |                                      | 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     | -            |
|  | 10. Hydrogen production              | T2               | CS    | -            |
| C. Metal industry                      | 1. Iron and steel production         | T2               | PS    | T            |
|  | 3. Aluminium production              | T2               | D, PS | -            |
|  | 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     | Lsub         |
|  |                                      | 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    | -            |

Emissions from Industrial processes and product use in Slovenia account for 6.8% of the total national GHG emissions, excluding LULUCF. They amounted to 1,586 kt CO<sub>2</sub> equivalents in 1986 and 1,006 kt CO<sub>2</sub> equivalents in 2023. The most important GHG of this sector was carbon dioxide, with 63.7% of emissions from this category, followed by HFCs with 29.5%, N<sub>2</sub>O with 5.1%, SF<sub>6</sub> with 1.7%, and PFCs with 0.1%. The main source of emissions is mineral industry with 52.4% of emissions, followed by consumption of F-gases (product uses as substitutes for ODS) with 29.5%. Significantly smaller are the contributions

from other product manufacture and use (6.8%), metal industry (5.1%), and chemical industry (5.8%), while use of non-energy products from fuels and solvent contributes 1.5% to the total emissions from this sector.

Since 1986, GHG emissions from Industrial Processes at first fell sharply to reach their lowest value in 1993, but then started to rise again and were in 2007 6.0% above 1986 level. Due to the global financial crises and lower industrial production, emissions in 2009 were 28.2% below the 1986 emissions but in the period 2010 – 2019 slowly increased by 24.5% while in 2020 decreased by 4.3% due to the epidemics and continue to decrease also in the following years. Emissions of GHG (in kt CO<sub>2</sub> eq.) for 1986-2022 are shown in Figure 4.1.1.



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

## 4.2 MINERAL INDUSTRY (CRT 2.A)

### 4.2.1 Cement Production (CRT 2.A.1)

#### 4.2.1.1 Category descriptions

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

The basic raw material for the production of cement is marl, which is a homogeneous mixture of limestone and clay and which was formed in the past geological periods through sedimentation. As there is no longer enough natural marl for mass production, a cement production mix, which must contain 75-78% of calcium carbonate ( $\text{CaCO}_3$ ), 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 2023 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–

2023 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 2005–2023 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 2023 only one plant has been in operation.

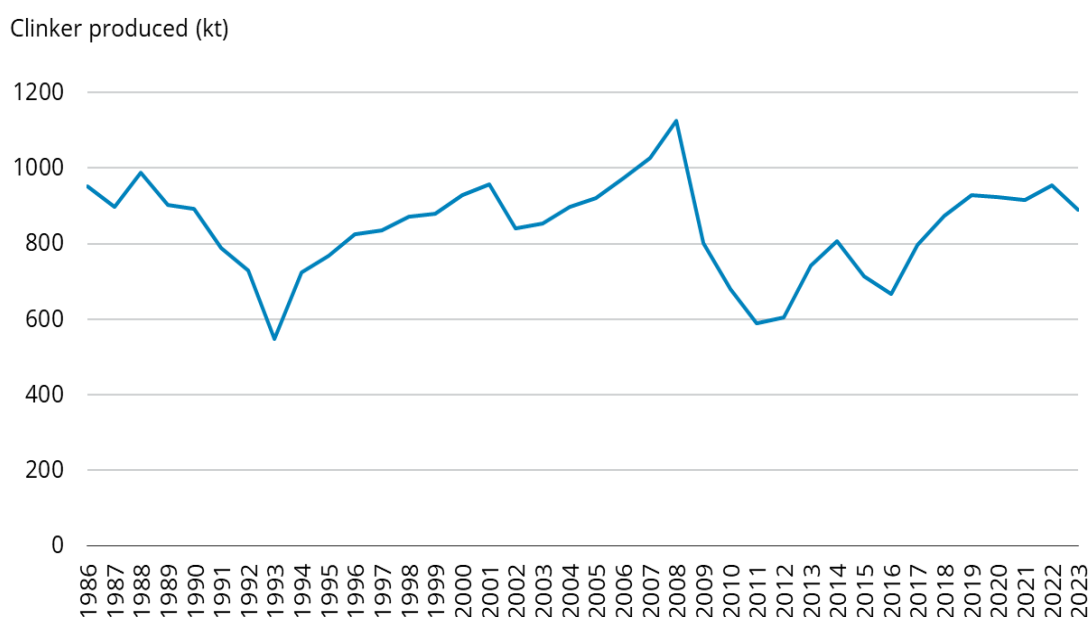
**Table 4.2.1: Emission factors used for calculation emissions from cement production.**

| 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 |
| 2021        | 0.512   | -          | 0.512 |
| 2022        | 0.514   | -          | 0.514 |
| 2023        | 0.512   | -          | 0.512 |

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.

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 the period 2019 - 2023 are included in the emission calculation for cement production and reported under the category Cement Production (CRF code: 2A1). CO<sub>2</sub> emissions from CKD for the period 2019 - 2023 are included in the emission inventory due to the change in fuel type used in cement production in that period. A cement factory increased the amount of waste used as fuel. Due to the application of alternative fuels, flue-gas cleaning has been needed. A bypass system has been used to reduce the content of chloride and sulphur oxides.



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

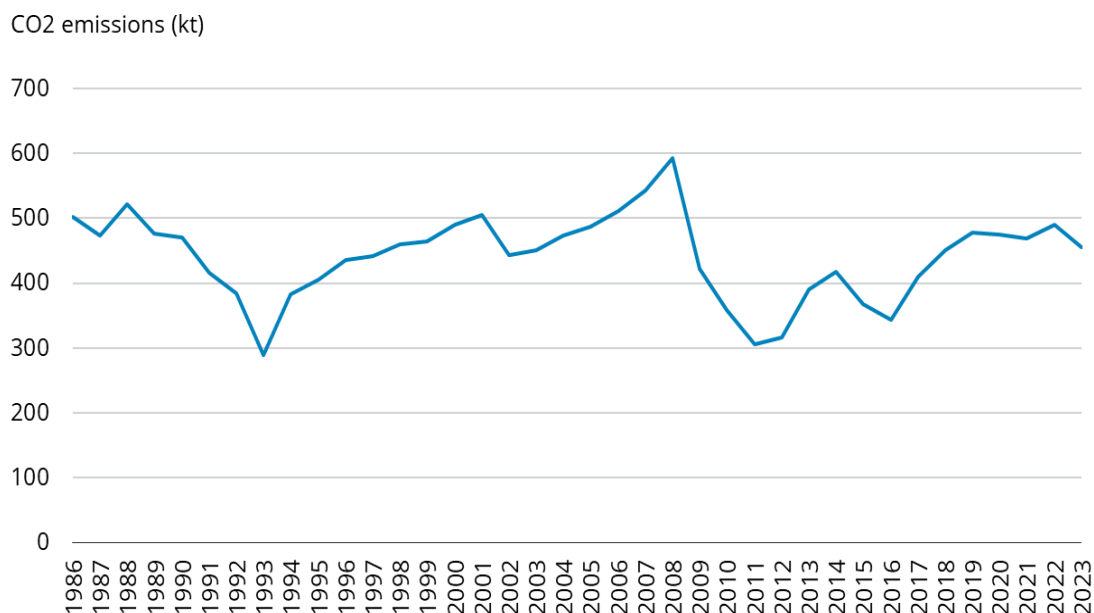
To calculate emissions from cement production after 2005 we have been using data obtained by ETS. The data on clinker production and plant specific emission factors for both cement factories have been annually verified by independent verifiers. The expert review team (ERT) recommended showing that the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

[Porocilo-o-izpolnitvi-obveznosti-za-leto-2023.xls](#)

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 4.2.2: 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 2023 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 2023 only one cement factory has been in operation. The amount of clinker produced, the composition of clinker and calculated EFs for the whole period have been thoroughly examined. The activity data on clinker production obtained from verified ETS reports were cross checked through direct communication with plant representatives. We also compared data on cement production and clinker production. The clinker production does not entirely

track cement production due to additional clinker imports. Cement has been produced not only from domestically produced clinker but also from imported clinker.

#### **4.2.1.5 Category-specific recalculations**

No recalculations have been performed since the last submission.

#### **4.2.1.6 Category-specific improvements**

No improvements are planned for the next submission.

### **4.2.2 Lime Production (CRT 2.A.2)**

#### **4.2.2.1 Category descriptions**

CO<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 was closed at the end of 2012 and the second one in 2022. However, in the year 2023 only one lime factory has 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 2005-2023 has been based on the data provided by the lime plants in the scope of ETS scheme delivered in verified ETS reports.

The amount of CaO and MgO in the lime produced or the amount of carbonates from the raw material were used as activity data for the emission calculations. The emission factors used for emission calculation are based on the stoichiometric ratio of CO<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 lime producers, 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 at the end of 2012. The second lime plant (producer 2) stopped producing lime in 2022 (Table 4.2.4).

**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                         |
| 2021 | 76896                 | 660                   | 0.785  | 1.092  | 61084                         |
| 2022 | 63990                 | 549                   | 0.785  | 1.092  | 50832                         |
| Year | CaCO <sub>3</sub> (t) | MgCO <sub>3</sub> (t) | EF (t CO <sub>2</sub> /t CaCO <sub>3</sub> ) | EF (t CO <sub>2</sub> /t MgCO <sub>3</sub> ) | Emissions CO <sub>2</sub> (t) |
| 2023 | 95982                 | 1664                  | 0.43971                                      | 0.52197                                      | 43101                         |

**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                         |
| 2021 | 7219    | 147     | 0.758                         | 1.092                         | 5828                          |
| 2022 | 609     | 11      | 0.758                         | 1.092                         | 490                           |

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

| Year | CaCO <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 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.

Producers 1 and 2 chose calculation method B, while Producer 3 chose calculation method A. Producer 3 was closed in 2012, and Producer 2 stopped its production in 2022. In 2023 Producer 1 chose 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).

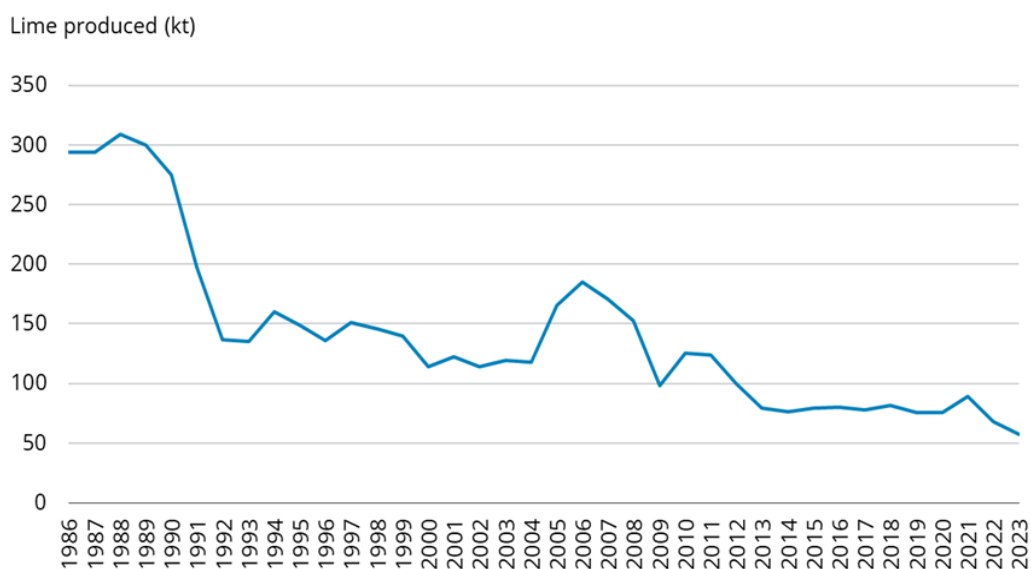
**Table 4.2.5: Total CO<sub>2</sub> emissions of all three producers, total lime production and calculated implied emission factor for the last few years.**

| Year  | 2005   | 2010   | 2015  | 2020  | 2021  | 2022  | 2023  |
|---|--------|--------|-------|-------|-------|-------|-------|
| Lime Produced (t)                                       | 165125 | 125117 | 79507 | 75638 | 88862 | 68224 | 57143 |
| Total emissions CO <sub>2</sub> (t)                     | 121346 | 90248  | 60001 | 56554 | 66911 | 51322 | 43101 |
| Implied emission factor (kg CO <sub>2</sub> /t of lime) | 735    | 721    | 755   | 748   | 753   | 752   | 754   |

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.

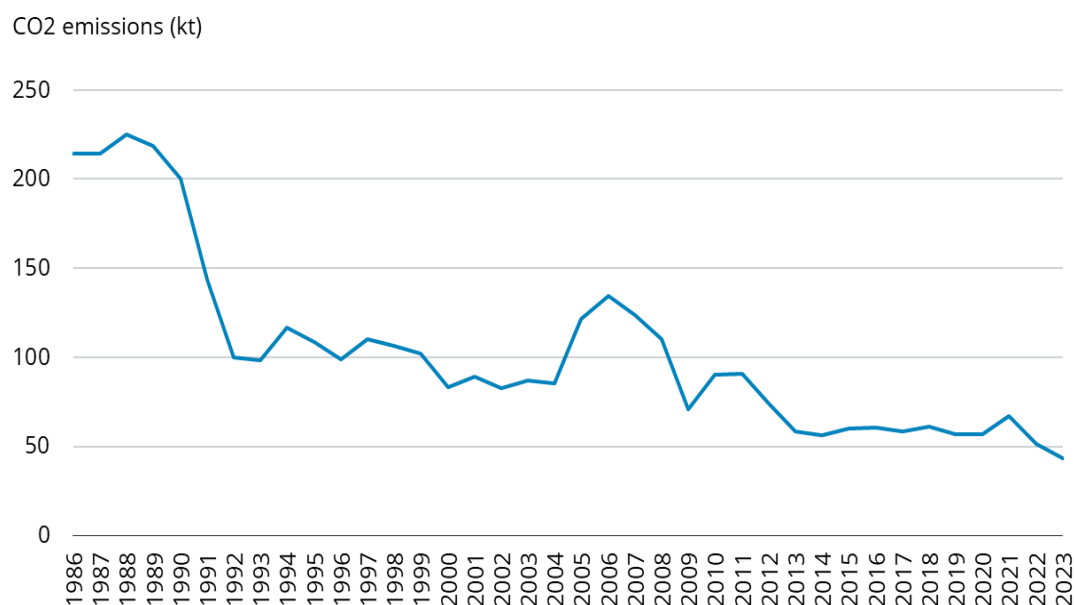
**Table 4.2.6: Emission factors used for calculation emissions from lime production.**

| Year      | Implied emission factor<br>(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   |
| 2021      | 0.753   |
| 2022      | 0.752   |
| 2023      | 0.754   |

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

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.

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

#### 4.2.2.4 Category-specific QA/QC and verification

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

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

#### **4.2.2.5 Category-specific recalculations**

No recalculations have been performed since the last submission.

#### **4.2.2.6 Category-specific planned improvements**

No improvements are planned for the next submission.

### **4.2.3 Glass Production (CRT 2.A.3)**

#### **4.2.3.1 Category description**

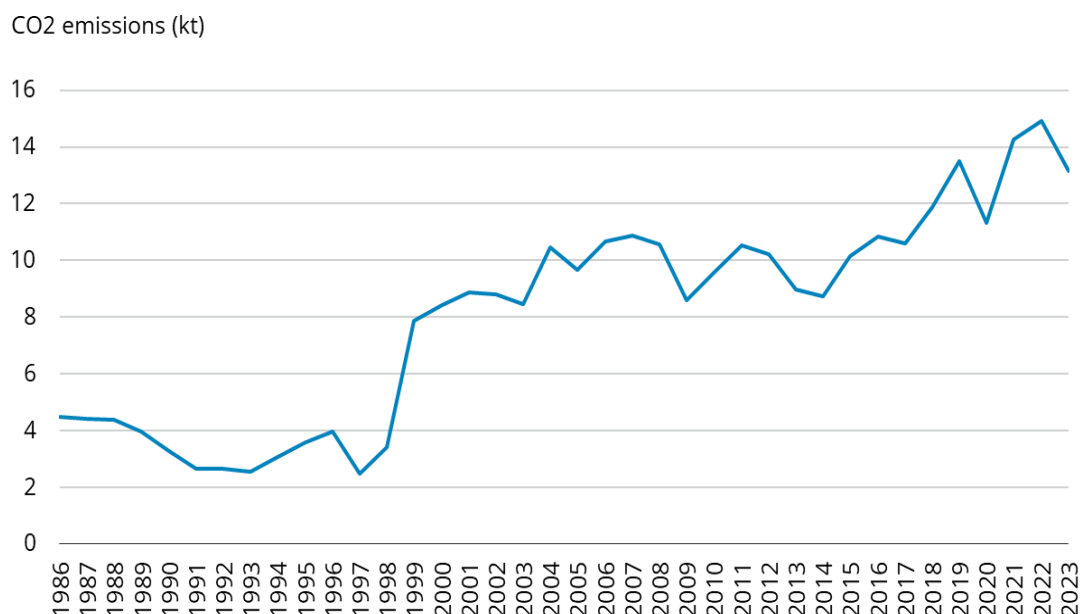
This chapter comprises CO<sub>2</sub> emissions from glass manufacturing and from the production of glass wool, where the production process is like glassmaking. The emissions are reported under Glass Production (CRF Code: 2A3). There are four glass and glass wool producers in Slovenia.

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.

#### **4.2.3.1 Methodological issues**

CO<sub>2</sub> emissions from glass production for the period 1999-2023 have been calculated considering 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>).

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.



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

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.

#### 4.2.3.2 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%.



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

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

#### **4.2.3.4 Category-specific recalculations**

No recalculations were performed since the last submission.

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

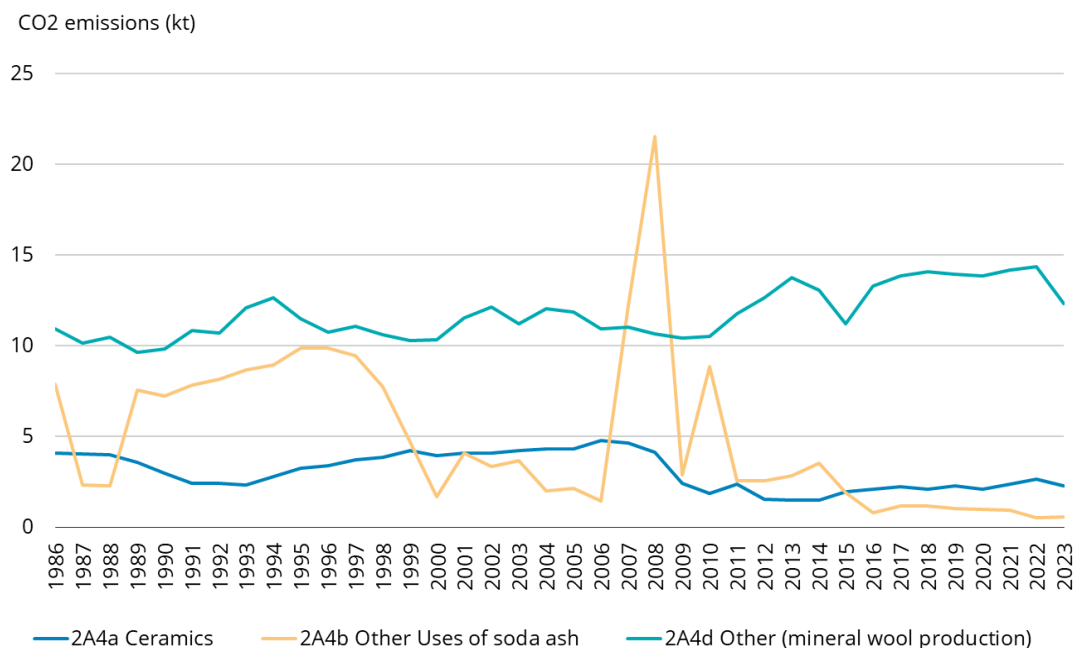
#### **4.2.4.2 Methodological issues**

##### 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 2005-2023 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. CO<sub>2</sub> emissions for the period 1986-1994 have been estimated with extrapolation method.



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

#### 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 1986-2023 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 1998-2023 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 for the period 1986-2012 have been obtained from the producer of mineral wool used for insulation purposes. The default 2006 IPCC emission factor 0.47732 t CO<sub>2</sub>/t dolomite has been used for the period 1986-

2012. For the period 2013-2023 ETS data on the consumption of individual carbonates have been available. The default 2006 IPCC emission factors 0.43971 t CO<sub>2</sub>/t calcium carbonate and 0.52197 t CO<sub>2</sub>/t magnesium carbonate have been used for the period 2013-2023.

#### **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 2023 the data on uncertainties from the ETS has been used in combination of uncertainties from 2006 IPPC GL. For the biggest company which emitted more than 82% of emissions this uncertainty was 1,41 %, while for the rest of emissions the uncertainty of AD was 5% and EF was 1%. Total combined uncertainty of emissions from other uses of carbonates was 2.05%.

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

We carried out surveys to determine that all carbonates use in the country was accounted for.

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

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

No recalculations were performed since the last submission.

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

No improvements are planned for the next submission.

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

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

#### **4.3.1.1 Category description**

The production of nitric acid ( $\text{HNO}_3$ ) 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 (CRT code: 2B2).

#### **4.3.1.2 Methodological issues**

Nitric acid production existed in Slovenia in the period 1997-2005. Since 2006 there is no production of nitric acid in Slovenia. No emissions of  $\text{N}_2\text{O}$  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 (CRT 2.B.5)

### 4.3.2.1 Category description

The greenhouse gas emissions are associated with the production of silicon carbide (SiC) and calcium carbide (CaC<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 (CRT code: 2B5).

### 4.3.2.2 Methodological issues

#### Silicon carbide production

Silicon carbide (SiC) is produced from silicon dioxide and petroleum coke. Petroleum coke is used as a source of carbon. CO<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 (CRT 2.B.6)**

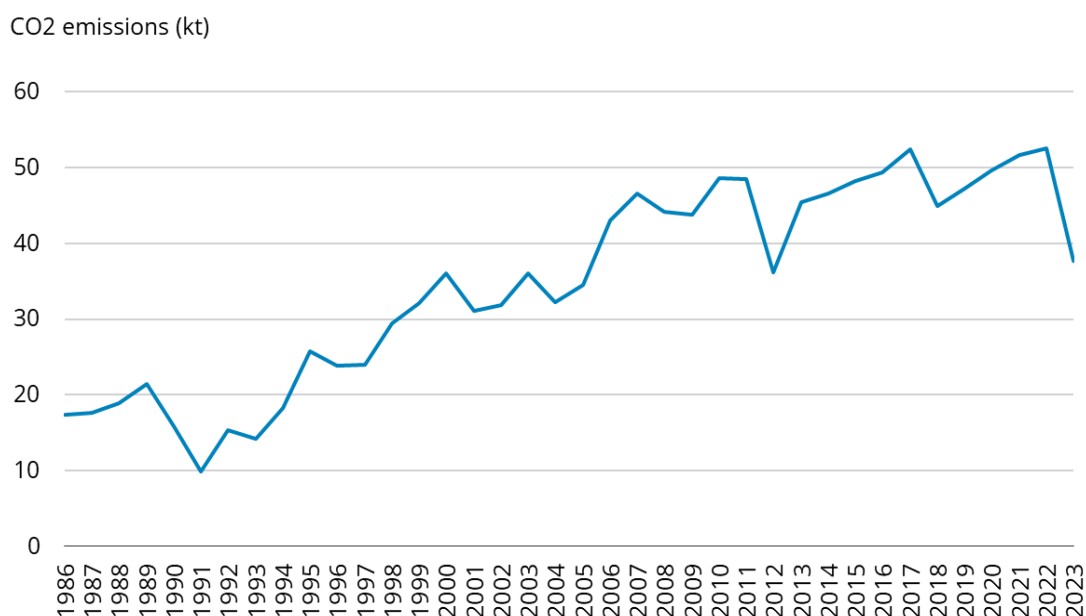
#### **4.3.3.1 Category description**

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 (CRT code: 2B6).

#### **4.3.3.2 Methodological issues**

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories sulphate route process does not give rise to the process of greenhouse gas emissions. But in the manufacturing of TiO<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 1986-2023. 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 (CRT 2.B.8)**

#### **4.3.4.1 Category description**

This category includes emissions arising from the production of petrochemicals (methanol, ethylene and propylene, ethylene dichloride, ethylene oxide, acrylonitrile). The petrochemical industry uses fossil fuels (e.g., natural gas) or petroleum refinery products (e.g., naphtha) as feedstock. In Slovenia, there was the only production of methanol. There is no other production of other petrochemicals in the country. CH<sub>4</sub> and CO<sub>2</sub> emissions from methanol production are reported under the subcategory Methanol (CRT 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 (CRT 2.B.10)**

#### **4.3.5.1 Category description**

This category includes emissions arising from the production of hydrogen by the steam reforming of natural gas. During this process, CO<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**

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

Due to the unavailability of methodology in the 2006 IPCC GL, CO<sub>2</sub> emissions are calculated using the same approach as for combustion emission using the same country specific NCV and CO<sub>2</sub> EF as for the energy sector, energy industry. The NCV and CO<sub>2</sub> EFs for natural gas were reported in the NIR (Tables 3.2.14 and 3.2.2 respectively).

#### **4.3.5.3 Uncertainties and time-series consistency**

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

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

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

A methodology for the determination of CO<sub>2</sub> emissions given in the 2019 Refinement to the 2006 IPCC Guidelines was examined. It was confirmed that the methodology currently applied is correct.

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

No recalculations were performed since the last submission.

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

No improvements are planned for this category.

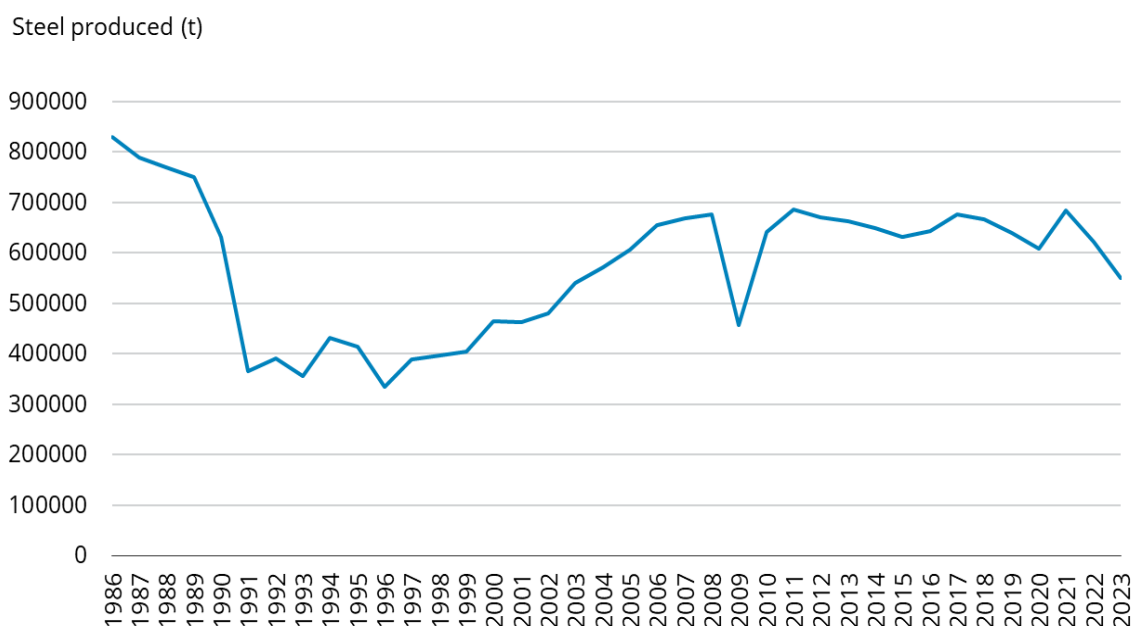
## 4.4 METAL PRODUCTION (CRT 2.C)

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

#### 4.4.1.1 Category description

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

In the production of iron CO<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 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**

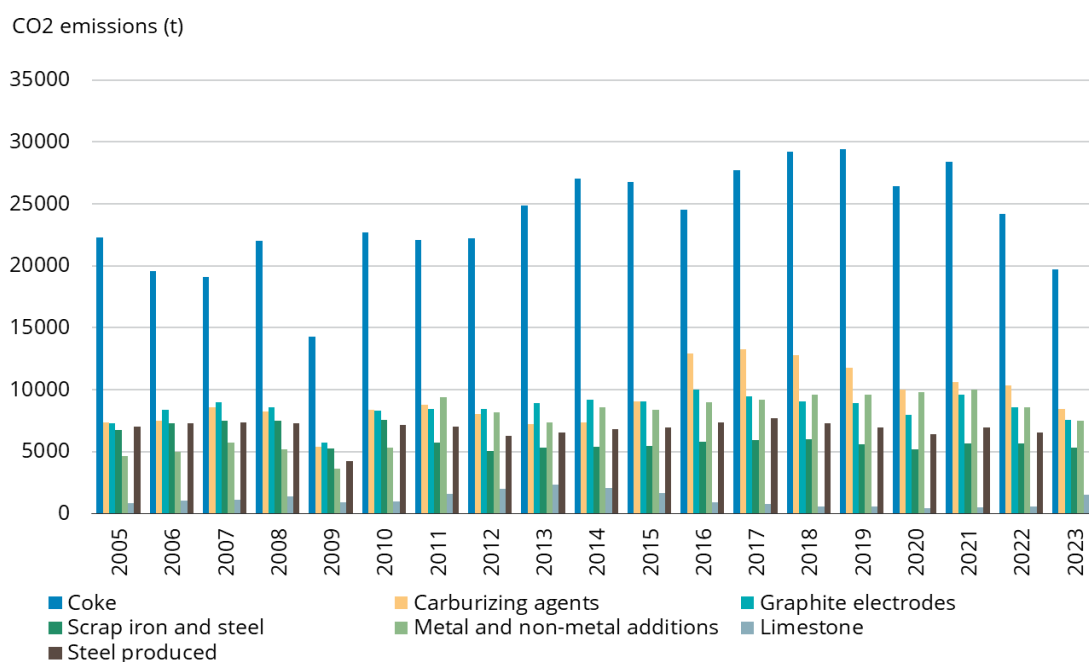
CO<sub>2</sub> emissions from iron production were calculated for the years 1986 and 1987. According to the UNFCCC ERT recommendation emissions of CO<sub>2</sub> from pig iron production have been recalculated for the years 1986 and 1987. CO<sub>2</sub> emissions had been calculated from the amount of pig iron produced. The production data were obtained from the producers. The emission factor used for emission calculation was obtained from the 2006 IPCC Guidelines, Volume 3: Industrial Processes and Product Use, Table 4.1, pg 4.25. The emission factor applied was 1.35 t CO<sub>2</sub>/t pig iron produced.

The CO<sub>2</sub> emissions from steel production for the period 2005-2023 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 2005-2023.

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 1988–2023 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 considered 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**

No improvements are planned for this category.

### **4.4.2 Ferroalloys Production (CRT 2.C.2)**

#### **4.4.2.1 Category description**

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

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

There had been only one ferroalloy producer in Slovenia. This factory was closed down in the first quarter of 2008 and consequently the production of ferroalloys was discontinued in 2008 as well. No ferroalloys were produced since 2008. This subsector contributed no emissions from 2009 onwards. CO<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 (CRT 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 must 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 despite 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.

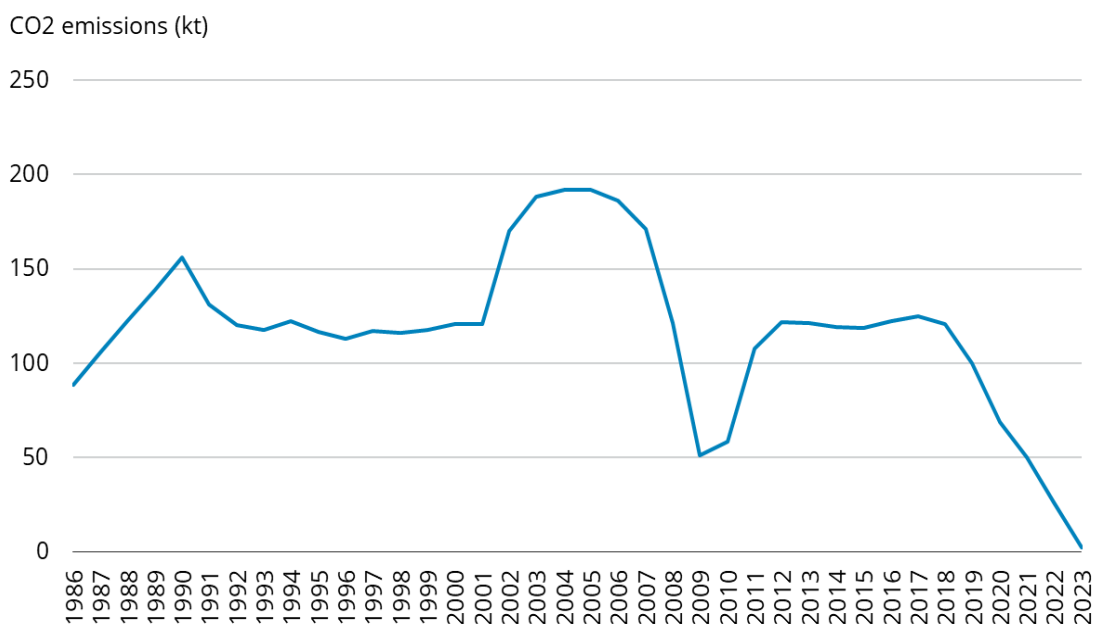
Simultaneously, the reduction cells in electrolysis unit B were reconstructed to use prebaked anodes.

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 the period 2020-2022, the production of aluminium decreased considerably due to a global pandemic and energy crisis and unstable political situation in Europe and worldwide. In March 2023, electrolysis was finally stopped.

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

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 2023 amounted to 0.412 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 the period 2020-2022, the CO<sub>2</sub> emissions decreased considerably due to smaller aluminium production because of the unstable situation on markets due to the global pandemic and energy crisis and unstable political situation in Europe and worldwide. The drastic drop in emissions is observed in 2023, due to switching off the electrolysis and closing the aluminium production (Figure 4.4.3).

In 2023, 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)

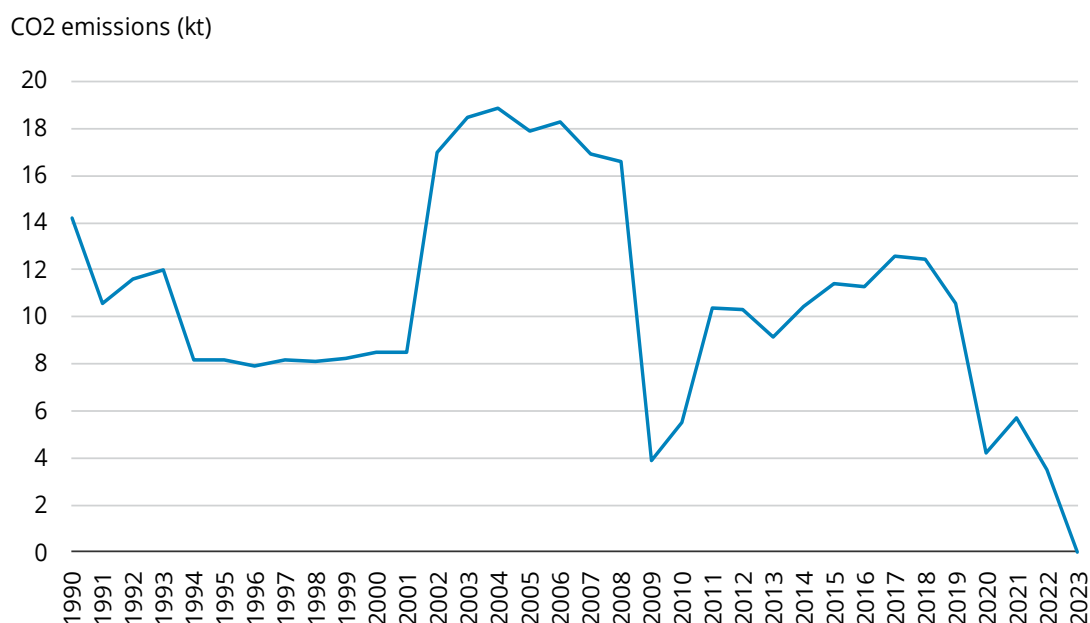
NAC = net prebaked anode consumption per tonne of aluminium (t C/t aluminium)

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).



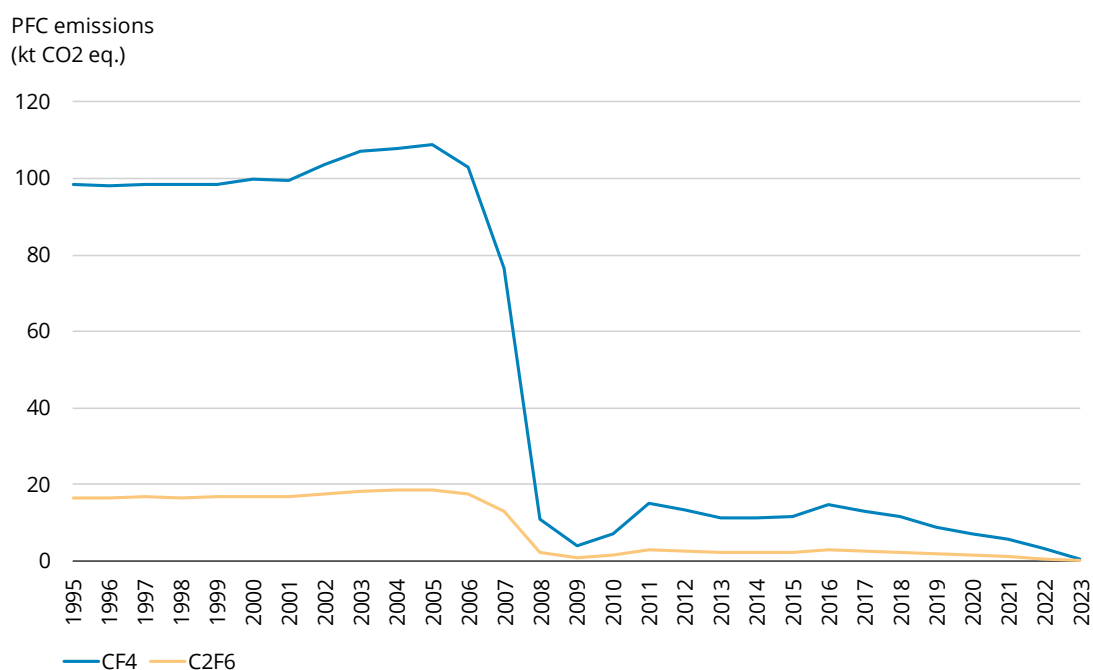
**Figure 4.4.4: CO<sub>2</sub> emissions in the process of anode production.**

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 to produce 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. In 2023 there was no production of anodes. 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 2023. 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 0.05 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 0.007 kg C<sub>2</sub>F<sub>6</sub>/ton Al in 2023.

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 - 2023. 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.



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

In 2023, electrolysis unit C with point feeding prebaked anode Pechiney technology has been in operation.

Referring to the fifth IPCC assessment report, 1 g CF<sub>4</sub> and 1 g C<sub>2</sub>F<sub>6</sub> have the greenhouse effect of 6630 and 11100 g CO<sub>2</sub>, respectively.

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,<br>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,<br>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,<br>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,<br>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 producer's expert team. We also visited the factory and observed a production operation and data acquiring in person.

#### **4.4.3.5 Category-specific recalculations**

No recalculations were performed since the last submission.

#### **4.4.3.6 Category-specific planned improvements**

No improvements are planned for the next submission.

### **4.4.4 Lead Production (CRT 2.C.5)**

#### **4.4.4.1 Category description**

The category comprises primary and secondary lead production. In the direct primary smelting process, the sintering step is skipped, and the lead concentrates and other materials are entered directly into a furnace in which they are melted and oxidized. The secondary production of refined lead amounts to the processing of recycled lead to prepare it for reuse. The vast majority of this recycled lead comes from scrapped lead acid batteries. The CO<sub>2</sub> emissions from lead production are reported under Lead Production (CRT code: 2C5).

#### **4.4.4.2 Methodological issues**

CO<sub>2</sub> emissions have been estimated for the period 1986-2023. 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 2017-2023 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 (1989-2023).

#### **4.4.4.3 Uncertainties and time-series consistency**

The uncertainty estimates are based on information on uncertainty from the 2006 IPCC GL  
 The uncertainty of the activity data amounts to 10%.  
 The uncertainty of the emission factors amounts to 50%.

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

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

#### **4.4.4.5 Category-specific recalculations**

No recalculations were performed since the last submission.

#### **4.4.4.6 Category-specific planned improvements**

No improvements are planned for the next submission.

### **4.4.5 Zinc Production (CRT 2.C.6)**

#### **4.4.5.1 Category description**

Zinc is produced from various primary and secondary raw materials. The primary processes use sulphidic and oxidic concentrates, while in secondary processes recycled oxidised and metallic products mostly from other metallurgical operations are employed. CO<sub>2</sub> emissions from zinc production are reported under Zinc Production (CRT code: 2C6).

#### **4.4.5.2 Methodological issues**

CO<sub>2</sub> emissions have been estimated for the period 1986-2023. 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 2017-2023 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 (CRT 2.D)**

### **4.5.1 Lubricant use (CRT 2.D.1)**

#### **4.5.1.1 Category description**

Lubricants are mostly used in industrial and transportation applications. The lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be divided into motor and industrial oils and greases. The CO<sub>2</sub> emissions from lubricant use are reported under Lubricant Use (CRT code: 2D1).

#### **4.5.1.2 Methodological issues**

CO<sub>2</sub> emissions have been estimated for the period 1986-2023. 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 5.8.1) 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 period 2012-2022 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.8.1) 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 (CRT 2.D.2)**

### **4.5.2.1 Category description**

Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are combusted during use (e.g., candles). The paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. The paraffin waxes are categorised by oil content and the amount of refinement. The CO<sub>2</sub> emissions from paraffin wax use are reported under Paraffin Wax Use (CRT code: 2D2).

### **4.5.2.2 Methodological issues**

CO<sub>2</sub> emissions for the period 2000-2023 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 GDP.

### **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**

The CO<sub>2</sub> emissions for the year 2022 were recalculated due to new activity data applied. The Statistical Office of the Republic of Slovenia provided updated data on the use of paraffin wax.

#### **4.5.2.6 Category-specific planned improvements**

No improvements are planned for this category.

### **4.5.3 Other (CRT 2.D.3)**

#### **4.5.3.1 Category description**

This sector comprises emissions of non-methane volatile organic compounds (NMVOC) from road paving with asphalt, asphalt roofing and solvent use, and CO<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, 2023 was applied for estimating NMVOC emissions from road paving with asphalt, asphalt roofing and solvent use. NMVOC emissions have been calculated for the period 1990-2023. Detailed information about the methodologies used is described in the Slovenian Informative Inventory Report 2025 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).

<https://cdr.eionet.europa.eu/si/un/clrtap/iir>

#### 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 2006-2023. 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 5.8.1) 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 year 2022 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 5.8.1) 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 (CRT 2.F)

### 4.6.1 Category description

This category includes HFC emissions, only. The emission sources, the time period and the gases included in the GHG inventory are presented in the Table 4.6.1. The gases have been used in the pure form and most often in the following blends: R-402a, R-404a, R-407a, R-407c, R-410a, R-417a and R-507a. For the purpose of the GHG inventory all blends have been transformed to the pure F-gases using the data from the Table 7.8 from 2006 IPCC GL, Vol 3.

**Table 4.6.1: Emission sources of F-gases with the time period.**

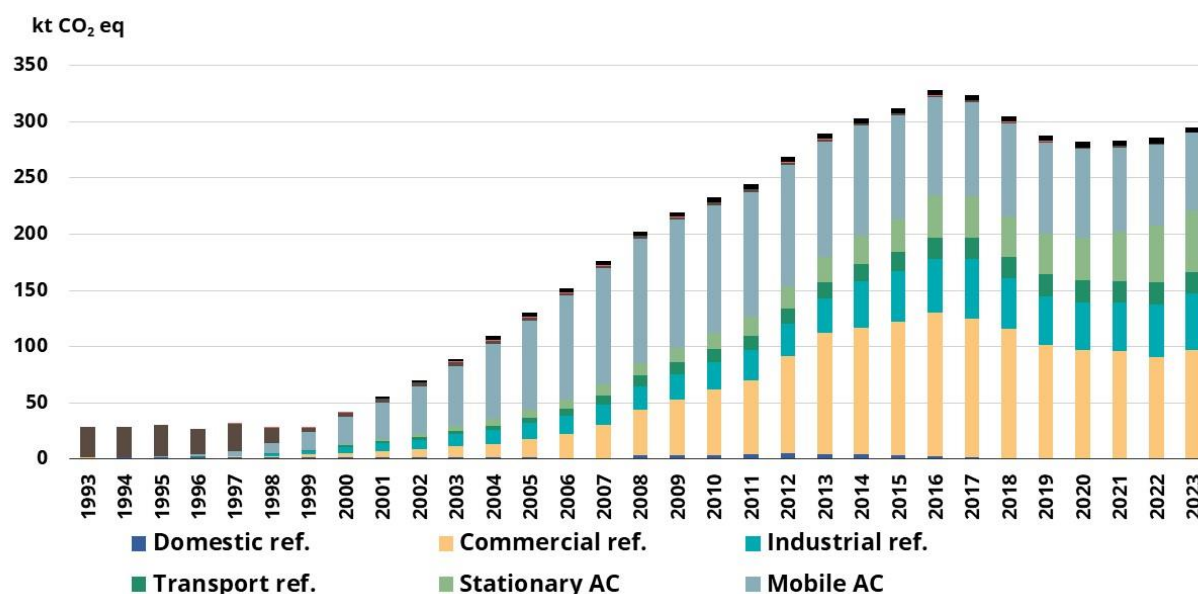
|   | period     | gases                               |
|---|------------|-------------------------------------|
| <b>Refrigeration and AC equipment</b>   |            |                                     |
| - domestic refrigeration                | Since 1993 | HFC-134a                            |
| - 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 2022 was Commercial refrigeration with contribution of 31.3%. Mobile Air-Conditioning was the second most important source in 2022, 28.3% of all HFC emissions arose from the MAC. The production and sales of cars with air conditioning has risen sharply in recent years, but due to the EU directive from 2011, the increase use of the refrigerant

with lower GWP (R-1234yf) was observed. In addition the sealing of AC system in the new vehicles is much better than in the old one.



**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)

## 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 15 years for medium and large appliances. Product lifetime for industrial refrigerators is 25 years, hence in 2022 the disposal emissions occurred for the first time.

Transport refrigeration

To determine the amount of refrigerant used in this category the data from the official database of registered vehicles have been used. The trucks and trailers with the cooling unit has been divided into 3 groups according to the size: small – less than 3.5 t, medium – between 3.5 and 10 t, and large – more than 10 t. The amount of refrigerant in each type of vehicle has been taken from the 2006 IPCC Guidelines, Vol. 3, Table 7.9. For small trucks and trailers the lower value from the range 3 kg has been used, for large the highest value 8 kg and for middle the average value 5.5 kg of refrigerant. The operation emissions have been calculated using emission factor of 30%. In Slovenia in the transport refrigerators only HFC 134a and HFC 404a have been used. No data are available on share of each F-gas, therefore it has been assumed that half of the amount is R134a and half is R404a. We also don't know how fast the ODS have been replaced with F-gases.

For the inventory purpose we have assumed that no F-gases were in these vehicles in the years before 1995.

According to the database on registered vehicles 80 to 200 trucks and trailers with the cooling unit have been yearly deleted from the database in the recent period. According to the evidence on disposed vehicles, these vehicles have not been disposed in Slovenia. In Slovenia there is no centre for decommissioning of spent trucks and buses therefore no transport refrigerators can be legally disposed in the country.

To avoid illegal disposal of old vehicles and to encourage the owners of the deregistered vehicle to dismantle the vehicle in accordance with environmental protection regulations in April 2018 the new legislation come into force. According to this legislation the owners of the nonregistered vehicles have to pay the duty for a deregistered vehicle. This obligations ends when the vehicle is decommissioned or when the vehicle is re-registered. The obligation also ceases if the owner deregisters the vehicle from registration submits to the competent authority:

- a) certificate of destruction of the vehicle in accordance with regulations on environmental protection,
- b) a police report showing that the vehicle was stolen,
- c) proof that the vehicle is registered in another country,
- d) export customs declaration confirming the exit of the vehicle from the EU customs area

This duty is not valid for heavy duty trucks, however it looks that all old trucks are exported to the other countries. In some cases for the decommission, but more often to be further used in the countries with less strict environmental standards. For 2021 we have obtained the data on the export of used trucks and trailers and the main findings are:

- the number of exported used trucks and trailers was 7390 (in the same time an import of such vehicles was 2046)
- about 75% of spent trucks and trailers were exported to the Former Yugoslav republics, which are not part of EU, as much as 62% to Serbia)
- the remaining was exported to the EU (21%), Africa (2%) and other countries 2%.



Taking into consideration that in 2021 about 2.9% of truck/trailers has an ATP unit, the number of exported transport refrigerators is more than 200 what is almost the same as the number of such vehicles deleted from the database on registered vehicles in this year.

Emissions from transport equipment accidents are not included in the inventory because exact data on the amount of refrigerant which is lost during accident is not available. We have estimate this amount based on the total number of truck/trailers which were involved in the accident in the period 2015 – 2021. We have assume the same proportion of trucks/trailers with the cooling unit to be involved in the accident and that during every accident the total amount of refrigerant is lost, what is an overestimation. Emissions due to the accidents have been estimated to be between 1.2 and 1.9 kt CO<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.

At the beginning of disposal in 2008 we have used disposal factor 85% as suggested from the expert who is familiar with the situation at a car recycling facilities. This factor has slowly decreased and since 2015 the middle value of the default range is used.

The disposal factor of 85%, which was used at the start of decommissioning, was recommended by experts from the Ministry of the Environment, which supervised the implementation of the legislation in practice and had a good overview of used vehicle centres. This factor was very high because the end-of-life vehicle recovery facilities were only gradually adapting to the new legislation, which required that the collection of HFCs from air conditioners be carried out only by certified personnel and with appropriate equipment. Fortunately, there were very few used cars with air conditioning back then.

Until 2011, the system of end-of-life vehicles management was provided by public utility services. One essential measure for the functioning of the system was the introduction of the

“dismantling certificate”. Upon deregistration of a vehicle, the last owner of a vehicle qualifying as an end-of-life vehicle pursuant to regulations governing environmental protection and end-of-life vehicle management was obliged to present a certificate of vehicle destruction. The service of dismantling is free of charge for the last owner of a vehicle.

According to the most recent estimates, at least 30,000 end-of-life vehicles are generated in Slovenia each year. The actual number of dismantled ELVs differed considerably from these estimates largely due to abuse of the instrument of deregistration of vehicles. Vehicle location statements were being abused in such a way that the last owners were using them to deregister vehicles that were later being illegally dismantled. In view of the large number of vehicle location statements that were issued in Slovenia (approximately 15,000 annually), it was impossible to efficiently carry out control of vehicles that were deregistered in this way.

With the adoption of a new regulation in 2011 introducing extended producer responsibility, end-of-life vehicle management has become more transparent. In Slovenia there are currently 51 collection points for end-of-life vehicles that collect ELVs under the authorisation of three dismantling facilities operating within the framework of the extended producer responsibility system [Evidenca-nacrto-v-ravnanja-z-izrabljenimi-vozili.pdf](#) (gov.si) . In addition, 24 independent facilities for ELV dismantling operate. ( [Samostojni-obra-ti-za-razstavljanje-izrabljenih-vozil-in-pripadajoca-zbiralna-mesta.pdf](#) (gov.si) . For the last owner, recovery of an end-of-life vehicle is free of charge. Upon handing over an end-of-life vehicle for dismantling, the owner is issued a certificate of destruction.

In 2018 the additional regulation was adopted. Owners of vehicles, who deregister the vehicle become liable for the payment of duty on deregistered vehicles. The duty for deregistered vehicles must be paid every year by the owners of a certain category of vehicles, namely for passenger vehicles, light duty trucks (below 3.5 t) and three-wheeled mopeds.

Owners of these vehicles can avoid paying the fee in cases where it is clear from the records of registered vehicles that the vehicle was decommissioned in accordance with environmental protection regulations or if they provide proof that the vehicle was registered in another country. With this new legislation, the inspection of used vehicles will be improved. For now, there is no official data on where these vehicles if they are not disposed in the county, end up.

#### Emission factors used

On the table 4.6.2 comparison of EFs and other parameters used in the inventory (upper line) with the range from 2006 IPCC Guidelines is presented. At the beginning the emission factors have been taken from a research made by The Chamber of commerce and industry, while for the recent period EF used based on the actual data or on the expert judgements taking into account information available in the 2006 IPCC Guidelines.

**Table 4.6.2: HFC emissions in 2023, 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><br>Range from 2006 IPCC GL                  | 1<br>0.2 - 1      | 0.5<br>0.1 – 0.5  | 15<br>12 - 20     | 70<br>0 - 70 | 85<br>0 - 80   | 0.01                                  |
| <b>Commercial refrigeration</b><br>Stand alone<br>Range from 2006 IPCC GL | 3<br>0.5 – 3      | 8<br>1 – 15       | 12<br>10 – 15     | 70<br>0 – 70 | 40<br>0 – 80   | 97.1                                  |
| Medium and large<br>Range from 2006 IPCC GL                               | 3<br>0.5 – 3      | 25*<br>10 - 35    | 15<br>7 – 15      | 70<br>0 - 70 | 75<br>50 - 100 |                                       |
| <b>Industrial refrigeration</b><br>Range from 2006 IPCC GL                | 3<br>0.5 – 3      | 12*<br>7 - 25     | 25<br>15 - 30     | NO<br>0 - 90 | NO<br>50 - 100 | 50.3                                  |
| <b>Transport refrigeration</b><br>Range from 2006 IPCC GL                 | NO<br>0.1 - 1     | 30<br>15 - 50     | NA<br>6 - 9       | NO<br>0 - 70 | NO<br>0 - 50   | 18.5                                  |
| <b>Stationary Air Conditioning</b><br>Range from 2006 IPCC GL             | 0.6<br>0.2 - 1    | 1 – 10*<br>1 – 10 | 15<br>10 - 20     | 80<br>0 - 80 | 40<br>0 - 80   | 50.0                                  |
| <b>Mobile Air Conditioning</b><br>Range from 2006 IPCC GL                 | 0.5<br>0.5        | 10<br>10 - 20     | 15<br>9 - 16      | 50<br>0 - 50 | 25<br>0 - 50   | 69.1                                  |

*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 company's database of installed fire protection equipment is not complete. Because we are aware of this, we are not using the data from this database for the calculation, so for this reason, the emissions are not underestimated.

First data about HFC used as a replacement for CFC was collected for the research made in 1999 (Chamber of Commerce, 1999). In this research it was assumed that 400 kg of HFC would be used per year. According to information from The operational plan of the Republic of Slovenia for management of Halon, 5800 kg of CFC still existed in fire extinguishers in 2002. It was assumed that the total amount was replaced with substitutes until the end of 2005. Due to the lack of detailed data we have assumed that all CFC was replaced with HFC, which is probably an overestimation.

For the 2021 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 used for a replacement of gas which is released during the

firefighting. For this reason, amount filled in the installations in particular year is the same as emitted amount from the use.

Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated

In calculating emissions of HFC, IPCC methodology and the therein-stated assumption that emissions amount to 5% of the quantities used in new stationary systems were applied. This assumption is derived from experience with the use of Halon systems and is supposed to be appropriate also for estimating HFC emissions. Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated. The EF from the 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.

Reference for EF 5% for the first filling is the Operational plan on replacement of Halons with HFC. There the EF of 5% which were used for Halons is recommended, to be used also for HFC. We have used this value for the period 1996-1999. Since 2012, only one service company (Zarja) fills HFC-227ea into fire protection systems in Slovenia. Based on their experience, they suggested using an EF of 0.5%. We are using this value since 2012, while the EFs for years in between are interpolated.

Slovenia is the member of EU since 2004 and therefore all relevant EU regulations are directly applicable in the country. The legislation is therefore available on:  
[https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases\\_en](https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases_en)

In addition the Slovenian legislation is a Decree on the use of fluorinated greenhouse gases and ozone-depleting substances. This regulation defines:

- the competent authorities, supervision and sanctions for violations.
- determines the rules for training and issuing certificates to the person who carries out leak detection, capture, installation, maintenance, repair or dismantling of equipment containing F-gases and rules for the selection of training providers.
- determines the obligation to register equipment containing F-gases and the reporting obligation of the operator, maintainer and authorized company in relation to the use, collection and delivery of waste F-gases.

## 2.F.4 Aerosols/Metered Dose inhalers

In this category only emissions from metered dose inhalers is considered. Slovenia began to use HFC-134a in the MDI in 2001 as replacement for the CFC.

Data on MDI have been obtained from the Slovenian Health Insurance Institute. For calculation of emissions we have assume that all amount of HFC-134a from medical equipment which is sold in one year is release in the same year. EF is therefore equal to 100%. There is no production of this type of medicine in Slovenia.

## 4.6.3 Uncertainties and time-series consistency

The uncertainty estimates are based on an expert judgement and presented in the table 4.6.3 below.

**Table 4.6.3: Uncertainties in %.**

| Category  | AD | EF | Combined uncertainty |
|---|----|----|----------------------|
| 1. Refrigeration and Air Conditioning Equipment | 20 | 30 | 36.1                 |
| 2. Foam Blowing                                 | 10 | 50 | 51.0                 |
| 3. Fire Extinguishers                           | 10 | 20 | 22.4                 |
| 4. Aerosols/MDI                                 | 50 | 0  | 50                   |

## 4.6.4 Source-specific QA/QC and verification

After applying the standard QC procedure data, EFs and emissions have been undergoing the following QA/QC procedures:

- all EFs have been compared with the EFs from 2006 IPCC Guidance;
- values of stock have been compared with the data from neighbouring countries;
- emissions from every CRT category have been compared with the emissions from neighbouring countries

For the purpose of verifying the F gases, data from the reports in accordance with the Regulation 517/2014 have been used.

By 31 March 2015 and every year thereafter, each producer, importer and exporter that produced, imported or exported one metric tonne or 100 tonnes of CO<sub>2</sub> equivalent or more of fluorinated greenhouse gases and gases listed in Annex II during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

By 31 March 2015 and every year thereafter, each undertaking that used 1 000 tonnes of CO<sub>2</sub> equivalent or more of fluorinated greenhouse gases as feedstock during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

By 31 March 2015 and every year thereafter, each undertaking that placed 500 tonnes of CO<sub>2</sub> equivalent or more of fluorinated greenhouse gases and gases listed in Annex II contained in products or equipment on the market during the preceding calendar year shall report to the Commission the data specified in Annex VII on each of those substances for that calendar year.

Each importer of equipment that place on the market pre-charged equipment where hydrofluorocarbons contained in this equipment have not been placed on the market prior to the charging of the equipment shall submit to the Commission a verification document issued pursuant to Article 14(2).

Although we have some difficulties in understanding this report, we note that the data from these reports is quite different from what we report. Basically, the amounts of F gases in the reports are too small, especially HFC 134a, which is used to fill car air conditioners. The reason may be that smaller utilities do not need to report and may not buy this gas in Slovenia.

#### **4.6.5 Category-specific recalculations**

##### 2.F.1 Refrigeration and Air conditioning, , HFCs

Emissions of HFC from Industrial refrigeration for the period 2019-2022 were recalculated due to the improved of data on replenish quantity of F-gases from the authorised service companies.

#### **4.6.6 Source-specific planned improvements**

Slovenian F-gases database has not been completed yet. Every year, new devices are included and the amount of F-gases in stock is increasing. For this reason, data on stock will be updated regularly and, if needed, and recalculation of emissions will be performed. This can be regarded as an ongoing process and will probably lead to an improvement of the inventory.



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

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

#### 4.7.1.1 Category description

SF<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 from a high-voltage equipment.**

| Emissions from              | Units                       | 1986         | 1990         | 1995         | 2000         | 2005         | 2010         | 2015         | 2020         | 2023         |
|-----------------------------|-----------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| manufacturing               | kg                          | 0.1          | 0.0          | 0.9          | 1.4          | 2.6          | 2.3          | 1.2          | 0.5          | 0.0          |
| stock                       | kg                          | 428.4        | 431.1        | 481.2        | 657.1        | 786.7        | 751.2        | 730.1        | 699.2        | 699.2        |
| disposal                    | kg                          | -            | -            | -            | -            | -            | -            | 0.4          | -            | -            |
| <b>Total SF<sub>6</sub></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>753.5</b> | <b>731.7</b> | <b>700.0</b> | <b>699.2</b> |
| <b>Total SF<sub>6</sub></b> | <b>Gg CO<sub>2</sub> eq</b> | <b>10.1</b>  | <b>10.1</b>  | <b>11.3</b>  | <b>15.5</b>  | <b>18.5</b>  | <b>17.7</b>  | <b>17.2</b>  | <b>16.4</b>  | <b>16.4</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 0.15%. Experts justify such a low factor with an extremely high gas price.

At the end of life, all SF<sub>6</sub> equipment, including hermetically sealed-pressure switchgear, is properly decommissioned to avoid emissions. Any remaining gas is fully extracted using recovery systems that achieve acceptable blank-off pressure (i.e., vacuum generated during the recovery process to levels of 0.05 bars and lower). Used SF<sub>6</sub> is purified either on-site or off-site. A gas that is non-reusable is collected in the original cylinders in which the SF<sub>6</sub> gas was supplied and is sent to specialized incineration plants to other countries (e.g. France) for destruction. There is not such plant in Slovenia. The value 0.15% was obtained in the personal communication with the experts from the largest users of SF<sub>6</sub>. We have contacted more of them and majority assured that there is no leakages at all. There is no reason that in our case the leakages are higher from leakages during the installation for which value 0.15% is used.

When calculating 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 (CRT 2.G.2)

### 4.7.2.1 Category description

The other uses of SF<sub>6</sub> in Slovenia, which are included in the GHG inventory are:

- SF<sub>6</sub> used in research particle accelerators (since 1997);
- SF<sub>6</sub> used in electronic microscopes (since 2002);
- SF<sub>6</sub> used in equipment in medical particle accelerators (since 1986);
- SF<sub>6</sub> used in equipment in industrial particle accelerators (since 2017);
- SF<sub>6</sub> used in sound-proof windows (1995-1997);

### 4.7.2.2 Methodological issues

#### Research particle accelerator

SF<sub>6</sub> is used in university and research operated particle accelerators as an insulating gas. Typically, high voltage equipment is contained and operated within a vessel filled with SF<sub>6</sub> at a pressure exceeding atmospheric pressure.

There is only one research accelerator in Slovenia, it is in MIC - Microanalytical Centre at Jožef Stefan Institute (JSI). Accelerator "Tandetron" started to operate in December 1997. Acceleration of ions takes place electrostatically in a DC electric field provided by a rectifier with a voltage of up to 2 MV (two million volts). The accelerator is among the most technologically advanced electrostatic accelerators, as high voltage is created in the rectifier without mechanically moving parts with semiconductor diodes. The rectifier is very stable, because at an output voltage of 2 million volts, the voltage instability is only about 100 V.

**Table 4.7.2: SF<sub>6</sub> emissions from a research particle accelerator**

|  | 1997- installation | 2011, 2015, 2020 | Other years 1998-2023 |
|--|--------------------|------------------|-----------------------|
| <b>Number of accelerators</b>                        | 1                  | 1                | 1                     |
| <b>Capacity (kg )</b>                                | 350                | 350              | 350                   |
| <b>Leakages in kg at installation or maintenance</b> | 5                  | 5                | -                     |
| <b>Leakages in kg due to the use</b>                 | -                  | 3.5              | 3.5                   |
| <b>Total kg SF<sub>6</sub></b>                       | <b>5</b>           | <b>8.5</b>       | <b>3.55</b>           |
| <b>Total kt CO<sub>2</sub> eq</b>                    | <b>0.118</b>       | <b>0.200</b>     | <b>0.107</b>          |

The nameplate capacity of SF<sub>6</sub> is 350 kg. The largest leakages occurred at installation in 1997 and during maintenance (around 5 kg). The first maintenance was in 2011, and the following was in 2015 and 2020. According to the information from JSI they lost only 100 kg

of SF<sub>6</sub> in 25-years of operation what includes also leakages during installation and maintenance.

For inventory purpose we are therefore using Tier 3 methodology with PS EF to be 1% in normal year and 2.4% in the year of maintenance. The IPCC 2006 GL suggests that annual losses range between 5% and 7% of vessel capacity. These values are very high and in no way suitable for our situation. The losses generally depend on the vessel opening frequency plus the efficiency of the recovery and transfer equipment. On Table 4.7.2 emissions from a research particle accelerator are presented

### Electron microscopes

Electron Microscopes are divided into scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The accelerating voltage of a SEM is variable, usually in the range 0.5 to 30 kV and they don't use SF<sub>6</sub> as a high voltage insulator. In SEM, SF<sub>6</sub> is typically used as a gas that is introduced into the chamber to enhance the imaging of the sample surface by producing secondary electrons from the sample. No such use of SF<sub>6</sub> was detected in Slovenia.

**Table 4.7.3: SF<sub>6</sub> emissions from electron microscopes.**

|                                   | 2002-2006    | 2007-2008    | 2009-2010    | 2011-2012    | 2013-2014    | 2015-2016    | 2017-2018    | 2019-2023    |
|-----------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>Number of microscope</b>       | 2            | 3            | 4            | 5            | 6            | 7            | 8            | 9            |
| <b>Capacity (kg)</b>              | 10           | 10           | 10           | 10           | 10           | 10           | 10           | 10           |
| <b>Total amount in kg</b>         | 20           | 30           | 40           | 50           | 60           | 70           | 80           | 90           |
| <b>EF in %</b>                    | 2.6          | 2.6          | 2.6          | 2.6          | 2.6          | 2.6          | 2.6          | 2.6          |
| <b>Total kg SF<sub>6</sub></b>    | <b>0.52</b>  | <b>0.78</b>  | <b>1.04</b>  | <b>1.30</b>  | <b>1.56</b>  | <b>1.82</b>  | <b>2.08</b>  | <b>2.34</b>  |
| <b>Total kt CO<sub>2</sub> eq</b> | <b>0.012</b> | <b>0.018</b> | <b>0.024</b> | <b>0.031</b> | <b>0.037</b> | <b>0.043</b> | <b>0.049</b> | <b>0.055</b> |

It is different situation with a TEM which are using high voltage up to 200 kV. They are all using SF<sub>6</sub>, there was 2 such electronic microscope in Slovenia in 2002 and the number gradually increased to 9 in 2019. A typical nameplate capacity is 10 kg. These components are sealed and there are almost no emissions during operation. The microscopes are in the special room equipped with sensors which will detect any leakages. Possibly emissions are only during the yearly maintenance. Emissions are calculated with Tier 1 approach and default EF 2.6%. from IPCC 2006 GL, Vol 3, Table 8.3 and are presented in table 4.7.3.

### Medical particle accelerators

There were 2 medical particle accelerators in 1986 and since 2010 there are 8 medical particle accelerators in Slovenia. They are all located at Institute for Oncology in Ljubljana

and used for radiation therapy for patients with a cancer. No detailed data about this accelerators is available to the inventory team, therefore emissions are calculated using Tier 1 approach and default values from the IPCC 2006 GL, Vol 3, Table 8.9. The amount of SF<sub>6</sub> used is 0.5 kg/accelerator and leakages are 2%.

Emissions are presented on the Table 4.7.4.

**Table 4.7.4: SF<sub>6</sub> emissions from medical particle accelerators.**

|                                    | 1986-1989 | 1990-1994 | 1995-2000 | 2001-2005 | 2006-2008 | 2009  | 2010-2023 |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-------|-----------|
| Number of medical PA               | 2         | 3         | 4         | 5         | 6         | 7     | 8         |
| Capacity (kg)                      | 0.5       | 0.5       | 0.5       | 0.5       | 0.5       | 0.5   | 0.5       |
| Total amount in kg SF <sub>6</sub> | 1         | 1.5       | 2         | 2.5       | 3         | 3.5   | 4         |
| EF (kg/kg)                         | 2         | 2         | 2         | 2         | 2         | 2     | 2         |
| Total kg SF <sub>6</sub>           | 2         | 3         | 4         | 5         | 6         | 7     | 8         |
| Total kt CO <sub>2</sub> eq        | 0.047     | 0.071     | 0.094     | 0.118     | 0.141     | 0.165 | 0.188     |

#### Industrial accelerators

It is not easy to get information about the use of linear particle accelerators (LPAs) in the industry because they do not publish this information online, as do medical or research institutions. That's why we turned to the Nuclear Safety Administration of the Republic of Slovenia for help, since in accordance with the legislation (Regulation on Radiation Activities), it keeps records of LPAs, which are radiation facilities of minor importance.

There are two facilities of this type in Slovenia - one is used for scanning trucks in the port of Koper, and the other for sterilizing new medical equipment. The nameplate capacity of the first one is 4 kg and the second one 1.55 kg SF<sub>6</sub>.

**Table 4.7.5: SF<sub>6</sub> emissions from industrial accelerators.**

|                             | 2017  | 2018  | 2019  | 2000  | 2021  | 2023  |
|-----------------------------|-------|-------|-------|-------|-------|-------|
| Number of companies         | 1     | 1     | 1     | 2     | 2     | 2     |
| Amount in kg                | 1.55  | 1.55  | 1.55  | 5.55  | 5.55  | 5.55  |
| Total kg SF <sub>6</sub>    | 45    | 36    | 31    | 10.3  | 3.3   | 2.8   |
| Total kt CO <sub>2</sub> eq | 1.058 | 0.846 | 0.728 | 0.242 | 0.077 | 0.065 |

Emissions from the first company are calculated with the IPCC default EF from IPCC 2006 GL, Vol 3, Table 8.2. which is suitable for Europe.

Emissions in the second companies was very high in the past, because they had a lot of breakdowns, which require repairs several times a year. During this repairs, all SF<sub>6</sub> was released, and the supply pipes were also purged with SF<sub>6</sub>. They will no longer do this in the future, they have also acquired their own device for gas cleaning, which will enable that after cleaning the SF<sub>6</sub> is returned to the system. In calculation of emissions from this company their estimate of yearly leakages are included (Tier 3)

Emissions from this source are in the Table 4.7.5.

#### Sound-proof windows

In the period 1995-1997 the production of double-glazed sound-proof windows had occurred in Slovenia. All windows had been exported, thus no emissions from stock occurred. Since 1997 there has been no use of SF<sub>6</sub> for production of the soundproof windows in Slovenia. According to the Regulation on certain fluorinated greenhouse gasses, placing of double glazed windows filled with SF<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>

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 calculation of emissions from manufacturing the EF of 10% has been used.

#### **4.7.2.3 Uncertainties and time-series consistency**

The uncertainty estimates are based on an expert judgement.

The uncertainty of the activity data amounts to 20%.

The uncertainty of the emission factor amounts to 10%.

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

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

#### **4.7.2.5 Category-specific recalculations**

No recalculations were performed since the last submission.

#### **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 (CRT 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 1986-2023. 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 1999-2023 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.

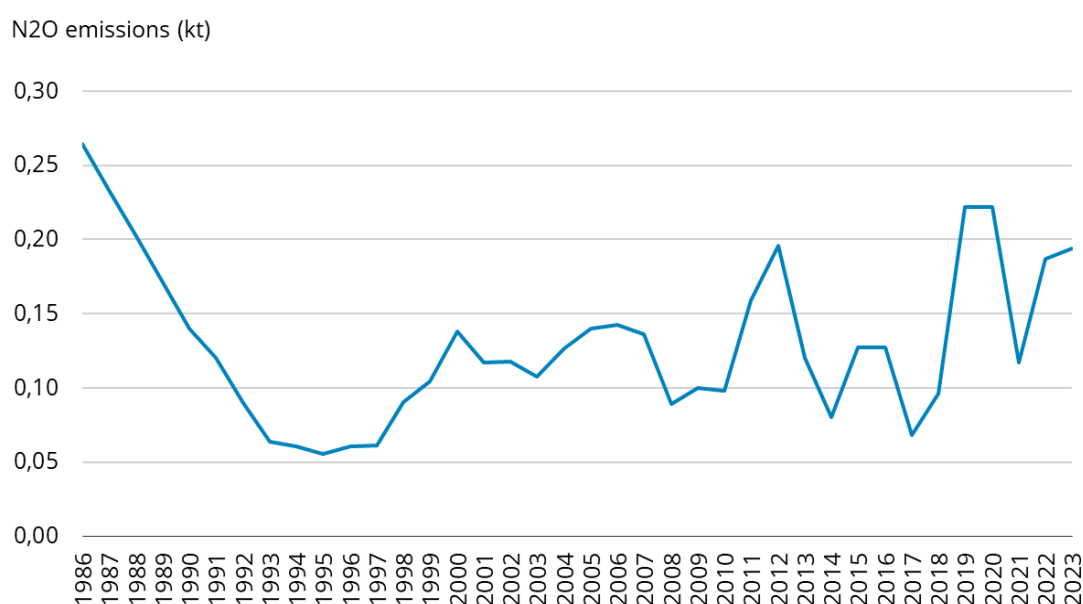


Figure 4.7.1: N<sub>2</sub>O emissions from product uses.

#### **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**

The N<sub>2</sub>O emissions for the year 2022 were recalculated due to new activity data applied. The Statistical Office of the Republic of Slovenia provided updated data on the N<sub>2</sub>O use in medical applications.

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

No improvements are planned for this category.



## 5 AGRICULTURE (CRT sector 3)

### 5.1 Overview of sector

In agricultural activities, emissions of GHGs are generated from a variety of different sources. This section includes the quantification of CH<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 2023 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 | -       |
| <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 2023 amounted to 1,632 Gg CO<sub>2</sub> eq, which represents 11% of all emissions. Agriculture represents the main source of methane and N<sub>2</sub>O emissions, namely 63.6% of all methane emissions and 66.6% of all N<sub>2</sub>O emissions. In the agricultural sector, CH<sub>4</sub> emissions accounted for 71.6% of emissions and N<sub>2</sub>O emissions accounted for 25.9% of emissions, while CO<sub>2</sub> emissions accounted for 2.5% only. GHG emissions from agriculture show small oscillations for individual years, but the general trend is on the decrease. In 2023, emissions were 20.5% below the emissions in the base year.

The most important sub-sector represented emissions from enteric fermentation, which contributed 59.8% of all emissions from agriculture, followed by emissions from agricultural soils, with 22.4%; the rest is contributed by emissions of methane and N<sub>2</sub>O from animal manure (15.2%) while CO<sub>2</sub> emissions due to the liming and application of urea and other C-containing fertilizers represented only 2.5% of emissions in this sector (Figure 5.1.1).

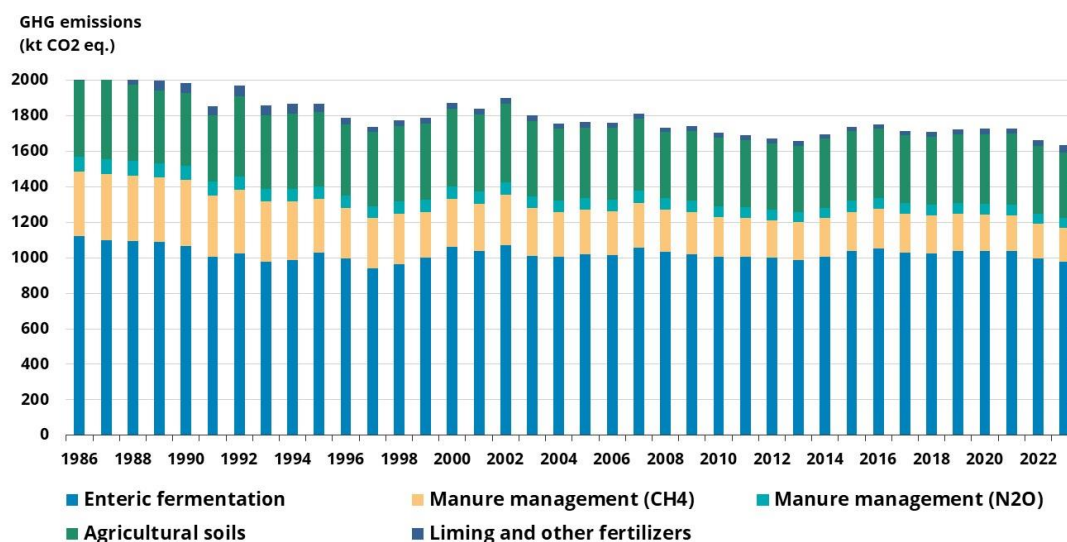


Figure 5.1.1: GHG emissions from agriculture activities in Gg CO<sub>2</sub> eq.

## 5.2 Enteric Fermentation (CRT 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.

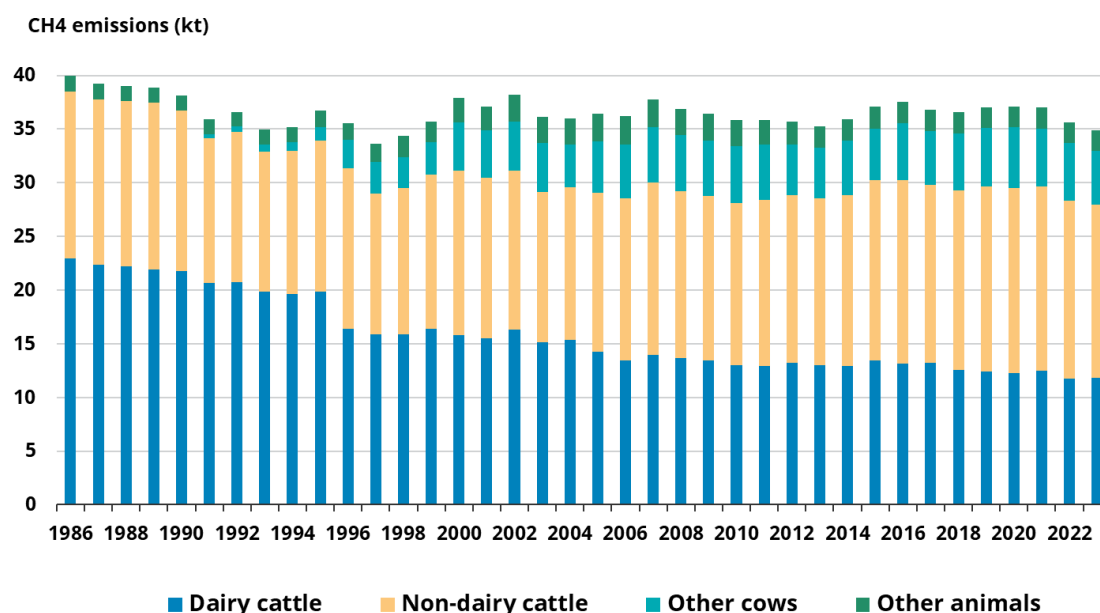


Figure 5.2.1: CH<sub>4</sub> emissions from enteric fermentation in Gg.

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 33.8% of total CH<sub>4</sub> emissions from enteric fermentation, other cows 14.3%, while non-dairy cattle represent about 46.4% of total CH<sub>4</sub> from enteric fermentation. Jointly, cattle are responsible for 94.5% of total CH<sub>4</sub> emissions from enteric fermentation in 2023 (Figure 5.2.1).

The contribution of all other animals to methane emissions from enteric fermentation, e.g. sheep, horses, swine, goats and rabbits, listed here according to the importance of their contributions, is around 5.5%. 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 (2019) 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). Since 2007 they are available on the SORS data portal SI-STAT data portal: <https://pxweb.stat.si/SiStat/en/Podrocja/Index/85/agriculture-forestry-and-fishery>

Some pieces of information, such as number of calves per cow and year, concentration of fat in milk for the period before the year 2000 and average daily gains in fattening cattle, were obtained from Central database CATTLE, managed by Agricultural Institute of Slovenia (most recent reports by Sadar et al., 2023 and Žabjek et al., 2023 or calculated on request).

**Table 5.2.1: The correspondence between statistical and IPCC categories**

| IPCC                      | SORS  |
|---------------------------|---|
| Dairy cattle              | Dairy cows over 2 years   |
| Other cows (suckler-cows) | Other cows over 2 years   |
| Non-dairy cattle          | All other cattle  |
| Non-dairy cattle          | <p><b>YOUNG CATTLE – under 1 year</b><br/> calves for slaughter- young bulls<br/> calves for slaughter - young heifers<br/> calves for fattening - young bulls<br/> calves for fattening - young heifers</p> <p><b>YOUNG CATTLE – 1 -2 years</b><br/> breeding heifers in calf<br/> other breeding heifers<br/> heifers for fattening<br/> bulls, oxen</p> <p><b>CATTLE – over 2 years</b><br/> breeding heifers in calf<br/> other breeding heifers<br/> heifers for fattening<br/> bulls for breeding<br/> 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.

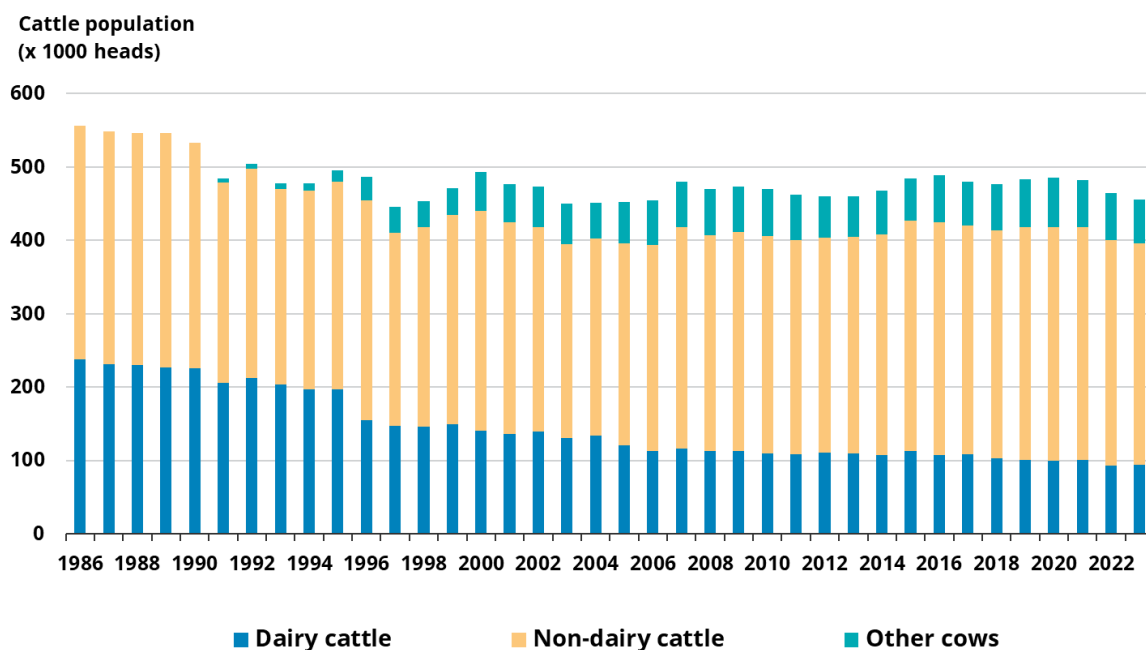
But discrepancies with FAO data still exist. In the FAO database, livestock numbers have been grouped in 12-month periods, ending on September 30 of the year stated in the tables. SORS collects data on animal population in December and reports them in the current year. Until 2018 in the FAO database, these data are applied for the next year. Considering this explanation, all data on animal population in the FAO database and in our statistical database are the same. The only difference is in the size of poultry population.

2019 IPCC methodology provides two different methods for estimating the quantity of methane from enteric fermentation. A more detailed method (Tier 2) for calculating emissions is used for cattle because of the comparatively large population and considerable emission per head and the default methodology (Tier 1) is used for other animals.

### 5.2.2.1 Cattle (CRT 3.A.1)

#### Dairy cattle

The method for estimation of emissions due to enteric fermentation is based on data on dairy cow population (Figure 5.2.2) and their performance expressed in terms of milk production per year (Figure 5.2.3), milk composition, pregnancy rate and activity (grazing). IPCC (2019) methodology was used taking into account the local production practices.



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

In the first step, net energy requirements for the maintenance ( $NE_m$ ), activity ( $NE_a$ ), milk production ( $NE_l$ ) and pregnancy ( $NE_p$ ) were estimated. Maintenance requirements were calculated on the basis of animal weight. It was supposed that animals producing more milk were heavier than those producing less milk. The relationship  $W = 418.8 + 0.0313 \times M$  was used to estimate body weight ( $W$ , in kg).  $M$  in the equation is the milk production in standard lactation (kg in 305 days). The equation was first proposed in 2009. It is based on expert estimates. In 2023, the equation was tested on the basis of data from slaughterhouses. The equation was found to be appropriate and it was therefore decided not to make any changes. In case of grazing, additional energy required for animals to obtain their food was added up ( $NE_a$ , 17 % of maintenance requirements). Coefficient which was used to calculate the net energy required for maintenance was increased by 20% in case of cows in lactation (i.e.  $0.386 \text{ MJ d}^{-1} \text{ kg}^{-1}$ , IPCC, 2019). Requirements for milk production were estimated on the basis of milk production and milk fat content. Requirements for pregnancy were calculated on the basis of cow weight and constant (10 % of maintenance requirements) according to IPCC (2019). In order to express the requirements for pregnancy on a yearly basis (365 days) the obtained values were multiplied by the number of calves per cow and year. In Slovenia, cattle are not used for work. Therefore, no requirements for this kind of activity were taken into account.

In the second step, the gross energy intake was estimated on the basis of net energy requirements that were estimated during the first step. To do this, the information on the concentration of net energy for lactation in diets is needed. It is the most critical point of the whole procedure. Overestimation of the net energy concentration in the diet would result in underestimation of gross energy intake and vice versa. It may considerably affect the final result. The concentration of the net energy for lactation depends mainly on its concentration in the basal diet and on the proportion of concentrates in the diet. The latter depends largely on daily milk production and intake capacity of a dairy cow. Therefore, it was decided to use country-specific data at this stage. Based on data from milk recording (the monitoring service performs monthly measurements of the milk yield of every individual cow) a total of 705.860 lactation curves were calculated for the period between January 1, 2000 and June 1, 2009. On the basis of the results, typical lactation curves for the range between 3500 and 12000 kg of milk in standard lactation were calculated for the intervals of 500 kg. Expected daily milk yields (for each individual day in lactation) were calculated for all these classes.

Based on daily milk yields and assumed concentrations of net energy for lactation in basal diet, the required proportions of concentrates in diets were estimated roughly. The equation for total mixed ratios presented by 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 (2019).

The emission factor was calculated from the data on gross energy intake (GE) and the methane conversion rate ( $Y_m$ , %) according to IPCC (2019):

$$\text{Emissions (kg/animal/year)} = (GE \text{ (MJ/year)} \times Y_m \text{ (\%)} \div 55.65 \text{ MJ/ kg methane})/100$$

The methane conversion rates ( $Y_m$ ) were linked to productivity (milk yield) using the following equation:

$$Y_m = 7.2309 - 0.000142857 \times \text{milk yield (kg/animal/year)}$$

The equation was derived from the data in IPCC (2019). It resulted in the same values as in the manual (6.5 for 5000 kg and 6.0 for 8500 kg milk per year). The EFs and milk yields are shown in Table 5.2.2 and Figure 5.2.3.

**Table 5.2.2: Milk yield and EFs for dairy cattle in kg/head/year.**

|            | 1986  | 1987  | 1988  | 1989  | 1990  | 1991  | 1992  | 1993  | 1994  |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Milk yield | 2818  | 2763  | 2770  | 2796  | 2774  | 3252  | 2836  | 2800  | 3015  |
| EF         | 96.8  | 96.3  | 96.4  | 96.6  | 96.5  | 100.5 | 97.4  | 97.4  | 99.4  |
|            | 1995  | 1996  | 1997  | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  |
| Milk yield | 3168  | 3833  | 3975  | 4092  | 4252  | 4625  | 4807  | 5198  | 5063  |
| EF         | 100.9 | 106.2 | 107.4 | 108.4 | 109.8 | 112.7 | 114.1 | 116.8 | 115.9 |
|            | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  |
| Milk yield | 4855  | 5479  | 5709  | 5727  | 5763  | 5530  | 5519  | 5515  | 5592  |
| EF         | 114.6 | 118.7 | 119.6 | 119.9 | 120.3 | 118.7 | 118.7 | 118.8 | 119.4 |
|            | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  | 2021  |
| Milk yield | 5435  | 5716  | 5598  | 6024  | 5954  | 6123  | 6178  | 6356  | 6341  |
| EF         | 118.6 | 120.2 | 119.1 | 121.7 | 121.5 | 122.6 | 122.8 | 123.8 | 124.0 |
|            | 2022  | 2023  | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  |
| Milk yield | 6706  | 6392  |       |       |       |       |       |       |       |
| EF         | 126.4 | 124.6 |       |       |       |       |       |       |       |

Emission factor for methane released from enteric fermentation depends mainly on the level of milk production. By the increase of annual milk production from 3000 to 6000 kg of milk per cow, the emissions increase from about 101 to 122 kg of methane per year. Average milk production per cow was more than doubled during the period 1986 – 2022. The increase was due to transition to open market economy and was accompanied by specialization of dairy sector. The proportion of concentrates in the diets for dairy cows increased and dual purpose Simmental and Brown Swiss cows were in part replaced by cows of specialized Holstein-



Frisian breed. The increase in milk yield was also affected by the public agricultural advisory service and by the results of breeding programmes.

The increase in IEF for dairy cattle is due to the increase in the milk yield. In 2022, the CS EF (126.4 kg/head/year) was comparable to the updated EF for dairy cattle for Western Europe from IPCC 2019 Refinement (126 kg/head/year) and considerably higher than updated default EF for Eastern Europe (93 kg/head/year) from the same source. Since agriculture sector in Slovenia is more similar to the systems in the countries from West Europe, the CS EF seems reasonable.

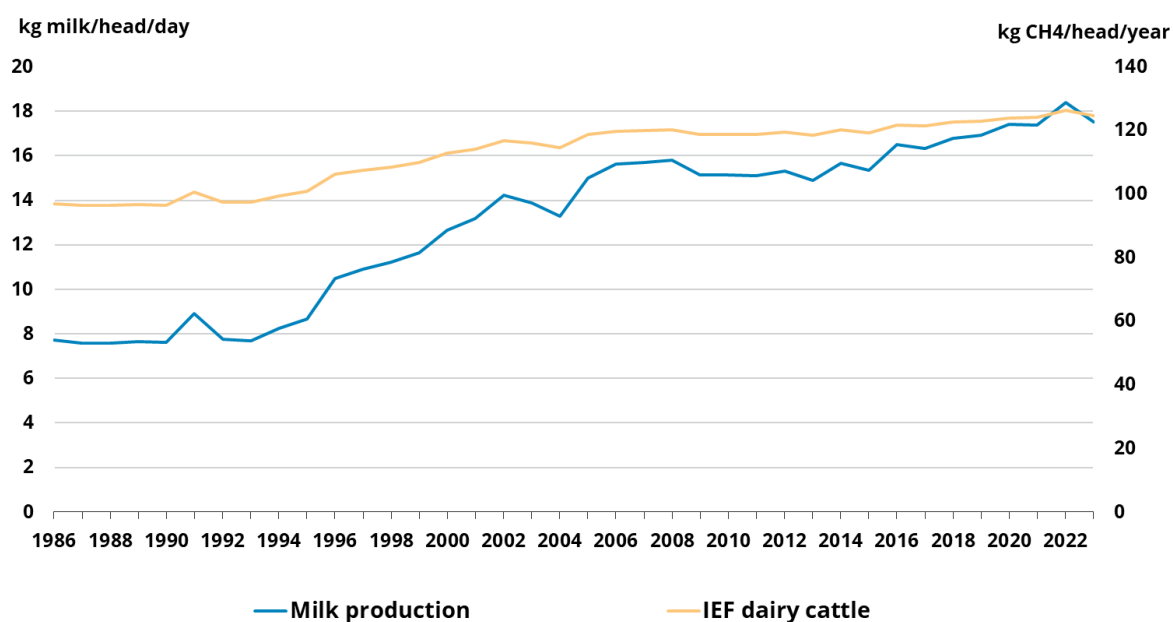


Figure 5.2.3: Milk production per cow in kg milk/head/day and IEF in kg CH<sub>4</sub>/head/year.

### 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 83.5 to 84.1 kg per cow per year (Table 5.2.3).

### Non-dairy cattle

This group comprises young cattle (cattle for fattening, heifers) and sires (breeding bulls). Data on the number of heads of non-dairy cattle according to different categories are reported by the SORS.

The method for estimation of emissions due to enteric fermentation is based on data on population and their performance expressed in terms of growth rate, pregnancy rate and

activity (grazing). IPCC (2019) methodology was used taking into account the local production practices.

#### Young cattle (cattle for fattening, heifers)

Since in younger animals the rumen does not function normally yet, calves up to the age of 3 months were not considered. In calculating methane emissions, only  $\frac{3}{4}$  of young bovine animals up to 1 year were considered.

In the first step, net energy requirements for the maintenance ( $NE_m$ ), activity ( $NE_a$ ), growth ( $NE_g$ ) and pregnancy ( $NE_p$ ) were estimated. Maintenance requirements were calculated on the basis of the average animal weight. For heifers it was supposed that the final weight is 90 % of the weight which characteristic for dairy cows (see 5.2.2.1). For the fattening cattle the final weight of 650 kg was supposed. Average weight was calculated on the basis of expected final weight and expected weight at the age of 3 months. In case of grazing, additional energy required for animals to obtain their food was added up ( $NE_a$ , 17 % of maintenance requirements). Coefficient which was used to calculate the net energy required for maintenance of heifers was  $0.322 \text{ MJ d}^{-1} \text{ kg}^{-1}$  (IPCC, 2019). It was increased by 15% in case of intact males (i.e.  $0.335 \text{ MJ d}^{-1} \text{ kg}^{-1}$ , IPCC, 2019). Requirements for growth were estimated on the basis of information on growth rate, average body weight and specific body weight of adult female. For the heifers the growth rate was calculated by dividing the difference between final and birth weight by the expected age at first calving (in days). For fattening cattle no exact data on daily gains existed for the period before 2005. There was official information (Statistical Yearbook) on total weight gain (country level) and number of various cattle categories for the year 1986. It has been assumed that the weight gain of growing heifers from their sixth month of age to first mating amounts to 600 g per day, and of pregnant heifers to 500 g per day. The remaining weight gain (according to the Statistical Yearbook) has been equally distributed across other growing categories of cattle and thus the average daily weight gain for young bovine animals for fattening has been assessed as 740 g per day. Since 2005, more precise average daily gains for young bovine animals for fattening have been obtained. For the period 2005-2009, they were calculated based on slaughter date and slaughter weight data from slaughterhouses and on the birth dates of individual animals recorded in the Central database CATTLE (Verbič and Jeretina, 2009, unpublished). This is a large database to which public access cannot be granted. Since 2010, data on daily gains have been published regularly by the Agricultural Institute of Slovenia (most recent report by Žabjek et al., 2023). Average daily gains between 1986 and 2005 were estimated by interpolation. For the period 2005-2022, average daily gains on a yearly basis were used for calculations. Requirements for growth were calculated according to equation given by IPCC (2019), taken into account a specific coefficient  $C = 0.8$  for females and  $C = 1.2$  for males. In heifers, the requirements for pregnancy were calculated on the basis of adult cow weight and a constant value of 10% of its maintenance requirements (IPCC, 2019). In order to express the requirements for pregnancy on a yearly basis (365 days) the obtained values were multiplied by the factor (365/age at first calving).

In the second step, the gross energy intake was estimated on the basis of net energy requirements that were estimated during the first step. To transform net energy requirements into gross energy, the estimated energy digestibility was needed. Equations to predict the

energy digestibility for individual categories were estimated on the basis of national feeding standards (Verbič and Babnik, 1999) and the expected feed intake was estimated according to Kirchgeßner et al. (2008). In the first step the required concentrations of the metabolisable energy were assessed. In the second step they were converted into organic matter digestibility (dOM) by the use of equation:

$$dOM = 13.95 + \text{concentration of metabolisable energy} \times 5.74.$$

The equation was derived on the basis of wide range of forages, cereals and oil seed meals presented in DLG Feeding Tables (DLG, 1997). Then it was converted into energy digestibility (DE%) using the same conversion factor as described for dairy cattle. The following equations for predicting average energy digestibility (DE%) were derived on the basis of the above mentioned procedure:

$$\begin{array}{ll} \text{Cattle for fattening} & DE\% = 57.2 + 13.72 \times \text{daily weight gain (g)} \\ \text{Breeding heifers} & DE\% = 54.9 + 16.28 \times \text{daily weight gain (g)} \end{array}$$

Finally, the gross energy intake (GE) was calculated as:

$$GE = \frac{\frac{NE_m + NE_a + NE_p}{DE\%} + \frac{NE_g}{REG}}{\frac{REM}{100}}$$

The ratio of net energy available for maintenance to digestible energy (REM) and the ratio of net energy available for growth to digestible energy (REG) were calculated as suggested by IPCC (2019).

Emission factor was calculated from data on gross energy intake (GE) and methane conversion rate ( $Y_m$ , %) according to IPCC (2019):

$$\text{Emissions (kg/animal/year)} = (GE \text{ (MJ/year)} \times Y_m \text{ (\%)} \div 55.65 \text{ MJ/kg of methane})/100$$

For methane conversion rate ( $Y_m$ ) the value of 6.3% was used, as recommended by IPCC (2019).

### Breeding bulls

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

The country specific  $CH_4$  EFs are presented on the Table 5.2.3. Emission factors for non-dairy cattle are affected not only by differences in emission factors for individual categories, but also by the ratios in their abundance. Thus, for 2009 and 2010, non-dairy cattle were characterized by very low emission factors. It can be explained by a significant increase in the proportion of calves for slaughter (by 83 and 106% compared to the 2004-2008 average). Since in younger animals the rumen does not function normally yet, calves are not considered to be a source of

methane from enteric fermentation. The reason for the increase in the extent of slaughter of calves in 2009 and 2010 is in very poor economic situation. In 2009, milk prices decreased by more than 20% compared to 2008. In 2010, milk prices increased slightly again (+ 2.1% compared to 2009), but nevertheless remained significantly lower than in the previous period. The year 2011 was again more optimistic for the cattle sector (milk prices increased by 13.8%). It resulted in reduction of slaughter of calves and also their number decreased to a similar level as before.

All other data, which are not presented in the NIR, are available in the Annex 3 to the NIR and in the CRF tables.

**Table 5.2.3: EFs for non-dairy cattle and other cows in kg/head/year**

|                      | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|----------------------|------|------|------|------|------|------|------|------|------|
| Other cows           | 84.1 | 84.0 | 84.0 | 84.0 | 84.0 | 84.1 | 84.0 | 84.1 | 84.0 |
| Heifers              | 48.0 | 47.9 | 47.9 | 48.0 | 47.9 | 48.8 | 48.1 | 48.0 | 48.5 |
| Cattle for fattening | 55.4 | 55.6 | 55.7 | 55.8 | 55.9 | 56.1 | 56.2 | 56.3 | 56.5 |
| Breeding bulls       | 69.8 | 69.8 | 69.8 | 69.8 | 69.8 | 69.9 | 69.9 | 70.0 | 70.1 |
| Other cattle         | 48.7 | 48.7 | 48.7 | 48.8 | 48.8 | 49.3 | 49.1 | 49.1 | 49.4 |
|                      | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| Other cows           | 84.0 | 84.0 | 84.0 | 84.0 | 84.0 | 84.0 | 84.0 | 84.0 | 83.9 |
| Heifers              | 48.7 | 49.9 | 50.2 | 50.4 | 50.7 | 51.3 | 51.7 | 52.4 | 52.2 |
| Cattle for fattening | 56.6 | 56.8 | 56.9 | 57.1 | 57.2 | 57.4 | 57.5 | 57.6 | 57.7 |
| Breeding bulls       | 70.1 | 70.2 | 70.2 | 70.3 | 70.4 | 70.4 | 70.4 | 70.4 | 70.5 |
| Other cattle         | 49.6 | 49.8 | 50.0 | 50.1 | 50.3 | 51.1 | 51.9 | 53.0 | 52.8 |
|                      | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Other cows           | 83.9 | 83.8 | 83.8 | 83.8 | 83.8 | 83.7 | 83.7 | 83.7 | 83.7 |
| Heifers              | 51.9 | 53.0 | 53.4 | 53.5 | 53.5 | 53.2 | 53.1 | 53.2 | 53.2 |
| Cattle for fattening | 57.8 | 58.0 | 58.0 | 58.1 | 57.9 | 57.8 | 57.8 | 57.9 | 57.9 |
| Breeding bulls       | 70.5 | 70.5 | 70.5 | 70.5 | 70.5 | 70.5 | 70.5 | 70.5 | 70.5 |
| Other cattle         | 52.7 | 53.8 | 53.6 | 53.2 | 52.9 | 51.5 | 50.9 | 53.1 | 53.2 |
|                      | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Other cows           | 83.7 | 83.5 | 83.5 | 83.5 | 83.6 | 83.5 | 83.5 | 83.5 | 83.5 |
| Heifers              | 53.0 | 53.5 | 53.2 | 53.9 | 53.7 | 53.9 | 54.0 | 54.4 | 54.3 |
| Cattle for fattening | 57.9 | 57.8 | 57.9 | 57.9 | 57.9 | 58.3 | 58.2 | 58.2 | 58.2 |
| Breeding bulls       | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 |
| Other cattle         | 52.8 | 53.0 | 53.6 | 53.9 | 53.4 | 53.8 | 54.5 | 54.1 | 54.0 |
|                      | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Other cows           | 83.6 | 83.6 |      |      |      |      |      |      |      |
| Heifers              | 54.8 | 54.4 |      |      |      |      |      |      |      |
| Cattle for fattening | 58.3 | 58.2 |      |      |      |      |      |      |      |
| Breeding bulls       | 70.6 | 70.6 |      |      |      |      |      |      |      |
| Other cattle         | 53.9 | 53.6 |      |      |      |      |      |      |      |

### 5.2.2.2 Swine (CRF 3.A.3)

The number of swine (Figure 5.2.4) has been taken from the Statistical Yearbook.

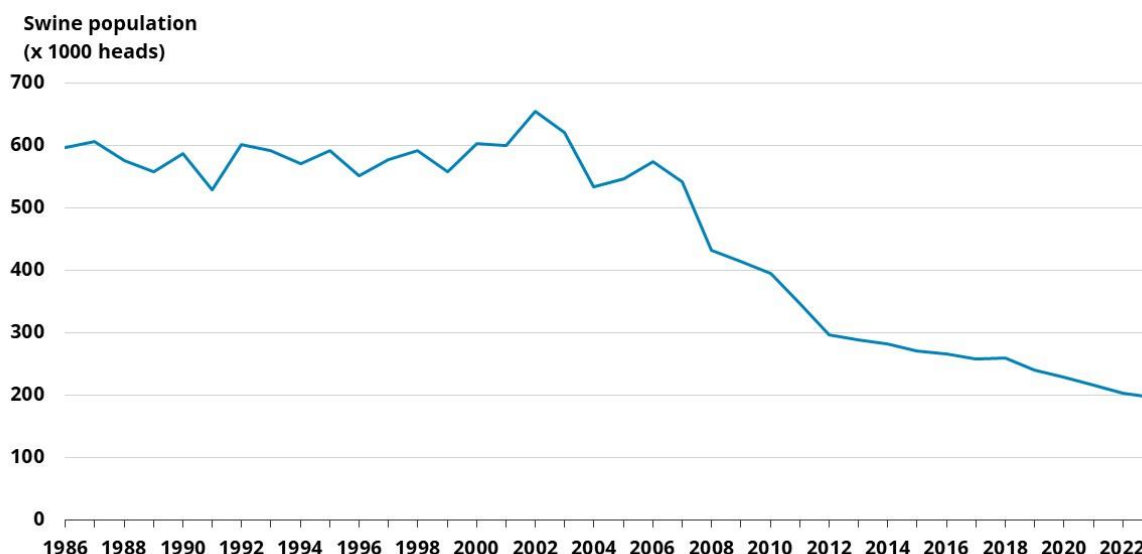


Figure 5.2.4: Number of swine in thousands.

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 5.2.5) has been estimated in the same way as the number of sheep. As goats have not been counted before 1992, we consider the number of 8.000 heads as an estimate. The population data does not include lambs and young goats.

Considering the rather small number of sheep and goats, Tier 1 methodology and default EFs from the 2019 Refinement to the 2006 IPCC Guidelines have been used for estimating methane emissions; 9 kg of methane annually per head for sheep and for goats.

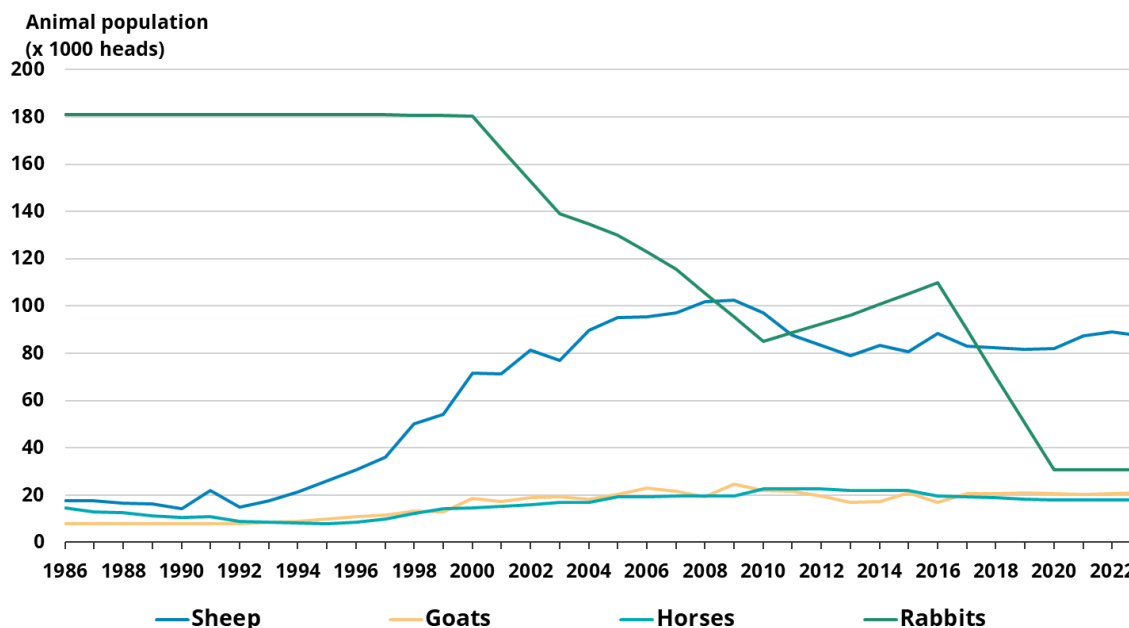


Figure 5.2.5: Number of sheep, goats, horses and rabbits in thousands.

#### 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. For 2021 and 2022, the same values as for 2020 were used. Methane emissions have been estimated by applying default emission factors according to IPCC (2006) methodology, i.e. 18 kg per year.

#### 5.2.2.5 Rabbits (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, 2010, and 2020) or the Farm Structure Surveys (2003, 2005, 2007, 2013 and 2016). For the years in between, the values were estimated by interpolation. For 2021 and 2022, the same values as for 2020 were used. Methane emissions have been estimated by applying emission factor used in the Italian GHG inventory, i.e. 0.08 kg per animal per year.

### 5.2.3 Uncertainties and time-series consistency

Data on the number of livestock are not collected according to ownership of the livestock but according to who manages the livestock. The sample for the statistical survey on the number of livestock is selected according to the sampling methodology. Data collected using the sample is representative for the entire country. The sample is divided into four strata; each of them is determined regarding the size class of agricultural holding. The sample thus covers all large agricultural holdings, while other agricultural holdings are selected proportional to size

class and represent a specific weight in their size class. Based on information from SORS, the uncertainty of activity data is 10%.

According to 2006 IPCC Guidelines, the uncertainty of the EFs when using default methodology is at least 30%, but could be as high as 50%. When Tier 2 methodology is used, the uncertainty is likely to be in the range of 20%. As most emissions in this category are estimated using Tier 2 methodology, uncertainty estimate of 20% have been used

The combined uncertainty, calculated according to 2006 IPCC Guideline, Tier 1 methodology, amounts to 22.36%.

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

For calculation of emissions from agriculture a model which simultaneously assesses emissions of greenhouse gases, air pollutants and N balance has been developed. The main purpose of this model is the harmonization in reporting of the emissions of GHG and other pollutants. Calculations in the model have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also the ESD review, where all IEF and AD are compared with other countries and all outliers have to be justified.

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

The default factors for methane emissions from enteric fermentation in sheep and goats have been updated. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines.

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

No major improvements are planned

## 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 the manure. Methane arises in significantly larger amounts when manure is managed as slurry, while N<sub>2</sub>O prevails in storage of solid manure.

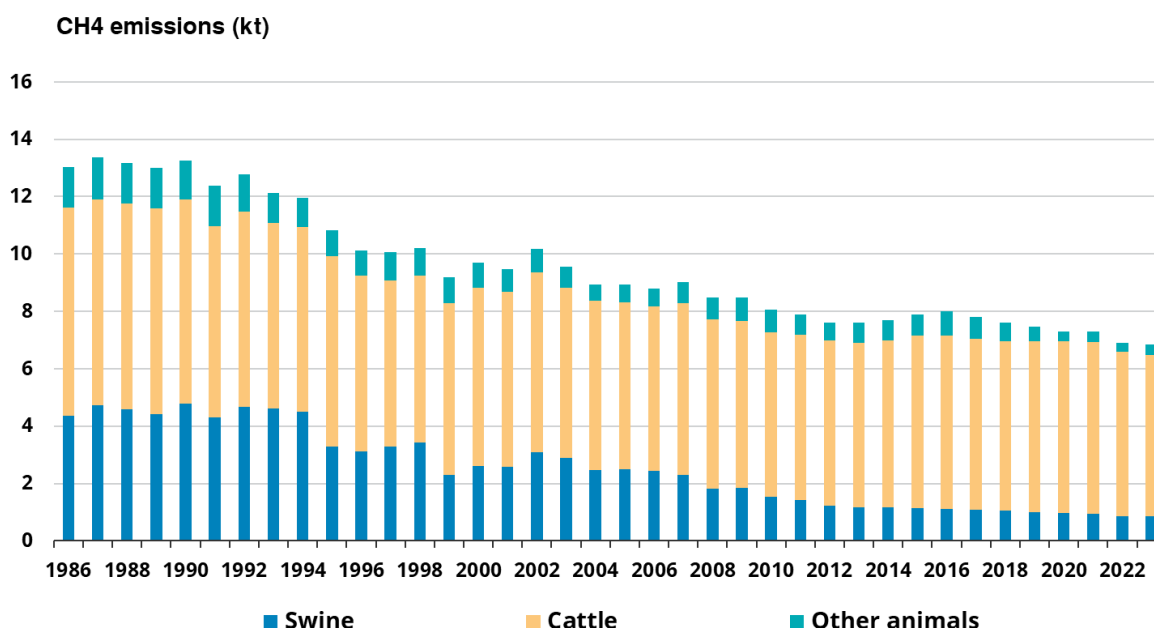


Figure 5.3.1: CH<sub>4</sub> emissions from manure management in Gg.

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)

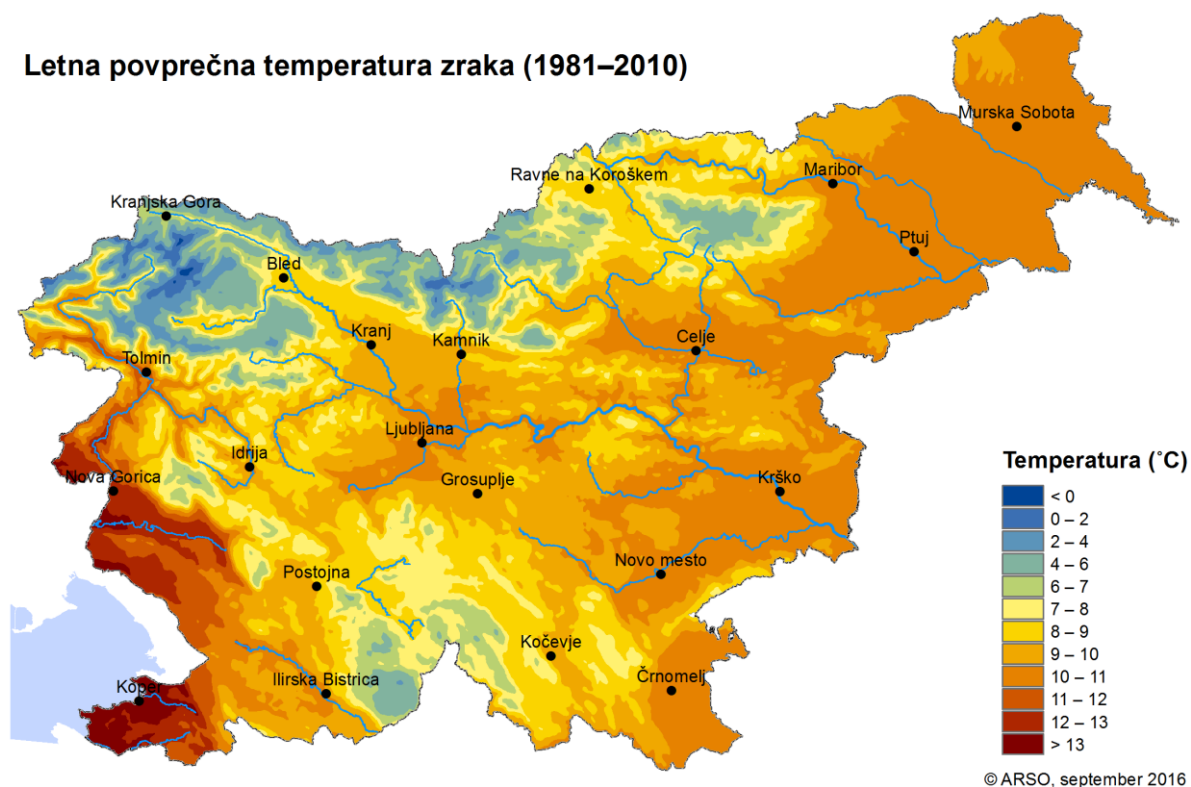


Figure 5.3.2: The average yearly air temperature in Slovenia in the period 1981-2010. (Sours: SEA)

<http://meteo.arso.gov.si/met/sl/climate/maps/>

[https://meteo.arso.gov.si/uploads/probase/www/climate/image/sl/by\\_variable/temperature/annual-mean-air-temperature\\_81-10.png](https://meteo.arso.gov.si/uploads/probase/www/climate/image/sl/by_variable/temperature/annual-mean-air-temperature_81-10.png)

## 5.3.2 Methodological issues

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

Annual quantities of volatile solids excreted via faeces and urine were estimated by means of data gathered while estimating the extent of enteric fermentation. The equation that was laid down by IPCC (2006) was applied. In comparison to previous methodology (IPCC, 1996) the energy of urine was taken into account in addition to energy of faeces. It was expressed as fraction of GE (UE=0.04). Through estimated intake of gross energy, the amount of volatile solids is directly linked to the production intensity (to milk production or daily weight gain).

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

In dairy cows the estimated amount of VS ranged between 1645 and 1974 kg per year and animal. For other cows, heifers and beef cattle the corresponding values were from 1515 to 1542, from 820 to 885 and from 813 to 845 kg per year and animal.

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

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

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 0.18 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, and 0.01 were used for liquid manure storage with natural crust cover, liquid manure storage below animal confinements, solid manure storage in heaps, solid manure in deep bedding systems, and grazing, respectively. A value of 0.014 was used for anaerobic digesters. It was derived using Formula 1 (Table 10.17, IPCC, 2006), taking into account the average methane emissions from co-generation units according to Libetrau et al. (2013) and a factor of 0.00 for the second part of the formula, as suggested by the IPCC for covered storage of digestate (Table 10.17, IPCC, 2006).

For the period after 1990, there is a lack of information on the proportion of individual manure management systems. Therefore, for the inventory report submissions up to 2025, the share of manure management systems was assessed based on the size and structure of cattle farms regularly reported by SORS. Based on data collected from a large number of dairy farms as part of the milk recording service (Babnik and Verbič, 2007; about 70% of all dairy cows were recorded), it was found that the estimates based on farm structure were quite reliable for 2005. However, the 2020 census data showed that the increase in the proportion of slurry based manure management systems did not follow the structural changes as expected. Therefore, new estimates were made for the entire time series in 2025. The estimates are based on data from 2005 (Babnik and Verbič, 2007) and the 2020 census (SORS). The latest data show that in 2020, 56,8% of cows and 35,3% of other cattle were housed in slurry-based systems. Since 2005, the proportion of cows housed in slurry systems has only increased by 3,6% (from 53,2 to 56,8%). To produce the estimates of manure management systems for the past period, we have also taken into account the same increase in other cattle.

Animals kept in liquid systems were further divided into animals kept in liquid manure storage with natural crust cover, animals kept in liquid manure storage below animal confinements and animals from which the excreta is treated in anaerobic digesters. Based on information on manure management that was collected in the frame of milk recording service on a large number of dairy farms in 2005 (Babnik and Verbič, 2007) it was estimated that the ratio between slurry stored in stores with natural crust and slurry stored below animal confinements is 0.46:0.54. Based on information from the same source the solid manure was divided into farmyard manure stored in heaps and deep bedding (0.90:0.10). The proportion of slurry treated in anaerobic digesters was estimated on the basis of data collected from biogas plants by the means of interview (data provided by Poje, unpublished). Based on above mentioned data and data on total number of cattle it was estimated that during the period 2006-2010 the proportion of digested cattle manures increased from 0.03 to 0.36 %. Anaerobic digesters were not markedly spread thereafter and therefore the same value was used for the period 2011-2022. Generally, biogas is produced from livestock manure which is generated within the farm.

**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           | 22.7 | 22.8 | 23.0 | 23.2 | 23.3 | 23.9 | 23.4 | 23.4 | 23.6 |
| Other cows           | 15.9 | 16.0 | 16.1 | 16.2 | 16.4 | 16.3 | 16.3 | 16.2 | 16.2 |
| Heifers              | 6.1  | 6.2  | 6.2  | 6.3  | 6.4  | 6.4  | 6.3  | 6.3  | 6.4  |
| Cattle for fattening | 6.3  | 6.3  | 6.4  | 6.4  | 6.5  | 6.5  | 6.4  | 6.4  | 6.4  |
| Breeding bulls       | 9.9  | 10.0 | 10.1 | 10.2 | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 |
| Other cattle         | 5.8  | 5.9  | 5.9  | 6.0  | 6.0  | 6.1  | 6.0  | 6.0  | 6.0  |
|                      | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| Dairy cows           | 23.8 | 24.6 | 24.7 | 24.8 | 25.0 | 25.4 | 25.6 | 26.1 | 26.0 |
| Other cows           | 16.1 | 16.1 | 16.0 | 16.0 | 15.9 | 15.9 | 15.9 | 16.0 | 16.0 |
| Heifers              | 6.4  | 6.4  | 6.5  | 6.5  | 6.5  | 6.5  | 6.6  | 6.6  | 6.6  |
| Cattle for fattening | 6.4  | 6.4  | 6.3  | 6.3  | 6.3  | 6.3  | 6.3  | 6.3  | 6.3  |
| Breeding bulls       | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 | 10.2 | 10.3 | 10.3 | 10.3 |
| Other cattle         | 6.0  | 6.0  | 6.0  | 6.0  | 6.0  | 6.0  | 6.1  | 6.3  | 6.2  |
|                      | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Dairy cows           | 25.8 | 26.4 | 26.5 | 26.7 | 26.8 | 26.6 | 26.6 | 26.6 | 26.8 |
| Other cows           | 16.0 | 16.0 | 16.0 | 16.0 | 16.1 | 16.1 | 16.1 | 16.1 | 16.1 |
| Heifers              | 6.6  | 6.7  | 6.8  | 6.8  | 6.8  | 6.8  | 6.8  | 6.9  | 6.9  |
| Cattle for fattening | 6.3  | 6.3  | 6.3  | 6.3  | 6.4  | 6.4  | 6.4  | 6.4  | 6.4  |
| Breeding bulls       | 10.4 | 10.4 | 10.4 | 10.5 | 10.5 | 10.6 | 10.6 | 10.6 | 10.6 |
| Other cattle         | 6.2  | 6.3  | 6.3  | 6.3  | 6.3  | 6.2  | 6.1  | 6.4  | 6.4  |
|                      | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Dairy cows           | 26.7 | 27.0 | 26.9 | 27.3 | 27.3 | 27.6 | 27.6 | 27.8 | 27.9 |
| Other cows           | 16.2 | 16.1 | 16.2 | 16.2 | 16.3 | 16.3 | 16.3 | 16.3 | 16.3 |
| Heifers              | 6.9  | 6.9  | 6.9  | 7.0  | 7.0  | 7.0  | 7.1  | 7.1  | 7.1  |
| Cattle for fattening | 6.5  | 6.5  | 6.5  | 6.5  | 6.5  | 6.5  | 6.5  | 6.6  | 6.6  |
| Breeding bulls       | 10.7 | 10.7 | 10.7 | 10.8 | 10.8 | 10.8 | 10.9 | 10.9 | 10.9 |
| Other cattle         | 6.4  | 6.4  | 6.5  | 6.6  | 6.5  | 6.5  | 6.6  | 6.6  | 6.6  |
|                      | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Dairy cows           | 28.3 | 28.0 |      |      |      |      |      |      |      |
| Other cows           | 16.3 | 16.3 |      |      |      |      |      |      |      |
| Heifers              | 7.1  | 7.1  |      |      |      |      |      |      |      |
| Cattle for fattening | 6.6  | 6.6  |      |      |      |      |      |      |      |
| Breeding bulls       | 10.9 | 10.9 |      |      |      |      |      |      |      |
| Other cattle         | 6.6  | 6.6  |      |      |      |      |      |      |      |

The fraction of grazing bovine animals for 1990 has been estimated on the basis of data on grazing animals on mountain pastures and expert estimate on the scale of grazing on intensive grasslands (Verbič et al., 1999). In 2000, all grazing animals on mountain and other pastures were recorded. This census showed that in 2000, one way or another, 21% of animals were

grazing. This data have been corrected with regard to the length of the grazing season, considering the fact that animals on mountain pastures will graze for 141 days on the average, and on other pastures for 210 days. As result, the corrected proportion of grazed animals for 2000 was estimated to be 0.117. The same procedure was used for the data obtained by sample survey on agricultural production methods in 2010. It showed that the corrected proportion of grazed animals increased to 0.126.

The estimate for 1990 was used for the period 1985-1990. For the period 1991-1999, the data on grazing were obtained by linear regression which was calculated on the basis of data for the years 1990 and 2000 and for the period 2001-2009 the estimates obtained by linear regression for the years 2000 and 2010. The 2020 census did not collect data on the number of animals kept on pasture. Extrapolated values based on the 2000-2010 period were used for the years through 2020. This resulted in a slight increase in the percentage of grazed animals (from 12.6% in 2010 to 13.6% in 2020). Grazing is supported by some measures of agricultural policy (organic farming, animal welfare measures), so it is assumed that the share of grazing animals in 2020 is not overestimated. For 2022, the same value as for 2020 was used.

Data on the number of livestock were the same as those used for calculating methane emissions from enteric fermentation. Emission factors are presented in the Table 5.3.1.

### 5.3.2.2 Swine (CRF 3.B.3)

#### Activity data

The population of swine (Figure 5.3.3) is divided into three segments:

- commercial (industrial) pig farms,
- market oriented family farms, and
- small scale (subsistence) family farms.

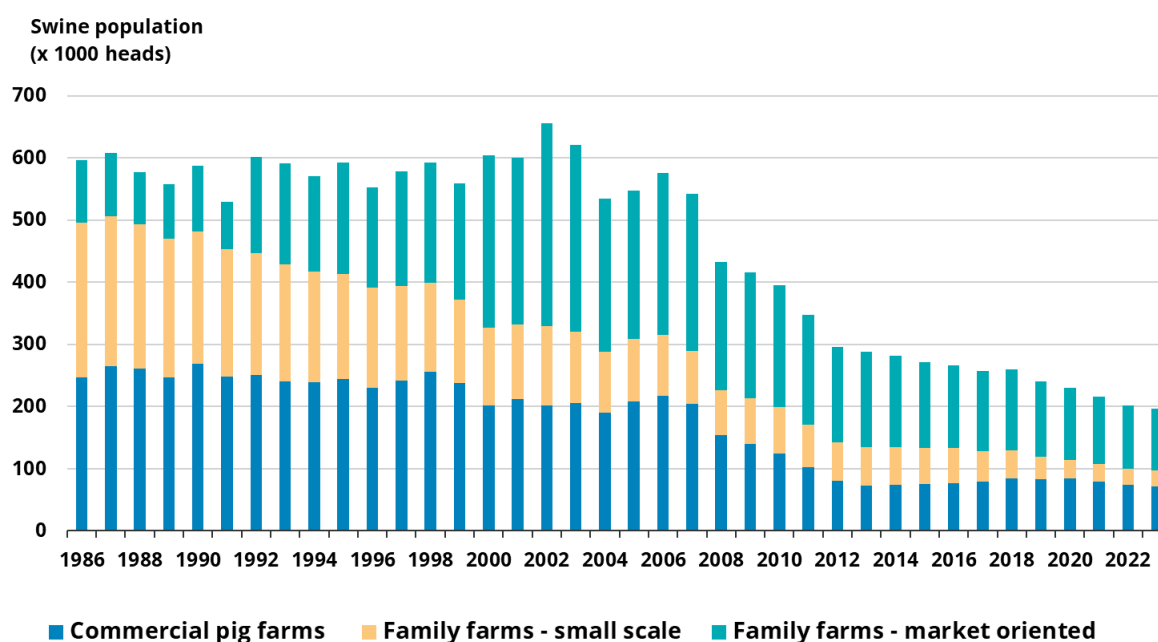


Figure 5.3.3: Number of swine in thousands.

Data published by the SORS allow a breakdown of the entire herd into commercial pig farms and family farms for the period 1986-2002. Family farms were further divided into market oriented and small scale farms. In 1986, the estimate of production for market oriented family farms was based on the data on acquisition of pigs from market oriented family farm production, which was published by the SORS. The number of swine in small scale family farm production has been estimated from the difference between the entire herd and market oriented production (commercial and market oriented family farms). For 2000, the number of pigs in the small scale family farm production has been estimated on the basis of the census of agricultural holdings. Pigs kept on farms with up to 10 pigs have been considered as small scale family farm production, pigs on family farms which kept more than 10 pigs have been considered as market oriented family farm production. From 1986 to 2000, the fraction of pigs in small scale family farm production kept diminishing. In the period between 1986 and 2000, the proportion of small scale production was obtained by interpolation. After 2000, data on farm structure for the years 2003, 2005, 2007, 2010, 2013, 2016 and 2020 have been reported by the SORS. These data were used to estimate the number of pigs on small scale family farms. For the years with non-existing data on farm structure (2001, 2002, 2004, 2006, 2008, 2009, 2011, 2012, 2014, 2015, 2017, 2018, 2019) the numbers of pigs on small scale family farms were obtained by interpolating the values for neighbouring years or by using the last available information (for 2021 and 2022). For the period after the year 2002 the number of pigs on commercial farms could not be obtained directly from the data reported by SORS. Therefore it was estimated using the data on farm structure for the years 2003, 2005, 2007, 2010, 2013, 2016 and 2020. The estimate is based on the number of pigs which are kept on farms with more than 399 pigs. The pigs belonging to this category (pigs kept on farms with more than 400 pigs) were allocated among commercial and market oriented family farms on the basis of their proportion in the year 2000. The pigs kept on farms with 10 to 399 pigs were entirely allocated to market oriented family farms.

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 2010-2023 only 0.6 to 1.6 % of total pigs were kept on organic farms. It was estimated that detailed information on manure management systems on these farms would not considerably contribute to improvement of data quality. The information on the number of pigs on organic farms for the period 2010-2023 is given in the Table 5.3.2.

**Table 5.3.2: Proportion of pigs which are kept on organic farms during the period 2010-2023 (Sources: Ministry of agriculture, forestry and food and SORS)**

|   | 2010    | 2011    | 2012    | 2013    | 2014    | 2015    | 2016    | 2017    |
|---|---------|---------|---------|---------|---------|---------|---------|---------|
| Total population of pigs                | 395,593 | 347,310 | 296,097 | 288,350 | 281,317 | 271,385 | 265,744 | 257,241 |
| Number of pigs on organic farms         | 2,367   | 2,219   | 2,458   | 2,798   | 3,135   | 3,345   | 3,648   | 3,793   |
| Proportion of pigs on organic farms (%) | 0.60    | 0.64    | 0.83    | 0.97    | 1.11    | 1.23    | 1.37    | 1.47    |
|   | 2018    | 2019    | 2020    | 2021    | 2022    | 2023    |         |         |
| Total population of pigs                | 259,125 | 240,138 | 229,483 | 215,713 | 202,148 | 196,139 |         |         |
| Number of pigs on organic farms         | 3,203   | 3,252   | 2,992   | 3099    | 3185    | 2710    |         |         |
| Proportion of pigs on organic farms (%) | 1.24    | 1.35    | 1.30    | 1.44    | 1.58    | 1.38    |         |         |

### 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 the information on typical body weight (BW) and IPCC (2019) excretion value (4.5 kg VS/1000 kg BW). 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 were used for liquid manure storage, solid manure storage in heaps, solid manure in deep bedding systems, and uncovered anaerobic lagoons, respectively. A factor of 0.014 was used for anaerobic fermenters. The basis for determining this factor is described in the chapter dealing with cattle. The following estimates and assumptions were considered in the calculation of methane emissions from manure storage facilities.

### Commercial Pig Farms

From 1985 to 1994 – using old-style separators on commercial farms, app. 20% of organic matter was separated from liquid manure. For this portion, the partial MCF for solid manure (0.02) has been taken into account. The remainder (80%) has been disaggregated into uncovered anaerobic lagoons (75%) and liquid manure (25%), taking into account a MCF 0.68 and 0.19, as suggested by IPCC (2006). The division into lagoons and liquid manure was founded on actual estimates of the extent of production on commercial farms, where the liquid

portion of manure after separation was applied to fields and grassland. Considering the ratio between solid phase and liquid manure, which was either led into lagoons or used for fertilization, the average MCF = 0.45 has been calculated.

Years from 1995 to 1999 were a period of introducing new separators and the beginning of operation of an anaerobic digester in the Farm Ihan. Introducing new separators on commercial farms increased the estimated portion of separated solid phase to 40%. Since the construction of a new wastewater treatment plant in Farm Ihan, it has been considered that mechanic separation separated 80% of VS on that commercial farm, while the remainder (20%) was captured as biogas. For large commercial farms it is generally considered that the ratio between the liquid part, which flows off to lagoons, and the liquid part, which is used as fertilizer, is the same as prior to 1995 (3:1). The estimated average MCF for that period was 0.278. Due to new farm reconstructions leading to improved slurry separation and introduction of additional capacity of anaerobic digesters, the methane conversion factor MCF on big farms after 1999 had decreased to 0.147 until 2005 and further to 0.057 in 2010. We assume that managers are interested in achieving the shortest possible retention times in manure stores before gas production and therefore we have assumed that the MCF value for anaerobic digesters was 0.014 (see above).

#### Market oriented family farm production

For market oriented family farm production, it is considered that 95% of animal excreta are collected in the form of liquid manure and 5% in the form of solid manure. Based on the ratio between liquid manure and solid manure, the average manure conversion factor MCF = 0.182 was used for calculations until 2006. Since then, farm reconstructions occurred also on family farms and average MCF has decreased to 0.176 in 2010.

#### Small scale family farm production

For small scale family farm production, it is estimated that 95% of pigs are reared in solid manure storage systems and 5% in liquid manure systems. For this type of production the average manure conversion factor MCF = 0.029 was calculated on the basis of IPCC (2006) guidelines.

Detailed information on manure management systems are given in Table 5.3.3. 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 5.3.3: Distribution of various manure management systems in pig production in %.**

|                             | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|-----------------------------|------|------|------|------|------|------|------|------|------|------|------|
| Slurry                      | 28.1 | 25.0 | 34.5 | 36.0 | 35.5 | 35.1 | 34.1 | 36.6 | 37.4 | 40.1 | 50.3 |
| Farmyard manure             | 35.5 | 37.5 | 32.3 | 31.5 | 31.1 | 28.7 | 29.1 | 26.6 | 24.6 | 24.5 | 22.1 |
| Separation (solid fraction) | 9.1  | 9.4  | 8.3  | 8.1  | 8.4  | 19.7 | 20.0 | 20.1 | 20.7 | 23.8 | 18.7 |
| Anaerobic lagoons           | 27.4 | 28.1 | 24.9 | 24.4 | 25.1 | 14.8 | 15.0 | 15.1 | 15.5 | 06.4 | 5.0  |
| Anaerobic digestion         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 1.6  | 1.7  | 1.7  | 1.7  | 5.1  | 4.0  |
|                             | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Slurry                      | 49.4 | 53.6 | 52.5 | 50.7 | 48.8 | 48.6 | 49.0 | 48.9 | 49.9 | 54.1 | 54.7 |
| Farmyard manure             | 21.3 | 20.9 | 20.1 | 19.9 | 19.7 | 18.4 | 17.1 | 18.2 | 19.2 | 20.2 | 21.1 |
| Separation (solid fraction) | 19.8 | 17.3 | 18.5 | 19.9 | 21.2 | 15.9 | 15.3 | 12.7 | 12.8 | 12.6 | 11.8 |
| Anaerobic lagoons           | 5.3  | 4.6  | 5.0  | 5.3  | 5.7  | 4.3  | 4.1  | 3.4  | 3.4  | 0.0  | 0.0  |
| Anaerobic digestion         | 4.2  | 3.7  | 4.0  | 4.3  | 4.6  | 12.9 | 14.4 | 16.9 | 14.7 | 13.1 | 12.4 |
|                             | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
| Slurry                      | 55.4 | 56.0 | 55.3 | 54.5 | 53.8 | 54.2 | 54.6 | 55.1 | 55.5 | 55.5 | 55.5 |
| Farmyard manure             | 22.0 | 22.9 | 22.8 | 22.6 | 22.4 | 20.5 | 18.6 | 16.8 | 14.9 | 14.9 | 14.9 |
| Separation (solid fraction) | 10.9 | 10.1 | 10.6 | 11.1 | 11.6 | 12.4 | 13.1 | 13.8 | 14.6 | 14.6 | 14.6 |
| Anaerobic lagoons           | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| Anaerobic digestion         | 11.7 | 10.9 | 11.4 | 11.8 | 12.2 | 12.9 | 13.6 | 14.3 | 15.0 | 15.0 | 15.0 |
|                             | 2023 |      |      |      |      |      |      |      |      |      |      |
| Slurry                      | 55.5 |      |      |      |      |      |      |      |      |      |      |
| Farmyard manure             | 14.9 |      |      |      |      |      |      |      |      |      |      |
| Separation (solid fraction) | 14.6 |      |      |      |      |      |      |      |      |      |      |
| Anaerobic lagoons           | 0.0  |      |      |      |      |      |      |      |      |      |      |
| Anaerobic digestion         | 15.0 |      |      |      |      |      |      |      |      |      |      |

**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 | 7.3  | 7.8  | 8.0  | 7.9  | 8.1  | 8.1  | 7.8  | 7.8  | 7.9  |
|                     | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| CH <sub>4</sub> EFs | 5.5  | 5.6  | 5.7  | 5.8  | 4.1  | 4.3  | 4.3  | 4.7  | 4.7  |
|                     | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| CH <sub>4</sub> EFs | 4.6  | 4.5  | 4.3  | 4.2  | 4.2  | 4.4  | 3.9  | 4.1  | 4.1  |
|                     | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| CH <sub>4</sub> EFs | 4.1  | 4.2  | 4.2  | 4.2  | 4.2  | 4.1  | 4.2  | 4.3  | 4.4  |
|                     | 2022 | 2023 |      |      |      |      |      |      |      |
| CH <sub>4</sub> EFs | 4.3  | 4.4  |      |      |      |      |      |      |      |



### 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 (B0), 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 (B0) 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 (Udovič, personal communication). It was also assumed that in 50% the manure is removed daily and stored in tanks (liquid system) while in 50 % it is collected under the batteries (i.e. poultry manure without bedding). After introduction of dung drying system to certain farms a new estimates were obtained for 2002. Layers which were assumed to be kept in floor system, in system where manure is collected under the batteries and in dung drying system, were allocated to solid system. Layers which were assumed to be kept in system where the manure is removed daily and stored in tanks was allocated to liquid systems. After 2017, the proportion of laying hens in battery cages began to fall. According to the 2020 census, only 15,4% of laying hens were still in battery cages (SORS). Therefore, a rapid decrease of the proportion of battery cage system was assumed for the period after 2016. As for the previous period, we have assumed that 50% of the manure from battery cages is collected in the form of liquid manure.

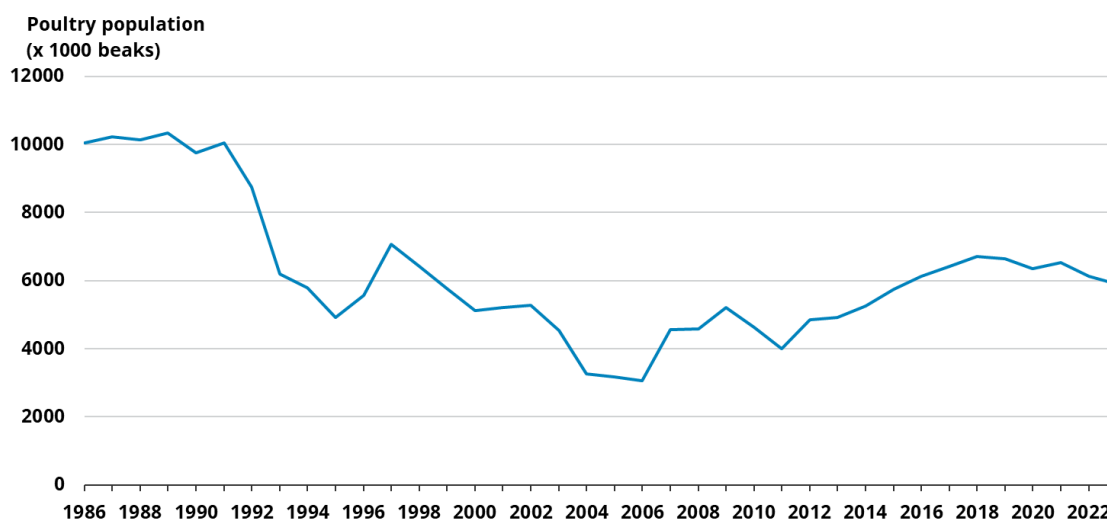


Figure 5.3.4: Number of poultry in thousands.

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).

#### **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 (Verbič after consultations with experts of the public advisory service, personal communication). Two hundred and fifty days of grazing season has been considered for sheep and 210 for goats and horses. As a result, the proportions of grazed animals were estimated to be 0.685, 0.460 and 0.288 for sheep, goats and horses, respectively. For the remaining period it has been considered that these animals were kept in straw based (solid) systems. Manure conversion factors of 0.02 and 0.01 were applied for housed and grazed animals, respectively.

#### **5.3.2.5 Rabbits (CRF 3.B.4)**

The IPCC (2006) default emission factor of 0.08 kg/head/year was used for rabbits. It was assumed that rabbits are not grazed and that only the solid manure system was used.

### **5.3.3 Uncertainties and time-series consistency**

Uncertainty of activity data amounts to 10% (Source: SORS, KIS).

The uncertainty estimate for EF in the 2006 IPCC Guidelines is 30% for default values and for Tier 2 EFs is not less than 20%. It is our experts' judgement that EFs for manure management are less accurate than those for enteric fermentation. According to their judgement, we are using uncertainty of 30% for 1986 and 25% for 2022.

Combined uncertainty amounts to 26.9%.

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

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

#### 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 estimates of VS excretion in pigs were updated for the entire reporting period. The default values have been replaced by values based on average body weight taking into account the 2019 Refinement to the 2006 IPCC Guidelines

Based on the results of the farm census, it was found that the share of cattle slurry systems was overestimated in the past. We have created new estimates for the entire time series. New estimates were made for manure management for laying hens. The gradual abandonment of cage system after 2016 was taken into account.

The number of broilers and geese for 2022 has been corrected. The statistical office has corrected the values following the submission of the previous report.

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

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census.

## 5.4 N<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 1986-2022 are presented. In the past a solid storage was a main type of MMS used while in the recent years the liquid systems prevailed.

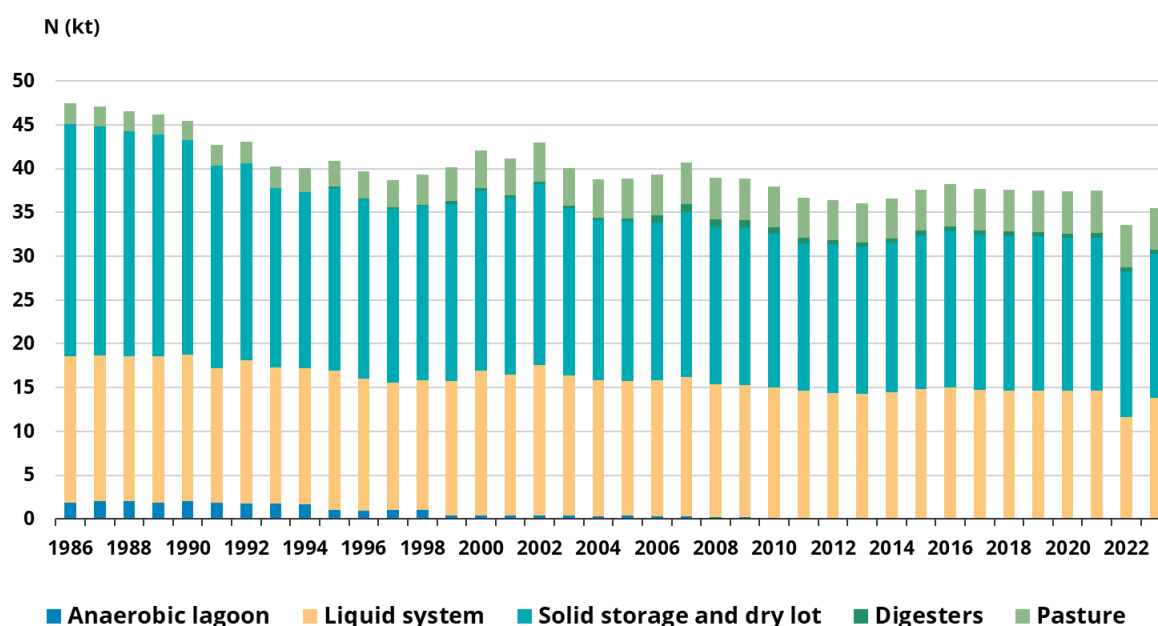


Figure 5.4.1: Nitrogen excretion per different MMS in kilotons.

### 5.4.2 Methodological issues

Mass balance approach which tracks nitrogen throughout the system was used to estimate N<sub>2</sub>O emissions. It was done by the means of detailed EMEP/EEA (2019) methodology, which is also used for national NH<sub>3</sub> and NO<sub>x</sub> emission inventory. Based on suggestion by IPCC (2006) (Chapter 10, 10.56), we have decided to use National NH<sub>3</sub> 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  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ , NO and  $\text{N}_2$  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  $\text{N}_2\text{O}$  emissions under the category “ $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  emissions due to nitrification and denitrification processes which results from the use of animal manure applied to soils. These emissions are reported under category “ $\text{N}_2\text{O}$  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 $\text{N}_2\text{O}$ 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. The primary source was EMEP/EEA (2019), which is based on IPCC (2006). The reason for selecting EMEP/EEA (2019) was that they provide information on nitrogen excretion in kg per animal, which is easier to apply than IPCC (2006), which provides information on nitrogen excretion per 1000 kg body weight. In dairy cows the nitrogen excretion has been linked to productivity, i.e. milk production (M, kg/year) and milk urea concentration (MU, mg/100 ml). The equation proposed by WUR (2014) was used:

$$\text{N excretion (kg/year)} = 129.9 + 0.0089 \times (M - 7744) + 1.7 \times (MU - 26)$$

The data on the milk urea concentration for the period from 2004 onwards are taken from the CATTLE database (Agricultural Institute of Slovenia), which contains data for about 80% of all

dairy cows in Slovenia. For the period before 2004, the average of the years 2004-2008 was used.

**Table 5.4.1: Nitrogen excretion rates for the calculation of ammonia emissions from animal production**

| Animal category                   | N excretion (kg N head /year) | Source  |
|-----------------------------------|-------------------------------|---|
| Cattle                            |                               |   |
| Dairy cows                        | 76.9-110.5                    | WUR (2014) taken into account milk production and milk urea concentration |
| Suckling cows                     | 41                            | EMEP/EEA (2019), based on information from IPCC (2006)                    |
| Calves, fattening cattle, heifers | 41                            | EMEP/EEA (2019), based on information from IPCC (2006)                    |
| Pigs                              |                               |   |
| Sows <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> | 77.4  | 76.9  | 77.0  | 77.2  | 77.0  | 81.2  | 77.5  | 77.2  | 79.1 | 80.5  |
|            | 1996  | 1997  | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004 | 2005  |
| <b>Nex</b> | 86.4  | 87.7  | 88.7  | 90.1  | 93.5  | 95.1  | 98.6  | 97.4  | 97.5 | 100.3 |
|            | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014 | 2015  |
| <b>Nex</b> | 104.0 | 101.9 | 102.7 | 98.5  | 98.1  | 97.9  | 99.6  | 98.2  | 99.3 | 97.8  |
|            | 2016  | 2017  | 2018  | 2019  | 2020  | 2021  | 2022  | 2023  |      |       |
| <b>Nex</b> | 102.2 | 101.4 | 104.3 | 105.1 | 108.2 | 108.4 | 110.5 | 109.7 |      |       |

In case of pigs, EMEP/CORINAIR (2002) excretion rates were used. A decision was made on the basis of reporting mode on the number of pigs in Slovenia. EMEP/CORINAIR (2002) N excretion rates concerns fattening pigs from 20 kg onwards and sows which also include piglets up to 20 kg of body mass. The same categories are reported by SORS. EMEP/EEA 2019 categories are not harmonised with those used in Slovenia (piglets up to 8 kg of body weight) and are therefore not applicable without adjustments.

For the purpose of comparison, in 2018, EMEP/CORINAIR (2002) excretion rates were compared to values derived by the use of IPCC (2006) methodology. Based on data on herd structure in 2017, EMEP/CORINAIR (2002) excretion rates resulted in average excretion rate of 12.2 kg of N per pig and year (Table 5.4.3). The corresponding value for IPCC (2006) methodology (values for West European countries) was 13.3 kg. It was decided to stick with the EMEP/CORINAIR (2002) methodology, which was generally adopted for reporting of emissions of N compounds in Slovenia.

Calculation of the average nitrogen excretion rate for 2017 is presented on the Table 5.4.3, while population data for the period 1986-2022 is available in the Annex 3 to the NIR.

**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> | <i>2,2294</i>  | <i>36</i>    | <i>-80,258</i>   |
| <b>Total</b>                          | <b>257,241</b> | <b>12.20</b> | <b>3,138,448</b> |

#### **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. The main sources for emission factors is EMEP/EEA, 2019 with an exception related to the proportion of TAN at the level of excretion where EFs for a farmyard manure and urine are from Menzi et al., 1997.

**Table 5.4.4: Emission factors and basic information on manure management systems in cattle production. (Sources for emission factors: EMEP/EEA, 2019 and Menzi et al., 1997 (marked with M))**

|  |         | Tied housing system              |                          | Loose housing system                  |
|--|---------|----------------------------------|--------------------------|---------------------------------------|
|  | Grazing | Farmyard* manure                 | Liquid* fraction (urine) | Slurry and anaerobic digesters        |
| Proportion of TAN at the level of excretion (in kg/kg total N)*  | 0.60    | 0.30 (M)                         | 0.825*** (M)             | 0.60                                  |
| <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<br>Other cattle: 240   | 0                        | 0                                     |
| N added in bedding (kg per animal per year)  | 0.00    | Cows: 2.92<br>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<br>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<br>Anaer. dig.: 0.0266** |
| Emissions from covered manure stores (proportion of TAN entering the stores)   | /       | /                                | 0.050                    | Slurry: 0.05<br>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<br>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<br>Anaer. dig.: 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                    | Slurry: 0.003<br>Anaer. dig.: 0.000   |

\* in farmyard manure system it was taken into account that 0.43 of N was retained in solid and 0.57 in liquid fraction

\*\* emission factor refers to the total N

\*\*\* The value proposed by Menzi et al. (1997) is 0.7 and the use of this value implies that the total amount of TAN excreted in the manure system is less than in the grazing or slurry based manure system. To harmonize the total amount of TAN excreted, we used a value of 0.825, which is close to the upper limit of the range given in the EMEP / EEA 2019.



Based on expert estimate it was assumed for the entire reporting period that 20 % of animal manures used on arable land were incorporated into the soil within about 12 to 24 hours after application (Table 5.4.4). It was assumed that basic emission coefficients for the above mentioned practice are reduced by 40 % (mean value for incorporation within 12 and within 24 hours, ECE/EB AIR/2014/8). For the period 2015-2022 it was also taken into account that a certain part of slurry was applied by the means of low emission techniques (36, 42, 43, 44, 44, 44, 44 and 45% for arable land and 0,70, 0,69, 0,69, 0,70, 0,69, 0,41, 0,35 and 0,35 % for grasslands in years 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022 respectively). The information is based on the area supported by Rural development programme (operation "low emission fertilization"). It was considered that low emission techniques were distributed into trailing hoses (70%) and trailing shoe (30 %). The estimates are based on information on investments in low emission equipment which was supported by the Rural development programme. For the efficiency of low emission techniques the values proposed by UNECE (2014) were taken into account.

### **Emissions from animal housing, manure stores and due to fertilization with animal manures in pig production (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. The main sources for emission factors is EMEP/EEA, 2019 with an exception related to the aerobic lagoon where two factors are from EPA, 2004.

**Table 5.4.5: Emission factors and basic information on manure management systems for the calculation of NH<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 and EPA, 2004 (marked with EPA))**

|  | Farmyard manure and solid* | Slurry | Anaerobic lagoon | Anaerobic fermenter |
|--|----------------------------|--------|------------------|---------------------|
| Proportion of TAN at the level of excretion (in kg/kg total N)*            | 0.70                       | 0.70   | 0.70             | 0.70                |
| <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<br>S: 600          | 0      | 0                | 0                   |
| N added in bedding (kg per animal per year)                                | FP: 0.8<br>S: 2.4          | 0      | 0                | 0                   |
| Mineralization of non-TAN N during storage (proportion of total non-TAN N) | 0                          | 0.1    | 1*** (EPA)       | 0.32                |

|  | 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<br>S: 0.24        | FP: 0.27<br>S: 0.35   | FP: 0.27<br>S: 0.35 | FP: 0.27<br>S: 0.35   |
| Emissions from uncovered manure stores (proportion of TAN entering the stores)   | 0.29                       | 0.11                  | 0.71*** (EPA)       | 0.0266**              |
| Emissions from covered manure stores (proportion of TAN entering the stores)   | /                          | 0.022                 | /                   | 0.0266**              |
| Emissions due to manure application – basic coefficients (proportion of TAN leaving the stores)                              | 0.450                      | FP: 0.40<br>S: 0.29   | /                   | FP: 0.40<br>S: 0.29   |
| Emissions due to manure application – coefficients for immediate manure incorporation (proportion of TAN leaving the stores) | 0.270                      | FP: 0.240<br>S: 0.174 | /                   | FP: 0.240<br>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

\*\*\* The EPA factor 0,71 refers to total nitrogen. For this reason, the mineralization factor was set to 1.

For the other low emission application techniques and their effectiveness the same assumptions as for cattle manures were used.

#### **Emissions from animal housing, manure stores and due to fertilization with animal manures in poultry production (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<br>solid | Laying hens<br>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. Some specific emission factors for rabbits are missing in the 2019 EMEP/EEA emission inventory guidebook. Values for sheep were used due to similarity of excreta. Grazing and farmyard manure management system are typical for goats, sheep, horses. The proportions of grazing animals were estimated by the means of expert opinion (Verbič, after consultations with experts of the public advisory service, personal communication). The description and estimates are given in chapter dealing with CH<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)   | 0.32   | 0.28   | 0.35   | 0.32 <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>a</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

#### 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% as recommended by IPCC..

Due to the use of IPCC default EF we have taken uncertainty estimates of 100% as suggested in the 2006 IPCC Guidelines.

Combined uncertainty amounts to 111.80%.

#### 5.4.4 Category-specific QA/QC

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

### **5.4.5 Category-specific recalculations**

Based on the results of the farm census, it was found that the share of cattle slurry systems was overestimated in the past. We have created new estimates for the entire time series. New estimates were made for manure management for laying hens. The gradual abandonment of cage system after 2016 was taken into account.

The number of broilers and geese for 2022 has been corrected. The statistical office has corrected the values following the submission of the previous report.

The nitrogen excretion rate for rabbits was set for the period after 2017. The factor for does was incorrectly applied to all breeding rabbits in previous reports.

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

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census.

## 5.5 N<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.

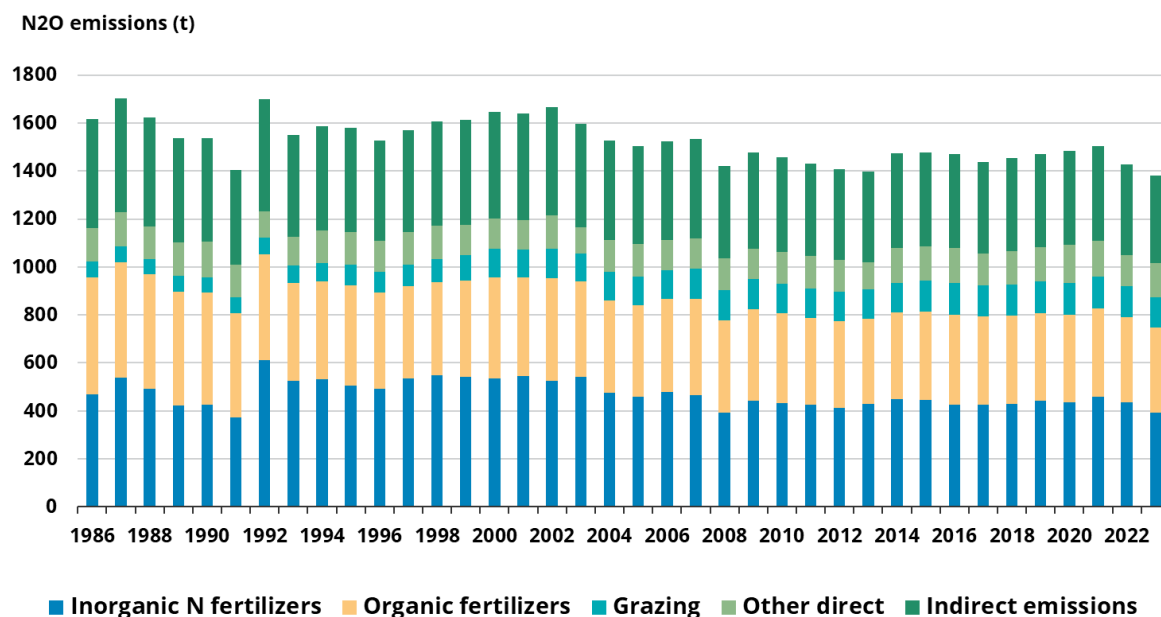


Figure 5.5.1: N<sub>2</sub>O emissions from agricultural soil in Gg.

### 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):

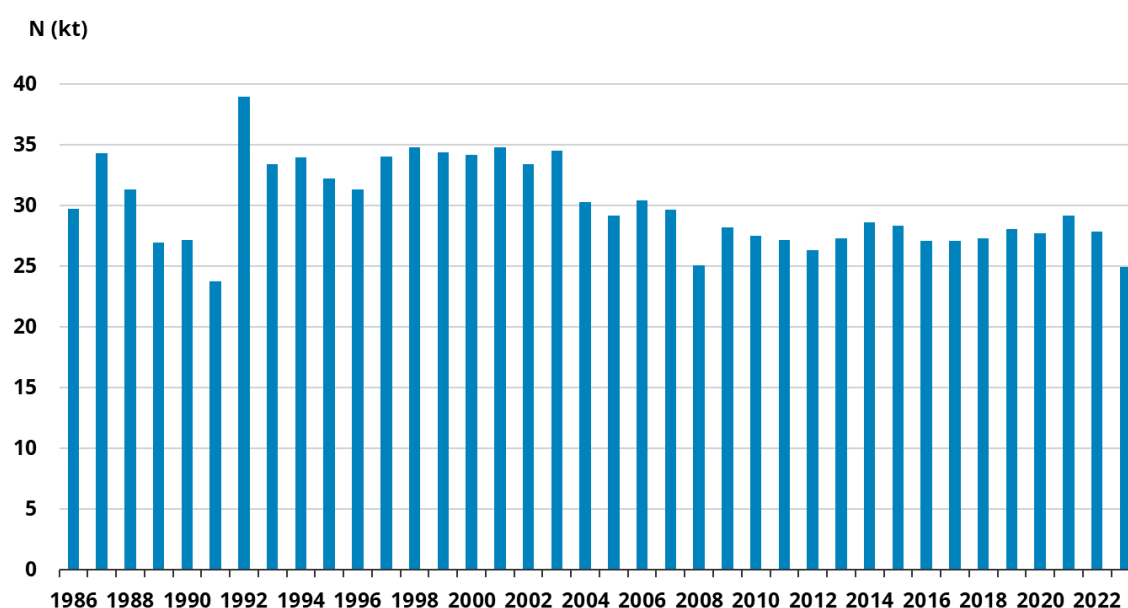
- mineral (inorganic) fertilizers;
- organic fertilizers, including animal manures, urban composts, digestates and sewage sludge;
- urine and dung deposited by grazing animals;
- crop residues;
- mineralization of soil organic matter which is associated with land use change or management of mineral soils;
- 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 NH<sub>3</sub> and NO<sub>x</sub> 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 (N<sub>2</sub>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 (NH<sub>3</sub>, NO<sub>x</sub>, N<sub>2</sub>O and N<sub>2</sub>) were subtracted from the total amount of N excreted by farm animals. The emissions were estimated according to EMEP/EEA (2019). The emission factor of 0.01 kg N<sub>2</sub>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 N<sub>2</sub>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 2014-2022 are available. For the period 1990-2013 the average value from the period 2014-2018 was considered. It was estimated that composts contained 14 kg of N per tonne. The estimate is based on the analyses of compost which were performed in the frame of monitoring programme for the period 2014-2018.

Data on digestates have been obtained from the reports submitted by biogas production plants to Environment Agency of the Republic of Slovenia. Biogas production from non-manure substrates started in 2006, however only the data for the period 2015-2022 are available. For the period 2006-2014 the quantities were estimated by linear regression taken into account zero value in 2005. In order to avoid double counting of N from animal manures, the latest was

subtracted from the total estimate. From the information which was gathered from biogas plants in 2010 and some recent information it was estimated that animal manures represent 1/3 of substrate which is used for biogas production. It was estimated that digestates contained 2.5 kg of N per tonne. The estimate is based on the analyses of digestates during the period 2014-2018. It refers to a mixture of solid and liquid digestates as produced by biogas plants.

The emission factor of 0.01 kg N<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)<br>AG <sub>DM</sub> = Crop (t, in DM) :<br>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>           | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 |
| <b>N<sub>2</sub>O</b> | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 |
|                       | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2005 | 2006 |
| <b>Area</b>           | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 | 2126 |
| <b>N<sub>2</sub>O</b> | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 | 26.7 |
|                       | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| <b>Area</b>           | 2126 | 2120 | 2135 | 2146 | 2211 | 2214 | 2219 | 2357 | 2358 | 2358 | 2360 |
| <b>N<sub>2</sub>O</b> | 26.7 | 26.7 | 26.8 | 27.0 | 27.8 | 27.8 | 27.9 | 29.6 | 29.6 | 29.6 | 29.7 |
|                       | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |      |      |      |      |      |
| <b>Area</b>           | 2350 | 2222 | 2226 | 2187 | 2178 | 2180 |      |      |      |      |      |
| <b>N<sub>2</sub>O</b> | 29.5 | 27.9 | 28.0 | 27.5 | 27.4 | 27.4 |      |      |      |      |      |

### 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, 2020, 2021 and 2022 it was taken into account that low emission application techniques are used on 8.8, 11.8, 14.7, 17.6, 20.6, 23.5 and 26.5% of arable land, respectively. It was considered that 60% of urea is used on arable land and that urea incorporation reduces ammonia emissions by 50 %. The decision was made on the basis of the fact that investments in machinery which enables urea incorporation are supported by the Rural development programme. For the total amount of N in

mineral fertilizers the same data as for direct  $\text{N}_2\text{O}$  emissions were used. In addition, data for urea consumption for the period 1994-2022 were obtained from SORS (personal communication). SORS does not publish these data, but they are reported to FAOSTAT and published with a slight delay. For the period 1985-1993 the proportion of urea in total mineral-N fertilizer consumption was estimated by extrapolation based on 1994-2013 period. The allocation of the rest of mineral-N 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) (Sušin, personal communication). From 2002 the data for CAN consumption are also available (SORS, personal communication, data not published in national statistics but reported to FAOSTAT).  $\text{NO}_x$  emissions were calculated by the use of an 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  $\text{N}_2\text{O-N/kg NH}_3$  and  $\text{NO}_x\text{-N}$  (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 ( $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$ ) 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 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 ( $\text{NH}_3\text{-N}$  and  $\text{NO}_x\text{-N}$ ) 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 N<sub>2</sub>O-N per kg of volatilised N (NH<sub>3</sub>-N and NO<sub>x</sub>-N) was used to assess N<sub>2</sub>O emissions, as suggested by IPCC (2006).

e. Urine and dung deposited by grazing animals

Estimates on the amount of NH<sub>3</sub>-N which is volatilized from grazing areas due to N deposited by grazing animals were done simultaneously with direct N<sub>2</sub>O emissions using EMEP/EEA (2019) methodology (Chapter 5.4.2.1). For emissions of NO<sub>x</sub>, emission factor 0.040 kg NO<sub>2</sub> per kg of nitrogen, which is deposited to soil in by grazing animals, was used (EMEP/EEA, 2019). In the second stage, emission factor 0.01 kg N<sub>2</sub>O-N per kg of volatilised N (NH<sub>3</sub>-N and NO<sub>x</sub>-N) was used to assess N<sub>2</sub>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 24% 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, 0.011 kg of N<sub>2</sub>O-N is emitted (IPCC, 2019).

b. Animal manure applied to soils

It has been considered that for every kg of N, which is applied to agricultural area, 0.24 kg of N is leached and run-off to watercourses and groundwater (IPCC, 2006). To get the amount of N applied to agricultural area, total amount of nitrogen excreted by housed farm animals has been corrected for the amount of NH<sub>3</sub>-N, N<sub>2</sub>O-N and N<sub>2</sub> 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 (0.011 kg N<sub>2</sub>O-N/kg of leached/run-off N) (IPCC, 2019).

c. Sewage sludge applied to soils

Emissions of N<sub>2</sub>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 0.24 kg of N per kg of applied N was lost into waters. Nitrous oxide emissions were then obtained by default factor 0.011 kg N<sub>2</sub>O-N per kg of leached/run-off N (IPCC, 2019).

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 0.24 kg of N per kg of applied N was lost into waters. Nitrous oxide emissions were then obtained by default factor 0.011 kg  $\text{N}_2\text{O}$ -N per kg of leached/run-off N (IPCC, 2019).

e. Urine and dung deposited by grazing animals

Emissions of  $\text{N}_2\text{O}$  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 (0.24 kg per kg) and default emission factor 0.011 kg  $\text{N}_2\text{O}$ -N per kg of leached/run-off N (IPCC, 2019). 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  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  Emissions from Managed Soils (5.5.2.). It has been taken into account that 0.24 kg of N per kg of released N from crop residues is lost into waters. Emission factor 0.011 kg  $\text{N}_2\text{O}$ -N per kg of leached/run-off N was used to calculate  $\text{N}_2\text{O}$  emissions (IPCC, 2019).

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

Emissions of  $\text{N}_2\text{O}$  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 0.24 kg of mineralized N is lost into waters. Emission factor 0.011 kg  $\text{N}_2\text{O}$ -N per kg of leached/run-off N was used to calculate emissions (IPCC, 2019).

### 5.5.3.3 Uncertainties and time-series consistency

Uncertainty estimates are based on expert judgement.

Uncertainty of activity data amounts to 25% in 1986 and 10% in the recent years.

Uncertainty of emission factor amounts to 250%.

Combined uncertainty amounts to 250.20%.

### 5.5.3.4 Category-specific QA/QC and verification

QA/QC procedures are described in the chapter 1.2.3 and 5.2.4. Input data, calculations and the results have been thoroughly vetted by experts in the KIS and in the SEA. Any errors that were found have been corrected. QA/QC procedure includes inquiries about new/more reliable



input information. In 2020, specific information on the use of various types of mineral fertilizers was obtained.

As an important QA/QC is also an ESD review, where all IEF and AD are compared with other counties and all outliers have to be justified.

#### **5.5.3.5 Category-specific recalculations**

The consumption of urea in 2022 has been corrected. Previously, the consumption of urea was slightly overestimated, while the consumption of nitrogen from other mineral fertilisers was underestimated by the same amount.

The area of managed organic soils was reassessed using a vector approach. The entire time series was corrected.

The emission factors used for the estimation of indirect nitrous oxide emissions due to nitrogen leaching ( $EF_5$  and  $FracLEACH(H)$ ) were updated for all nitrogen sources. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines.

In addition, the assessment of direct and indirect nitrous oxide emissions from agricultural soils was influenced by some corrections described under Manure management - nitrous oxide.

#### **5.5.3.6 Category-specific planned improvements**

It will be considered whether relevant information on manure storage practices can be obtained by processing the raw data collected as part of the 2020 Census. It will affect direct and indirect nitrous oxide emissions via the amount of nitrogen in animal manure.

## 5.6 Liming (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).

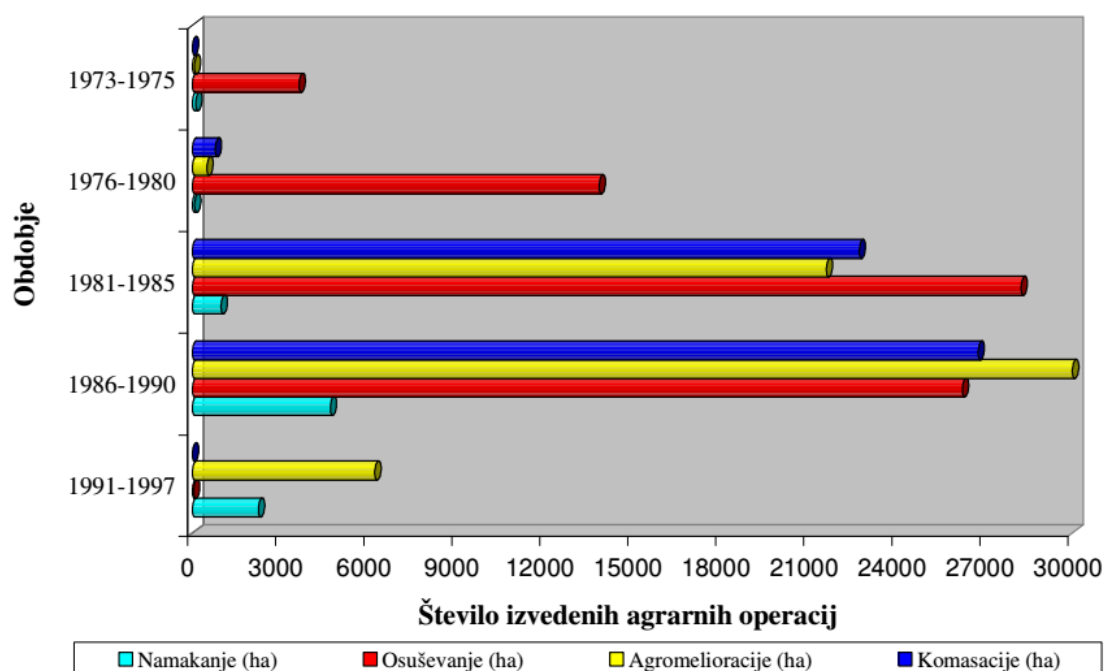


Figure 5.6.1: Area in hectares of different agricultural operations (irrigation-blue, drainage-red, agromelioration-yellow, land consolidation-blue), source: Miličić, 2007

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**

The consumption of urea in 2022 has been corrected. Previously, the consumption of urea was slightly overestimated, while the consumption of nitrogen from other mineral fertilisers was underestimated by the same amount.

### **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 (CRT sector 4)

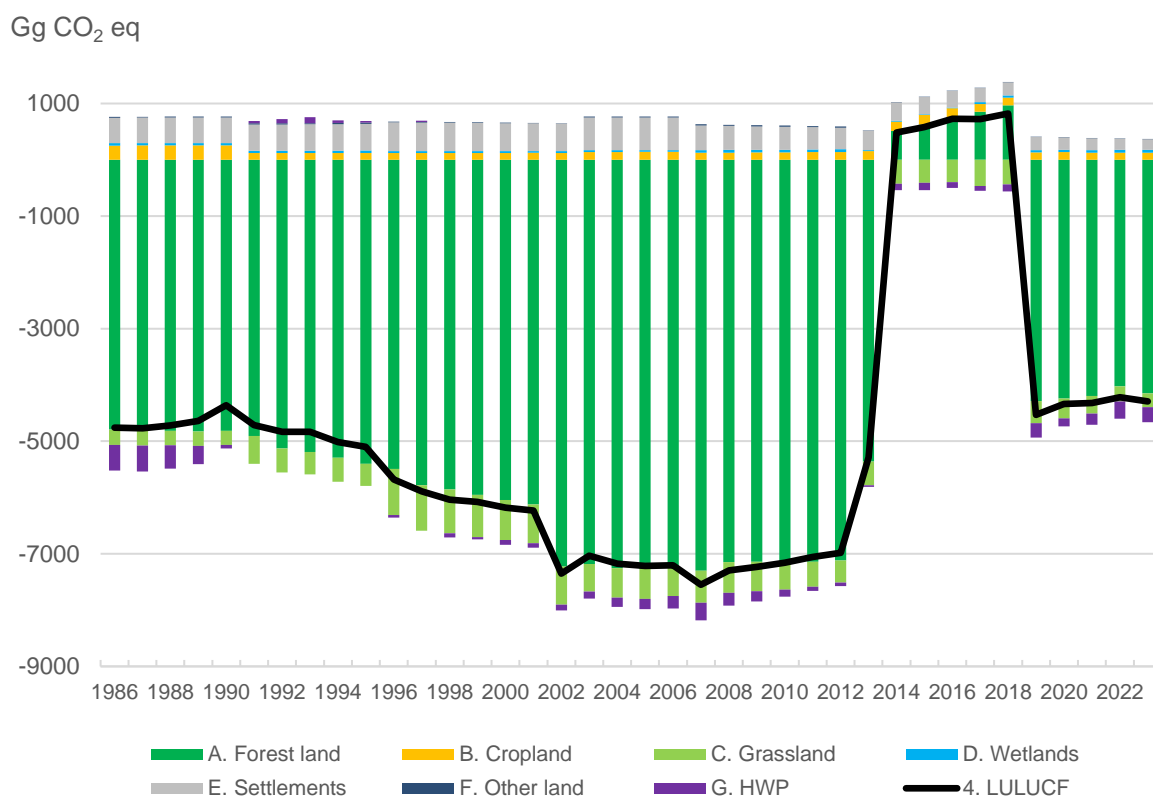
### 6.1 Overview of sector

The LULUCF sector comprises GHG emissions and removals resulting activities relating to land use land-use change and forestry. According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006, hereinafter 2006 Guidelines) Slovenia classifies its national land into 6 land-use categories; Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. Estimates of GHG emissions and removals in this sector are calculated from carbon stock changes in the five carbon pools, namely aboveground biomass, belowground biomass, dead wood, litter and soil. Reporting also includes emissions associated with N<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 2022 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 | -            |
|                            | 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, 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 2023, the LULUCF sector acted as a CO<sub>2</sub> sink of -4,291 Gg CO<sub>2</sub> eq as total emissions from this sector were higher than total removals (Figure 6.1.1). The most important category is forest land, which accounts for 97% of the sector's total net emissions. The LULUCF sector has been a net sink in recent years, largely due to declines in sanitary fellings and mortality rates. In terms of the overall trend of net removals from the LULUCF sector, removals decreased by 10 % from 1986 to 2023. Further decreases occurred from grassland and HWP. While net removals from grassland showed a decreasing trend, removals from HWP increased since 2016, due to increased biomass supply following natural disturbances in forests.



**Figure 6.1.1: Net emissions and removals in the LULUCF sector from 1986 to 2023**

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.

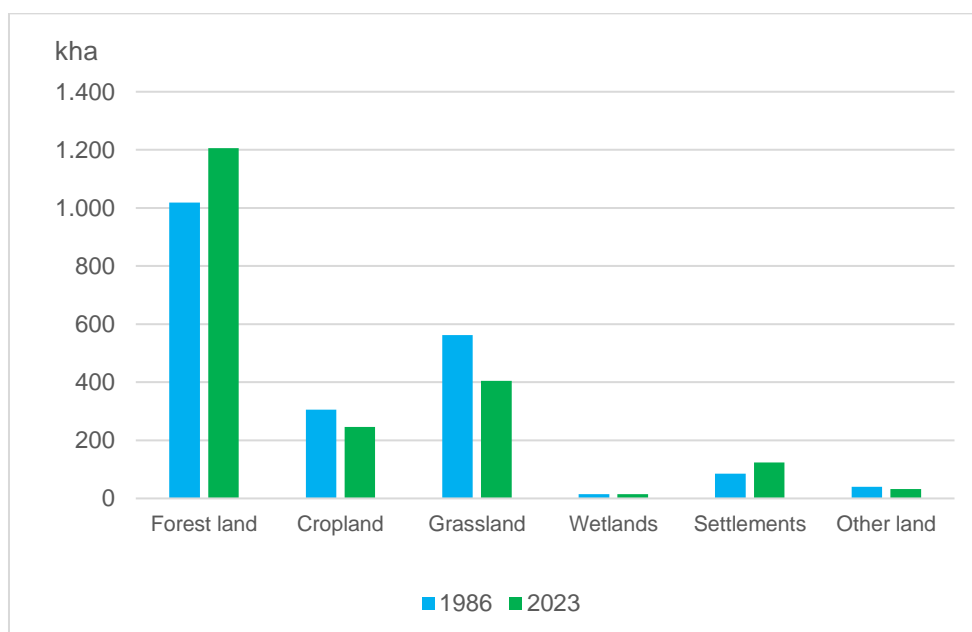
Country-specific emission factors and carbon stock values for forest land and, in some cases, for cropland and grassland are derived from surveys and measurements and have been used wherever possible. For other land use categories, IPCC default values or expert judgements are used.

The areas and shares of land use in 2023 are shown in Table 6.1.2, while the comparison of area by land use category between 1986 and 2023 is shown in Figure 6.1.2.

**Table 6.1.2: Area by categories of land use in the year 2023**

| Category    | Area, kha | Share, % |
|-------------|-----------|----------|
| Forest land | 1205.78   | 59.48    |
| Cropland    | 245.65    | 12.12    |
| Grassland   | 404.95    | 19.97    |
| Wetlands    | 15.23     | 0.75     |
| Settlements | 123.55    | 6.09     |
| 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 1986-2023. Total net emissions of CO<sub>2</sub> from the LULUCF sector were -4,758 Gg CO<sub>2</sub> eq in the base year (1986) and -4,291 Gg CO<sub>2</sub> eq in 2023. 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 were significantly affected by natural disturbances from 2014 to 2018. In this period the total harvest in damaged forests has increased by about 50%, 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 2023**

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 (%)                                    | -10%      | -13%   | -49%   | -10%   | 14%    | -58%   | -73%   | -41%    |
| 2023  | -4291     | -4148  | 128    | -244   | 48     | 191    | 4      | -271    |
| 2022  | -4219     | -4028  | 129    | -266   | 46     | 201    | 4      | -305    |
| 2021  | -4319     | -4197  | 129    | -314   | 44     | 210    | 4      | -195    |
| 2020  | -4337     | -4241  | 136    | -356   | 42     | 219    | 4      | -142    |
| 2019  | -4528     | -4288  | 134    | -394   | 40     | 228    | 4      | -253    |
| 2018  | 822       | 968    | 136    | -435   | 38     | 237    | 4      | -126    |
| 2017  | 724       | 856    | 134    | -467   | 36     | 246    | 4      | -86     |
| 2016  | 728       | 742    | 176    | -397   | 13     | 292    | 4      | -102    |
| 2015  | 580       | 624    | 173    | -410   | 13     | 306    | 4      | -129    |
| 2014  | 485       | 512    | 167    | -425   | 15     | 325    | 4      | -113    |
| 2013  | -5287     | -5358  | 157    | -425   | 16     | 344    | 5      | -25     |
| 2012  | -6981     | -7117  | 140    | -391   | 47     | 384    | 20     | -64     |
| 2011  | -7057     | -7139  | 137    | -443   | 46     | 397    | 20     | -75     |
| 2010  | -7156     | -7145  | 133    | -489   | 46     | 409    | 20     | -129    |
| 2009  | -7230     | -7144  | 130    | -518   | 46     | 419    | 19     | -183    |
| 2008  | -7297     | -7146  | 129    | -544   | 46     | 428    | 19     | -228    |
| 2007  | -7550     | -7299  | 127    | -569   | 46     | 438    | 19     | -311    |
| 2006  | -7201     | -7218  | 145    | -532   | 29     | 578    | 16     | -219    |
| 2005  | -7217     | -7266  | 142    | -533   | 30     | 579    | 16     | -185    |
| 2004  | -7176     | -7256  | 140    | -523   | 31     | 580    | 16     | -164    |
| 2003  | -7030     | -7179  | 138    | -489   | 32     | 581    | 16     | -129    |
| 2002  | -7352     | -7229  | 122    | -676   | 30     | 491    | 8      | -98     |
| 2001  | -6232     | -6124  | 124    | -688   | 31     | 494    | 8      | -78     |
| 2000  | -6181     | -6043  | 122    | -713   | 32     | 498    | 8      | -85     |
| 1999  | -6079     | -5953  | 122    | -752   | 34     | 501    | 9      | -40     |
| 1998  | -6038     | -5856  | 121    | -781   | 35     | 504    | 9      | -71     |
| 1997  | -5892     | -5782  | 119    | -807   | 36     | 508    | 10     | 24      |
| 1996  | -5678     | -5491  | 118    | -821   | 38     | 511    | 10     | -43     |
| 1995  | -5102     | -5403  | 123    | -388   | 42     | 474    | 21     | 28      |
| 1994  | -5017     | -5293  | 121    | -425   | 42     | 472    | 21     | 45      |
| 1993  | -4831     | -5193  | 120    | -396   | 42     | 470    | 21     | 106     |
| 1992  | -4831     | -5127  | 119    | -429   | 41     | 468    | 20     | 77      |
| 1991  | -4715     | -4908  | 120    | -493   | 41     | 466    | 20     | 40      |
| 1990  | -4362     | -4818  | 256    | -245   | 43     | 455    | 15     | -67     |
| 1989  | -4641     | -4825  | 256    | -255   | 43     | 455    | 15     | -329    |
| 1988  | -4718     | -4816  | 256    | -253   | 43     | 454    | 15     | -416    |
| 1987  | -4771     | -4803  | 254    | -274   | 42     | 454    | 14     | -460    |
| 1986  | -4758     | -4793  | 253    | -271   | 42     | 454    | 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**

### **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.

### 6.2.1 Forest land

Forest land is defined as land spanning more than 0.25 hectares with forest trees higher than 5 meters and canopy cover more than 10%, or trees able to reach this threshold *in situ*. It includes overgrown land (i.e. natural afforestation) on an area of at least 0.25 ha which has not been used for agricultural purposes in the last 20 years and on which forest trees can reach a height of at least 5 meters and a canopy cover has reached 75%. Forest land includes riparian and windbreak strips, wider than one tree height of a mature tree, in an area of at least 0.25 ha. Forest land also includes other wooded land, which is land covered with forest trees or other woody vegetation on an area of at least 0.25 ha and which has not been used for agricultural purposes in the last 20 years, including forest stables for game breeding and areas under power lines in forests on an area of at least 0.25 ha. Forest infrastructure that is not valued as a separate area is an integral part of forest. All Forest land is assumed managed.

### 6.2.2 Cropland

Cropland is defined as land suitable for agricultural production. Annual cropland includes arable land for annual crop production (cereals, potatoes, forage crops, vegetable crops, oilseeds, ornamental plants, herbs, strawberries, hop fields, etc), agricultural fallow land, and also temporary meadows and greenhouses. Perennial cropland includes areas for permanent crops such as vineyards, extensive and intensive orchards, olive groves, nurseries (for vines, fruit and forest trees), forest plantations and forest trees on agricultural land.

### 6.2.3 Grassland

Grassland is defined as agricultural land covered with grass and other herbage that is regularly mowed or grazed. This land is neither cultivated nor fallow. Perennial grassland includes overgrown areas, trees and shrubs, and forest trees on agricultural land with a minimum canopy cover of 10%. An annual grassland includes permanent meadows and pastures, including alpine pastures, and swampy meadows and pastures. The latter are located on organic or mineral-organic soils where groundwater rises only a few times a year. It also includes uncultivated arable land. It is assumed that all Grassland is managed.

### 6.2.4 Wetlands

Wetlands are defined as land that is temporarily or permanently saturated by water. Wetlands include areas such as fens, marshes, bogs and reeds that are not 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.

### 6.2.5 Settlements

Settlements are defined as infrastructure components where buildings, roads, parking places, mines, quarries and all other infrastructure are in human use. All Settlements are assumed to be managed.

## 6.2.6 Other land

Other land is defined as land with a vegetation height of less than 2 meters or land with a vegetation cover of less than 75% that is not used for agriculture. This includes developed areas with little or no vegetation such as rocks, sands, sandbars (greater than 5000 m<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**

| 1990-1995             | 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**

| 1995-2002             | 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**

| 2002-2006             | 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**

| <b>2006-2012</b>      | 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 2012-2016 in hectares**

| <b>2012-2016</b>      | FL      | CL_a   | CL_w  | GL_a   | GL_w  | WL    | SL     | OL    | Total <sub>2012</sub> |
|-----------------------|---------|--------|-------|--------|-------|-------|--------|-------|-----------------------|
| FL                    | 1204350 |        | 300   | 900    | 100   |       | 800    |       | 1206450               |
| CL_a                  |         | 190350 |       | 18600  |       |       | 100    |       | 209050                |
| CL_w                  |         | 500    | 48350 | 3800   | 300   |       |        |       | 52950                 |
| GL_a                  |         | 6600   | 800   | 290650 | 13200 |       | 1200   |       | 312450                |
| GL_w                  | 3700    | 300    | 200   | 4500   | 76050 |       | 100    |       | 84850                 |
| WL                    |         |        |       |        |       | 14350 | 0      |       | 14350                 |
| SL                    |         |        |       |        |       |       | 115050 |       | 115050                |
| OL                    |         |        |       |        |       |       |        | 32150 | 32150                 |
| Total <sub>2016</sub> | 1208050 | 197750 | 49650 | 318450 | 89650 | 14350 | 117250 | 32150 | 2027300               |

**Table 6.3.7: Land-use change matrix for the period 2016-2020 in hectares**

| <b>2016-2020</b>      | FL      | CL_a   | CL_w  | GL_a   | GL_w  | WL    | SL     | OL    | Total <sub>2016</sub> |
|-----------------------|---------|--------|-------|--------|-------|-------|--------|-------|-----------------------|
| FL                    | 1205850 |        | 100   | 1400   | 300   | 200   | 200    |       | 1208050               |
| CL_a                  |         | 192550 | 700   | 4000   |       | 200   | 300    |       | 197750                |
| CL_w                  |         | 400    | 47450 | 1600   |       |       | 200    |       | 49650                 |
| GL_a                  |         | 4500   | 500   | 306150 | 4700  | 100   | 2500   |       | 318450                |
| GL_w                  | 900     |        | 100   | 2100   | 86050 |       | 500    |       | 89650                 |
| WL                    |         |        |       |        |       | 14350 |        |       | 14350                 |
| SL                    |         |        | 100   |        |       |       | 117150 |       | 117250                |
| OL                    |         |        |       |        |       |       |        | 32150 | 32150                 |
| Total <sub>2020</sub> | 1206750 | 197450 | 48950 | 315250 | 91050 | 14850 | 120850 | 32150 | 2027300               |

Although many changes in nature took place in the period 2002-2012, the extent of conversions resulting from the previous land use change matrix was not realistic for Slovenia. The majority of converted areas resulting from the previous methodology, were small land use changes occurring due to differences in polygons boundaries that create so called “sliver polygons” when intersecting two layers. Another weakness of the vectorization process was the subjective delineation by which different land use types are determined in terms of polygons. The latter were often misinterpreted in the past, mainly due to the poor quality of

orthophotos and the subjectivity of the interpreters, which led to unreal changes. Some of the changes can also be attributed to the rasterization process. All these problems have already been discussed (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).

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<sub>LU, year of inventory</sub>* - area of selected land use category in year of inventory [ha]

*Area<sub>LU, previous inventory year</sub>* - area of selected land use category in previous year [ha]

*Area<sub>land converted to LU</sub>* - area of land converted to selected land use category [ha]

The standard error (in %) of an area estimate obtained for the years 2002, 2006 and 2012 in the targeted project (Mali et al. 2016) and for the year 2017 are presented below (Table 6.3.7).

**Table 6.3.8: Standard error (%) of an area estimate for the land-use categories**

| Land-use category                 | Standard error, % |           |           |           |
|-----------------------------------|-------------------|-----------|-----------|-----------|
|                                   | 2002-2006         | 2006-2012 | 2012-2016 | 2016-2020 |
| Forest land remaining forest land | 0.6               | 0.6       | 0.6       | 0.6       |
| Land converted to forest land     | 21.8              | 14.6      | 16.4      | 33.3      |
| Cropland remaining cropland       | 1.8               | 1.8       | 2.0       | 2.0       |
| Land converted to cropland        | 12.6              | 14.6      | 11.0      | 13.9      |
| Grassland remaining grassland     | 1.5               | 1.5       | 1.4       | 1.4       |
| Land converted to grassland       | 8.6               | 8.1       | 6.5       | 11.6      |
| Wetlands remaining wetlands       | 8.6               | 8.5       | 8.3       | 8.3       |
| Land converted to wetlands        | 100.0             | 44.7      | n.a.      | 44.7      |
| Settlements remaining settlements | 3.0               | 3.0       | 2.9       | 2.8       |
| Land converted to settlements     | 12.2              | 12.6      | 21.3      | 16.4      |
| Other land remaining other land   | 5.6               | 5.6       | 5.5       | 5.5       |
| Land converted to other land      | 70.7              | 70.7      | n.a.      | n.a.      |



**Table 6.3.9: Areas per LULUCF land-use categories from 1986 to 2023 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 |          |                 |               |               |              |                 |                |
| 2023      | 2027.30  | 1205.77         | 245.65        | 404.95        | 15.23        | 123.55          | 32.15          |
| 2022      | 2027.30  | 1206.10         | 245.90        | 405.40        | 15.10        | 122.65          | 32.15          |
| 2021      | 2027.30  | 1206.42         | 246.15        | 405.85        | 14.97        | 121.75          | 32.15          |
| 2020      | 2027.30  | 1206.75         | 246.40        | 406.30        | 14.85        | 120.85          | 32.15          |
| 2019      | 2027.30  | 1207.07         | 246.65        | 406.75        | 14.72        | 119.95          | 32.15          |
| 2018      | 2027.30  | 1207.40         | 246.90        | 407.20        | 14.60        | 119.05          | 32.15          |
| 2017      | 2027.30  | 1207.72         | 247.15        | 407.65        | 14.47        | 118.15          | 32.15          |
| 2016      | 2027.30  | 1208.05         | 247.40        | 408.10        | 14.35        | 117.25          | 32.15          |
| 2015      | 2027.30  | 1207.65         | 251.05        | 405.40        | 14.35        | 116.70          | 32.15          |
| 2014      | 2027.30  | 1207.25         | 254.70        | 402.70        | 14.35        | 116.15          | 32.15          |
| 2013      | 2027.30  | 1206.85         | 258.35        | 400.00        | 14.35        | 115.60          | 32.15          |
| 2012      | 2027.30  | 1206.45         | 262.00        | 397.30        | 14.35        | 115.05          | 32.15          |
| 2011      | 2027.30  | 1206.50         | 263.53        | 396.80        | 14.27        | 114.07          | 32.13          |
| 2010      | 2027.30  | 1206.55         | 265.07        | 396.30        | 14.18        | 113.08          | 32.12          |
| 2009      | 2027.30  | 1206.60         | 266.60        | 395.80        | 14.10        | 112.10          | 32.10          |
| 2008      | 2027.30  | 1206.65         | 268.13        | 395.30        | 14.02        | 111.12          | 32.08          |
| 2007      | 2027.30  | 1206.70         | 269.67        | 394.80        | 13.93        | 110.13          | 32.07          |
| 2006      | 2027.30  | 1206.75         | 271.20        | 394.30        | 13.85        | 109.15          | 32.05          |
| 2005      | 2027.30  | 1207.65         | 272.55        | 393.52        | 13.90        | 107.65          | 32.02          |
| 2004      | 2027.30  | 1208.55         | 273.90        | 392.75        | 13.95        | 106.15          | 32.00          |
| 2003      | 2027.30  | 1209.45         | 275.25        | 391.97        | 14.00        | 104.65          | 31.98          |
| 2002      | 2027.30  | 1210.35         | 276.60        | 391.20        | 14.05        | 103.15          | 31.95          |
| 2001      | 2027.30  | 1194.84         | 278.34        | 406.08        | 14.17        | 101.57          | 32.29          |
| 2000      | 2027.30  | 1179.33         | 280.08        | 420.96        | 14.30        | 99.99           | 32.63          |
| 1999      | 2027.30  | 1163.83         | 281.82        | 435.84        | 14.42        | 98.42           | 32.98          |
| 1998      | 2027.30  | 1148.32         | 283.56        | 450.73        | 14.54        | 96.84           | 33.32          |
| 1997      | 2027.30  | 1132.81         | 285.29        | 465.61        | 14.67        | 95.26           | 33.66          |
| 1996      | 2027.30  | 1117.30         | 287.03        | 480.49        | 14.79        | 93.68           | 34.00          |
| 1995      | 2027.30  | 1101.79         | 288.77        | 495.37        | 14.91        | 92.10           | 34.35          |
| 1994      | 2027.30  | 1086.29         | 292.10        | 508.32        | 14.89        | 91.08           | 34.61          |
| 1993      | 2027.30  | 1070.79         | 295.43        | 521.28        | 14.87        | 90.06           | 34.87          |
| 1992      | 2027.30  | 1055.29         | 298.75        | 534.23        | 14.85        | 89.04           | 35.13          |
| 1991      | 2027.30  | 1039.79         | 302.08        | 547.18        | 14.83        | 88.02           | 35.39          |
| 1990      | 2027.30  | 1024.29         | 305.41        | 560.13        | 14.81        | 87.00           | 35.65          |
| 1989      | 2027.30  | 1022.94         | 305.46        | 560.63        | 14.79        | 86.60           | 36.87          |
| 1988      | 2027.30  | 1021.59         | 305.51        | 561.13        | 14.76        | 86.20           | 38.10          |
| 1987      | 2027.30  | 1020.24         | 305.56        | 561.63        | 14.74        | 85.80           | 39.32          |
| 1986      | 2027.30  | 1018.89         | 305.61        | 562.13        | 14.71        | 85.40           | 40.55          |

### Average carbon stocks of carbon pools and data source

Above-ground biomass carbon stock were estimated based on data obtained by the national forest inventory (FECS) and national research studies (e.g. Mali et al., 2017b; Mali et al., 2018b).

Dead organic matter and soil organic carbon were determined from forest soil monitoring in 2007 as part of the BioSoil project.

Litter and soil organic carbon (SOC) stocks of agricultural land were estimated based on monitoring carried out in recent years (Mali et al., 2016; Mali et al., 2017a; Mali et al., 2018a; Šinkovec et al., 2020). The average values are shown in tables 6.3.10, 6.3.11, and 6.3.12. The values of SOC stocks were estimated for the depth of 0-30 cm of the mineral part of soil. Note that forest land, wetlands, settlements and other land were not subject of this monitoring.

**Table 6.3.10: Average carbon stocks in living biomass**

| Land use            | Above-ground biomass [t C ha <sup>-1</sup> ] | Below-ground biomass [t C ha <sup>-1</sup> ] | Living biomass [t C ha <sup>-1</sup> ] |
|---------------------|--|--|--|
| Forest land*        | *84.57                                       | 20.41  | 104.98                                 |
| Cropland annual     | 2.07   | 0.69   | 2.76                                   |
| Cropland perennial  | 9.29   | 6.48   | 15.77                                  |
| Grassland annual    | 1.89   | NA   | 1.89                                   |
| Grassland perennial | 35.02  | 13.13  | 48.15                                  |
| Wetlands            | 16.85  | 7.25   | 24.09                                  |
| Settlements         | 6.65   | 2.64   | 9.29                                   |
| Other land          | 5.00   | NA   | 5.00                                   |

\* The value for forest land refers to the year 2024

**Table 6.3.11: 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         | 6.03                              | 10.41                          | 16.43                                       |
| Cropland annual     | NA                                | NA                             | NA  |
| Cropland perennial  | NA                                | 3.70                           | 3.71  |
| Grassland annual    | NA                                | NA                             | NA  |
| Grassland perennial | 2.27                              | 7.58                           | 9.85  |
| Wetlands            | NA                                | NA                             | NA  |
| Settlements         | NA                                | NA                             | NA  |
| Other land          | NA                                | NA                             | NA  |

\* The value for forest land refers to the period 2020-2023

**Table 6.3.12: Average soil organic carbon stocks**

| Land use            | Mineral soil<br>[t C ha <sup>-1</sup> ] | n                     |
|---------------------|---|-----------------------|
| Forest land         | 103.31 ± 7.90                           | 136                   |
| Cropland annual     | 86.00 ± 5.29                            | 183                   |
| Cropland perennial  | 77.80                                   | Area weighted average |
| Vineyards           | 59.90 ± 6.61                            | 35                    |
| Intensive orchards  | 71.32 ± 6.40                            | 23                    |
| Extensive orchards  | 90.55 ± 8.84                            | 30                    |
| Grassland annual    | 94.86 ± 4.31                            | 141                   |
| Grassland perennial | 101.53                                  | Area weighted average |
| Overgrown areas     | 93.47 ± 14.42                           | 30                    |
| Trees and shrubs    | 107.16 ± 20.95                          | 23                    |
| Wetlands            | 10.76                                   | Area weighted average |
| Wetlands            | 158.21 ± 29.59                          | 25                    |
| Waters              | 0                                       | /                     |
| Settlements         | 29.85                                   | Area weighted average |
| Green urban areas   | 88.14 ± 23.37                           | 25                    |
| Sealed areas        | 0                                       | /                     |
| Other land          | 33.18                                   | EJ                    |

In 2022 and 2023, soil monitoring in wetlands and settlements was conducted as part of the inventory for non-forest land (Marinšek et al., 2023). The average soil organic carbon (SOC) stocks were estimated for the top 30 cm of soil (0-30 cm).

For wetlands, SOC stock assessments focused on swamps, reeds, and other marshy areas across 25 sites, yielding an average value of 158.21 t C ha<sup>-1</sup>. It was assumed that SOC stock for all inland water bodies, which are also classified as part of wetlands, is zero. This assumption resulted in an area-weighted average SOC stock of 10.76 t C ha<sup>-1</sup> for the entire wetlands category.

Similarly, SOC stock in settlements was assessed at 25 representative sites, with an average value of 88.14 t C ha<sup>-1</sup>. It was assumed that sealed areas within settlements have an SOC stock of zero by default. The area-weighted average SOC stock for settlements was calculated based on the proportion of green spaces (33.86%) and sealed urban areas.

For other land category, the SOC stock was estimated by expert judgment. This involved calculating a weighted average based on the areas of national land use classes 5000 and 6000, which were used as weights (see Table 6.2.1).

## 6.4 Forest Land (4A)

### 6.4.1 Source category description

Forest land category includes CO<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 2023 was 1205.77 kha, which is 59.48% 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 – 2023) 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 |                        |  |                                      |   |  |  |  |   |
| 2023      | 1205.77                | 1194.12                                  | 11.65                                | NO  | 11.40                                      | NO                                       | NO   | 0.1   |
| 2022      | 1206.10                | 1194.15                                  | 11.95                                | NO  | 11.65                                      | NO                                       | NO   | 0.1   |
| 2021      | 1206.42                | 1178.38                                  | 28.05                                | NO  | 27.75                                      | NO                                       | NO   | 0.1   |
| 2020      | 1206.75                | 1162.61                                  | 44.14                                | NO  | 43.84                                      | NO                                       | NO   | 0.1   |
| 2019      | 1207.07                | 1146.83                                  | 60.24                                | NO  | 59.94                                      | NO                                       | NO   | 0.1   |
| 2018      | 1207.40                | 1131.06                                  | 76.34                                | NO  | 76.04                                      | NO                                       | NO   | 0.1   |
| 2017      | 1207.72                | 1115.29                                  | 92.44                                | NO  | 92.14                                      | NO                                       | NO   | 0.1   |
| 2016      | 1208.05                | 1099.52                                  | 108.53                               | NO  | 108.23                                     | NO                                       | NO   | 0.1   |
| 2015      | 1207.65                | 1083.72                                  | 123.93                               | NO  | 123.63                                     | NO                                       | NO   | 0.1   |
| 2014      | 1207.25                | 1067.80                                  | 139.45                               | NO  | 139.11                                     | NO                                       | NO   | 0.1   |
| 2013      | 1206.85                | 1051.89                                  | 154.96                               | NO  | 154.58                                     | NO                                       | NO   | 0.1   |
| 2012      | 1206.45                | 1035.97                                  | 170.48                               | NO  | 170.06                                     | NO                                       | NO   | 0.1   |
| 2011      | 1206.50                | 1020.38                                  | 186.12                               | NO  | 185.67                                     | NO                                       | NO   | 0.08  |
| 2010      | 1206.55                | 1004.79                                  | 201.76                               | NO  | 201.29                                     | NO                                       | NO   | 0.07  |
| 2009      | 1206.60                | 1003.62                                  | 202.98                               | NO  | 202.51                                     | NO                                       | NO   | 0.05  |
| 2008      | 1206.65                | 1002.44                                  | 204.21                               | NO  | 203.72                                     | NO                                       | NO   | 0.03  |
| 2007      | 1206.70                | 1001.27                                  | 205.43                               | NO  | 204.94                                     | NO                                       | NO   | 0.02  |
| 2006      | 1206.75                | 1000.09                                  | 206.66                               | NO  | 206.16                                     | NO                                       | NO   | NO  |
| 2005      | 1207.65                | 999.49                                   | 208.16                               | NO  | 207.68                                     | NO                                       | NO   | NO  |
| 2004      | 1208.55                | 998.89                                   | 209.66                               | NO  | 209.21                                     | NO                                       | NO   | NO  |
| 2003      | 1209.45                | 998.29                                   | 211.16                               | NO  | 210.73                                     | NO                                       | NO   | NO  |
| 2002      | 1210.35                | 997.69                                   | 212.66                               | NO  | 212.26                                     | NO                                       | NO   | NO  |
| 2001      | 1194.84                | 996.48                                   | 198.36                               | NO  | 197.93                                     | NO                                       | NO   | NO  |
| 2000      | 1179.33                | 995.27                                   | 184.06                               | NO  | 183.61                                     | NO                                       | NO   | NO  |
| 1999      | 1163.83                | 994.06                                   | 169.76                               | NO  | 169.29                                     | NO                                       | NO   | NO  |
| 1998      | 1148.32                | 992.85                                   | 155.47                               | NO  | 154.97                                     | NO                                       | NO   | NO  |
| 1997      | 1132.81                | 991.64                                   | 141.17                               | NO  | 140.64                                     | NO                                       | NO   | NO  |
| 1996      | 1117.30                | 990.43                                   | 126.87                               | NO  | 126.32                                     | NO                                       | NO   | NO  |
| 1995      | 1101.79                | 989.22                                   | 112.58                               | NO  | 112.00                                     | NO                                       | NO   | NO  |
| 1994      | 1086.29                | 988.13                                   | 98.16                                | NO  | 97.60                                      | NO                                       | NO   | NO  |
| 1993      | 1070.79                | 987.05                                   | 83.74                                | NO  | 83.20                                      | NO                                       | NO   | NO  |
| 1992      | 1055.29                | 985.96                                   | 69.33                                | NO  | 68.80                                      | NO                                       | NO   | NO  |
| 1991      | 1039.79                | 984.88                                   | 54.92                                | NO  | 54.40                                      | NO                                       | NO   | NO  |
| 1990      | 1024.29                | 983.79                                   | 40.50                                | NO  | 40.00                                      | NO                                       | NO   | NO  |
| 1989      | 1022.94                | 982.44                                   | 40.50                                | NO  | 40.00                                      | NO                                       | NO   | NO  |
| 1988      | 1021.59                | 981.09                                   | 40.50                                | NO  | 40.00                                      | NO                                       | NO   | NO  |
| 1987      | 1020.24                | 979.74                                   | 40.50                                | NO  | 40.00                                      | NO                                       | NO   | NO  |
| 1986      | 1018.89                | 978.39                                   | 40.50                                | NO  | 40.5                                       | NO                                       | NO   | NO  |

Table 6.4.2: Emissions/removals from Forest land (1986 – 2023) 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> |                        |  |                                      |   |  |   |  |   |
| 2023                                       | -4148.78               | -4072.60                                 | -76.17                               | NO  | -74.11                                     | NO  | NO   | -2.06                                       |
| 2022                                       | -4150.58               | -4072.69                                 | -77.89                               | NO  | -75.83                                     | NO  | NO   | -2.06                                       |
| 2021                                       | -4198.18               | -4018.90                                 | -179.29                              | NO  | -177.23                                    | NO  | NO   | -2.06                                       |
| 2020                                       | -4244.85               | -3965.11                                 | -279.74                              | NO  | -277.69                                    | NO  | NO   | -2.06                                       |
| 2019                                       | -4290.57               | -3911.32                                 | -379.26                              | NO  | -377.20                                    | NO  | NO   | -2.06                                       |
| 2018                                       | 966.85                 | 1444.69                                  | -477.83                              | NO  | -475.78                                    | NO  | NO   | -2.06                                       |
| 2017                                       | 849.50                 | 1424.54                                  | -575.04                              | NO  | -572.99                                    | NO  | NO   | -2.05                                       |
| 2016                                       | 733.23                 | 1404.39                                  | -671.16                              | NO  | -669.11                                    | NO  | NO   | -2.05                                       |
| 2015                                       | 622.31                 | 1384.22                                  | -761.91                              | NO  | -759.86                                    | NO  | NO   | -2.05                                       |
| 2014                                       | 511.44                 | 1363.89                                  | -852.45                              | NO  | -850.40                                    | NO  | NO   | -2.04                                       |
| 2013                                       | -5361.22               | -4419.28                                 | -941.94                              | NO  | -939.90                                    | NO  | NO   | -2.04                                       |
| 2012                                       | -7142.56               | -6112.18                                 | -1030.39                             | NO  | -1028.35                                   | NO  | NO   | -2.04                                       |
| 2011                                       | -7144.81               | -6020.20                                 | -1124.61                             | NO  | -1122.91                                   | NO  | NO   | -1.70                                       |
| 2010                                       | -7147.06               | -5928.22                                 | -1218.84                             | NO  | -1217.48                                   | NO  | NO   | -1.36                                       |
| 2009                                       | -7147.38               | -5921.28                                 | -1226.10                             | NO  | -1225.08                                   | NO  | NO   | -1.02                                       |
| 2008                                       | -7147.71               | -5914.35                                 | -1233.35                             | NO  | -1232.67                                   | NO  | NO   | -0.68                                       |
| 2007                                       | -7302.55               | -6061.94                                 | -1240.61                             | NO  | -1240.27                                   | NO  | NO   | -0.34                                       |
| 2006                                       | -7284.03               | -6040.35                                 | -1243.68                             | NO  | -1243.68                                   | NO  | NO   | NO  |
| 2005                                       | -7271.04               | -6022.26                                 | -1248.79                             | NO  | -1248.79                                   | NO  | NO   | NO  |
| 2004                                       | -7258.02               | -6004.18                                 | -1253.84                             | NO  | -1253.84                                   | NO  | NO   | NO  |
| 2003                                       | -7244.95               | -5986.12                                 | -1258.83                             | NO  | -1258.83                                   | NO  | NO   | NO  |
| 2002                                       | -7232.20               | -5968.08                                 | -1264.12                             | NO  | -1264.12                                   | NO  | NO   | NO  |
| 2001                                       | -6132.08               | -4956.45                                 | -1175.63                             | NO  | -1175.63                                   | NO  | NO   | NO  |
| 2000                                       | -6046.90               | -4959.23                                 | -1087.67                             | NO  | -1087.67                                   | NO  | NO   | NO  |
| 1999                                       | -5962.23               | -4961.99                                 | -1000.23                             | NO  | -1000.23                                   | NO  | NO   | NO  |
| 1998                                       | -5878.06               | -4964.73                                 | -913.33                              | NO  | -913.33                                    | NO  | NO   | NO  |
| 1997                                       | -5794.39               | -4967.45                                 | -826.95                              | NO  | -826.95                                    | NO  | NO   | NO  |
| 1996                                       | -5499.22               | -4758.12                                 | -741.09                              | NO  | -741.09                                    | NO  | NO   | NO  |
| 1995                                       | -5407.80               | -4752.31                                 | -655.49                              | NO  | -655.49                                    | NO  | NO   | NO  |
| 1994                                       | -5316.98               | -4747.09                                 | -569.89                              | NO  | -569.89                                    | NO  | NO   | NO  |
| 1993                                       | -5226.70               | -4741.88                                 | -484.82                              | NO  | -484.82                                    | NO  | NO   | NO  |
| 1992                                       | -5136.95               | -4736.67                                 | -400.28                              | NO  | -400.28                                    | NO  | NO   | NO  |
| 1991                                       | -4923.68               | -4607.41                                 | -316.27                              | NO  | -316.27                                    | NO  | NO   | NO  |
| 1990                                       | -4835.23               | -4602.33                                 | -232.90                              | NO  | -232.90                                    | 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 1986-2023 were from -4,806.98 Gg CO<sub>2</sub> to -4,148.78 Gg CO<sub>2</sub> with a maximum value of -7,302.55 Gg CO<sub>2</sub> 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 1986-2023, annual removals and emissions ranged between -4,577.07 and -4,072.60 Gg CO<sub>2</sub>. The maximum value of removals in this subcategory was in 2012. In the period 2014-2018, the category acted as a net source of emissions, which was mostly due to natural disturbances, beginning with the ice break that occurred in early 2014 (Veselič et al., 2015; Nagel et al., 2016). In subsequent years, there were massive bark beetle outbreaks in the forests, resulting in a significant increase in sanitary felling (de Groot et al., 2018). In addition, there were some windthrows in 2017 and 2018 that further damaged the forests. NFI data for the period 2012-2018 showed that felling in 2014-2018 increased by more than 50% compared to the previous period, while mortality also increased significantly. The calculation for this period also shows that the net increment in forests has decreased. Recent data for the period 2018-2024 showed that the growing stock in forests increased which is mostly due to decrease in sanitary felling and mortality.

### 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 merchantable volume of stem from the ground to a top diameter of 6.99 cm, excluding stump and branches.

### Biomass expansion factor

Growing stock dependent biomass expansion factors (BEF) were determined using the generalized functions (Teobaldelli et al., 2009), considering different forest types/genera (i.e. broadleaved, conifers, *Abies* & *Picea*, *Larix*, and *Pinus*). The reciprocal equation (Equation 3) was used to express the relationship between BEF, defined as the ratio of tree biomass compartment to stand volume. Looking at the country-specific average values for BEF, BCEF and *R*, they are comparable and within the range of the default values (Table 3A.1.10, IPCC, 2003 and Tables 4.4 and 4.5, IPCC, 2006).

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

*y* – biomass expansion factor (dimensionless)

*x* – mean growing stock (m<sup>3</sup>/ha)

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

**Table 6.4.3: Values for parameters *a* and *b* according to Teobaldelli et al. (2009)**

| Forest type/genera          | <i>a</i> | <i>b</i> |
|-----------------------------|----------|----------|
| Broadleaved                 | 1,171    | 4,423    |
| Conifers                    | 1,153    | 12,400   |
| <i>Abies</i> & <i>Picea</i> | 1,126    | 8,002    |
| <i>Larix</i> sp.            | 1,104    | 8,797    |
| <i>Pinus</i> sp.            | 1,102    | 17,990   |

**Table 6.4.4: Average values for BEF, BCEF and *R* for the ten most important tree species in Slovenia**

| Tree species               | BEF  | BCEF  | <i>R</i> |
|----------------------------|------|-------|----------|
| <i>Fagus sylvatica</i>     | 1.19 | 0.694 | 0.24     |
| <i>Picea abies</i>         | 1.15 | 0.461 | 0.29     |
| <i>Abies alba</i>          | 1.15 | 0.460 | 0.29     |
| <i>Quercus petraea</i>     | 1.19 | 0.690 | 0.31     |
| <i>Pinus sylvestris</i>    | 1.18 | 0.496 | 0.29     |
| <i>Acer pseudoplatanus</i> | 1.19 | 0.619 | 0.25     |
| <i>Carpinus betulus</i>    | 1.19 | 0.750 | 0.25     |
| <i>Castanea sativa</i>     | 1.19 | 0.570 | 0.24     |
| <i>Pinus nigra</i>         | 1.21 | 0.508 | 0.30     |
| <i>Ostrya carpinifolia</i> | 1.22 | 0.768 | 0.31     |

### Root-to-shoot ratio

The ratio of below-ground biomass to above-ground biomass (R) for temperate continental forests was used according to Table 4.4 of the 2006 Guidelines. For conifers, *Quercus* spp. and other broadleaf species, different R ratios were used depending above-ground biomass stock. The average R values for key tree species in Slovenia are shown in Table 6.4.4.

### Basic wood density

Based on analyses of national data from previous studies by Slovenian Forestry Institute and Biotechnical Faculty, the basic wood density (D) was estimated to be 0.584 t/m<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 and from the national forest inventory (NFI) 2020-2023 were used to apply stock-difference method. The NFI 2020-2023 was conducted on concentric permanent fixed plots of a sampling grid with density 2 km × 2 km. The volume of above-ground biomass was 330.65 m<sup>3</sup>/ha (Table 6.4.5).

**Table 6.4.5: 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 |

|       |                |     |
|-------|----------------|-----|
| 2024* | 343.40 ± 14.08 | 741 |
|-------|----------------|-----|

\* Temporary data

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 19.75, 19.76, 24.22 m<sup>3</sup>/ha), respectively. The latest data from the NFI 2024 show that the average dead wood volume was 27.3 m<sup>3</sup>/ha.

## Litter

Litter includes all non-living biomass less than 10 cm in diameter, lying dead, in various states of decomposition above the mineral or organic soil. This includes litter, 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 6.4.6) based on forest soil monitoring conducted in 2007 on a systematic 8 km × 8 km grid as part of the Forest and Forest Ecosystem Condition Survey (FECS). Separate estimates of carbon stocks in the O<sub>i</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 6.4.6: 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 et al., 2013) for the period 1996-2006 show no statistically significant differences in the carbon stock change of litter. The results are explained and presented below (Figure 6.4.1).

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

The average soil organic carbon (SOC) stock was estimated at 103.31 t C/ha (Table 6.4.7) based on forest soil monitoring conducted in 2007 on a systematic 8 km × 8 km grid as part of the Forest and Forest Ecosystem Condition Survey (FECS). The SOC stock was estimated for the depth of 0-40 cm of the mineral part of the soil.

Carbon stock in the mineral part of the soil was calculated using the following equation:

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

$C_{pool}$  - 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 %)

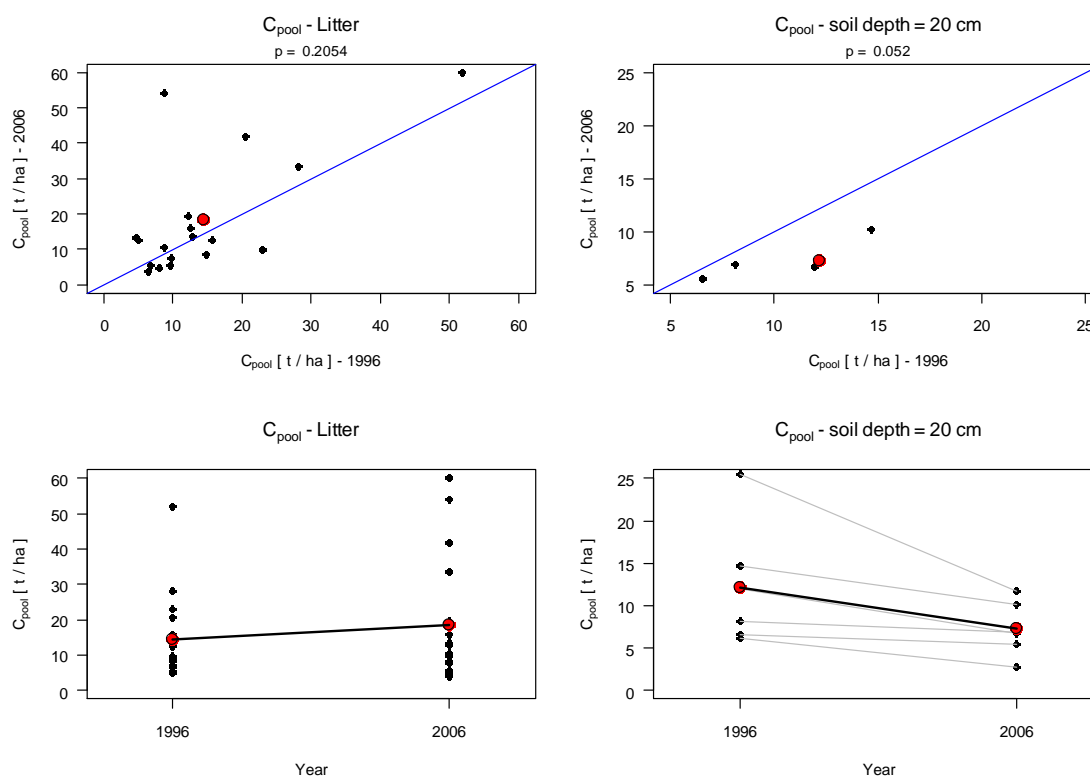
**Table 6.4.7: Average soil organic carbon stock of forest land**

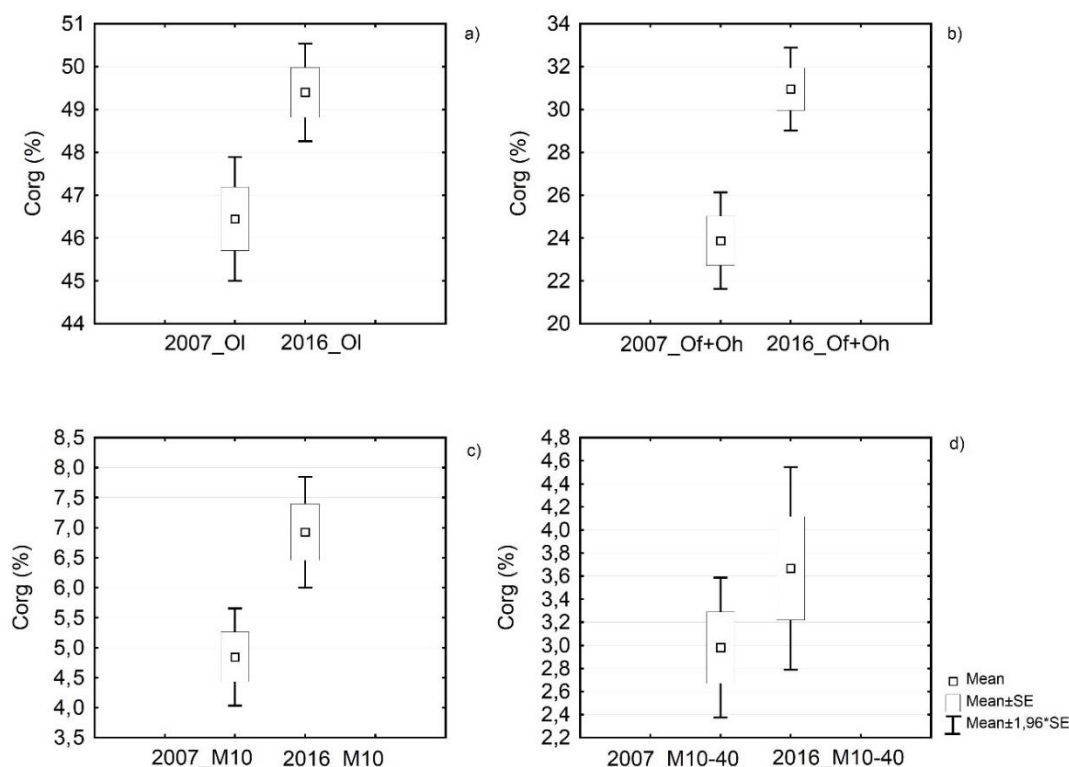
| Layer                   | Average carbon stock [t C ha <sup>-1</sup> ] | n   |
|-------------------------|--|-----|
| M <sub>10</sub> horizon | 35.25 ± 2.06                                 | 141 |
| M <sub>40</sub> horizon | 68.32 ± 6.22                                 | 136 |
| Forest land             | 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 et al., 2013) for the period 1996-2006 show no statistically significant differences in the SOC stock of forest soils (Figure 6.4.1).

For the year 1996, three subsamples of soil were collected from each plot for the organic (i.e. litter) and mineral layers. For the mineral part of the soil, samples were taken with a soil auger ( $\varnothing = 7$  cm) at a fixed depth (0-5, 5-10, 10-20, and 20-40 cm) and for organic layer within  $25 \times 25$  cm square. Subsamples were collected at 5 m intervals from the plot centre in a  $120^\circ$  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). Regulation on the protection of waters against pollution caused by nitrates from agricultural sources (2009) prohibits fertilization of forest land. Article 11 of the Regulation also prohibits fertilization on overgrown agricultural land and on infertile land and inland waters. Apparently, there is no legal document that regulates the area of drainage and rewetting of forest land. However, the Rules on forest protection state that any intervention in a forest area that may lead to devaluation of the forest must be approved by the Slovenia Forest Service, which keeps a

register of interventions in the forest, containing in particular information on the exact location of the intervention, its content, the area affected and the causes of the intervention, the time of implementation and the operator of the intervention, as well as the legality of the intervention.

### **Emissions from wildfires**

It should be noted that emissions from forest fires refer to the entire forest area (i.e. the total forest land). Since controlled burning is not allowed in Slovenia, all fires in forests are classified as “wildfires”. It is assumed that all fires affected productive forests. The area of forest fires in Slovenia is relatively small, less than 0.5% of forest. To estimate GHG emissions released directly from forest fires, the Tier 2 method (based on area burned and mass of fuel at the country level) was used. Equation 2.27 (IPCC 2006) was used to calculate emissions from wildfires.

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

$A$  – area burnt [ha]

$M_B$  – mass of fuel available for combustion [kg d.m. ha<sup>-1</sup>]

$C_f$  – combustion factor (dimensionless)

$G_{ef}$  – 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 emission factors for extra tropical forest were adopted. Data on mass of available fuel ( $M_B$ ) were taken from the Forest Fire Database of the Slovenia Forest Service, where these data have been recorded since 1994. The database contains information on the location, type of fire, area burned, type of vegetation burned and so on. The fraction of biomass combusted ( $C = 0.45$ ) was taken from Table 2.6 (IPCC 2006). Emissions from wildfires were estimated using Equation 2.27 of the 2006 Guidelines.

**Table 6.4.8: Emission factors used from Table 2.5 (IPCC 2006)**

| Gas              |                          | Emission factor ( $G_{ef}$ ) |
|------------------|--------------------------|------------------------------|
|                  |                          | [g / kg d.m.]                |
| CO <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. Since 2004, the data have been published every year and have been used accordingly to estimate the mass of available fuel. As suggested by the ERT, the amount of dead organic matter (average for Slovenia) was included in the mass of available fuel.



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

**Table 6.4.9: Productive forest land affected by wildfires and resulting GHG emissions 1986-2023**

| 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) |
|------|-----------|----------------------|---------|----------------------|----------------------|-----------------------|------------|
| 2023 | 4.93      | 0.447                | 0.030   | 0.001                | 0.001                | 0.000                 | 0.003      |
| 2022 | 3188.99   | 108.871              | 7.425   | 0.326                | 0.208                | 0.018                 | 0.694      |
| 2021 | 24.60     | 1.070                | 0.073   | 0.003                | 0.002                | 0.000                 | 0.007      |
| 2020 | 73.38     | 3.811                | 0.260   | 0.011                | 0.007                | 0.001                 | 0.024      |
| 2019 | 72.75     | 2.565                | 0.175   | 0.008                | 0.005                | 0.000                 | 0.016      |
| 2018 | 15.15     | 0.582                | 0.040   | 0.002                | 0.001                | 0.000                 | 0.004      |
| 2017 | 176.47    | 5.833                | 0.398   | 0.017                | 0.011                | 0.001                 | 0.037      |
| 2016 | 237.41    | 7.970                | 0.543   | 0.024                | 0.015                | 0.001                 | 0.051      |
| 2015 | 47.98     | 1.829                | 0.125   | 0.005                | 0.003                | 0.000                 | 0.012      |
| 2014 | 13.03     | 0.599                | 0.041   | 0.002                | 0.001                | 0.000                 | 0.004      |
| 2013 | 48.36     | 2.461                | 0.168   | 0.007                | 0.005                | 0.000                 | 0.016      |
| 2012 | 606.53    | 22.507               | 1.535   | 0.067                | 0.043                | 0.004                 | 0.143      |
| 2011 | 159.08    | 4.768                | 0.325   | 0.014                | 0.009                | 0.001                 | 0.030      |
| 2010 | 52.06     | 1.420                | 0.097   | 0.004                | 0.003                | 0.000                 | 0.009      |
| 2009 | 114.73    | 3.321                | 0.226   | 0.010                | 0.006                | 0.001                 | 0.021      |
| 2008 | 46.69     | 1.541                | 0.105   | 0.005                | 0.003                | 0.000                 | 0.010      |
| 2007 | 98.61     | 2.941                | 0.201   | 0.009                | 0.006                | 0.000                 | 0.019      |
| 2006 | 1022.81   | 58.379               | 3.981   | 0.175                | 0.112                | 0.010                 | 0.372      |
| 2005 | 142.23    | 4.306                | 0.294   | 0.013                | 0.008                | 0.001                 | 0.027      |
| 2004 | 76.87     | 2.102                | 0.143   | 0.006                | 0.004                | 0.000                 | 0.013      |
| 2003 | 1592.84   | 58.634               | 3.999   | 0.176                | 0.112                | 0.010                 | 0.374      |
| 2002 | 77.47     | 2.839                | 0.194   | 0.009                | 0.005                | 0.000                 | 0.018      |
| 2001 | 240.36    | 6.982                | 0.476   | 0.021                | 0.013                | 0.001                 | 0.044      |
| 2000 | 124.14    | 3.747                | 0.256   | 0.011                | 0.007                | 0.001                 | 0.024      |
| 1999 | 321.10    | 8.596                | 0.586   | 0.026                | 0.016                | 0.001                 | 0.055      |
| 1998 | 725.10    | 19.642               | 1.340   | 0.059                | 0.038                | 0.003                 | 0.125      |
| 1997 | 383.33    | 10.813               | 0.737   | 0.032                | 0.021                | 0.002                 | 0.069      |
| 1996 | 243.75    | 7.007                | 0.478   | 0.021                | 0.013                | 0.001                 | 0.045      |
| 1995 | 148.88    | 4.211                | 0.287   | 0.013                | 0.008                | 0.001                 | 0.027      |
| 1994 | 835.47    | 21.018               | 1.433   | 0.063                | 0.040                | 0.003                 | 0.134      |
| 1993 | 1196.92   | 29.928               | 2.041   | 0.090                | 0.057                | 0.005                 | 0.191      |
| 1992 | 344.97    | 8.573                | 0.585   | 0.026                | 0.016                | 0.001                 | 0.055      |
| 1991 | 559.51    | 13.819               | 0.942   | 0.041                | 0.026                | 0.002                 | 0.088      |
| 1990 | 615.77    | 15.114               | 1.031   | 0.045                | 0.029                | 0.003                 | 0.096      |
| 1989 | 120.00    | 2.927                | 0.200   | 0.009                | 0.006                | 0.000                 | 0.019      |
| 1988 | 181.75    | 4.406                | 0.300   | 0.013                | 0.008                | 0.001                 | 0.028      |
| 1987 | 393.00    | 9.466                | 0.646   | 0.028                | 0.018                | 0.002                 | 0.060      |
| 1986 | 515.00    | 12.326               | 0.841   | 0.037                | 0.024                | 0.002                 | 0.079      |

All data related to the burned areas are based on databases of Slovenia Forest Service (SFS). The areas are identified and geo-located. The annual data related to fires are annually published by SFS. All GHG emission from forest fires are reported under Forest land remaining forest land.

### 6.4.4.3 Land converted to Forest land

Data for land-use change from other land use to forest land are described in chapter 0 and chapter 6.3.1. For the calculation of the annual change in carbon stocks in other land converted to Forest land the Tier 2 (IPCC 2006) approach is used.

The average annual area converted from other land uses to forest land in the period 2002-2020 is between 0.53 and 0.78 kha according to land use change matrices (Table 6.3.4 to Table 6.3.7). As described in chapter 0 the land use change to forests appear only from grassland. Conversions to forest land are not direct human induced. The areas are under spontaneous afforestation (natural expansion) of forest. However, the SFS system of forest management differentiates forest lands covered by management plans according to production function and other ecological and social functions.

Definition of forest (Forest Act) in relation to management plans; land with an area of more than 0.25 hectares with trees higher than 5 meters or trees able of reaching this threshold *in situ*. This includes abandoned agricultural land (cropland, grassland) with natural expansion of forest (canopy cover > 75%) that has existed for more than 20 years.

#### Carbon stock changes in living biomass

The carbon stock change of living biomass was calculated considering the increase and decrease of carbon stock with respect to the areas in transition to forest land. Annual increment of stem wood over bark on land converted to forest was estimated using NFI data (i.e. FECS). Equation 2.15 and Equation 2.16 from the 2006 Guidelines were used for the calculation. The method of converting volume to biomass for estimating carbon stocks in living biomass follows that described in subsection 6.4.4.1.

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

$\Delta C_B$  – 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>

$\Delta C_{CONVERSION}$  – 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>

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

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

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

$B_{BEFORE}$  – 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.

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

$\Delta C_{DOM}$  - 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.

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

$\Delta C_{Mineral}$  - 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 ( $SOC_{FL} = 103.31 \text{ t C ha}^{-1}$ ) was estimated from forest soil monitoring (Table 6.4.7). Country-specific values for annual and perennial grassland soil ( $SOC_{GL\_a} = 94.86 \text{ t C ha}^{-1}$ ,  $SOC_{GL\_w} = 101.53 \text{ t C ha}^{-1}$ ) were estimated from agricultural soil monitoring (Table 6.3.12).

**Organic soils**

Activity data for organic soils was revised using area data from the Pedology Map, which is consistent with the areas in the Agriculture sector. It is assumed that no land with organic soils is converted to forest land. Therefore, emissions from organic soils on land converted to forest land were not reported. For 70% of the national land-use classes that have organic soils, the annual difference in land use change is less than 1%, while in the other 30% of classes the difference rarely exceeds 5%. The difference is analysed by cross-tabulation of vector layers and the result is in most cases due to the methodology ("sliver" effect). Therefore, we believe that areas with organic soils are more likely to be stable.

## Non-CO<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 growing stock (carbon stock) and dead wood stock as basis for UNFCCC reporting for all Slovenian forests. Uncertainties related to the 95% confidence interval are expressed as twofold standard errors of the mean are presented in Table 6.4.10.

**Table 6.4.10: Uncertainties from FECS 2000, 2007, 2012 and 2018**

| Parameter     | FECS 2000 | FECS 2007 | FECS 2012 | FECS 2018 |
|---------------|-----------|-----------|-----------|-----------|
| Growing stock | ±4.68 %   | ±4.21 %   | ±4.08 %   | ±4.20 %   |
| Dead wood     |           | ±11.27 %  | ±9.72 %   | ±9.88 %   |
| Litter        |           | ±14.41 %  |           |           |
| Soil          |           | ±7.65 %   |           |           |

### 6.4.6 Source specific QA/QC and verification

The data based on forest statistics are produced by the Slovenian Forestry Institute (SFI). Data descriptions are available in Slovenian language.

QC measures related to national Forestry Inventory data were:

- A manual for FECS was prepared.
- Field instruments were calibrated and checked.
- All methods were tested in pilot inventory in 2006 (grid 16 x 16 km).
- In preparatory phase all field personnel was trained for:
  - correct use equipments.
  - correct measurements and classifications.

- understanding of the guidelines and specific instructions.
- Verification measurements were carried out during field seasons - 4 teams from SFI were controlling the field measurements and work of Slovenian Forest Service teams.
- Field data was entered in database and checked for major discrepancies.
- All data used for our calculation is saved on our data server and are protected from unauthorized access.

All soil samples (from soil inventory on 8 km x 8 km) were delivered and stored in laboratory at SFI according to internal quality management system.

General QA/QC, taking into account the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

#### **6.4.7 Source specific recalculations**

Recalculations were conducted for the period 2018-2022 for the forest land remaining forest due to updated emission factors for living biomass and dead wood, derived from recent estimates from the NFI 2020-2023. Minor adjustment have been applied to other years as well owing to refinements in the method used for calculating the merchantable volume. Additionally, recalculations were made for land converted to forest land, incorporating updated emission factors specifically for dead wood.

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

No major improvements are planned for this category in the next annual submission.

## 6.5 Cropland (4B)

### 6.5.1 Source category description

The cropland category includes CO<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 12.12% of the country's land area in 2023. 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 53% between 1986 and 2023 (i.e., from 259.99 to 122.75 Gg CO<sub>2</sub>). Cropland remaining Cropland and Land converted to Cropland are the key categories in the trend analysis.

Table 6.5.1: Activity data for Cropland (1986 – 2023) 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 |                     |                   |                                    |                                    |   |   |                                       |   |  |
| 2023      | 245.68              | 2.14              | 218.78                             | 26.90                              | 1.17                                      | 25.38                                   | NO                                    | 0.35                                      | NO                                       |
| 2022      | 245.93              | 2.16              | 218.78                             | 27.15                              | 1.25                                      | 25.55                                   | NO                                    | 0.35                                      | NO                                       |
| 2021      | 246.18              | 2.17              | 218.92                             | 27.26                              | 1.31                                      | 25.61                                   | NO                                    | 0.34                                      | NO                                       |
| 2020      | 246.43              | 2.21              | 219.07                             | 27.37                              | 1.37                                      | 25.67                                   | NO                                    | 0.33                                      | NO                                       |
| 2019      | 246.68              | 2.21              | 219.21                             | 27.47                              | 1.43                                      | 25.72                                   | NO                                    | 0.32                                      | NO                                       |
| 2018      | 246.93              | 2.33              | 219.35                             | 27.58                              | 1.49                                      | 25.78                                   | NO                                    | 0.31                                      | NO                                       |
| 2017      | 247.18              | 2.34              | 219.49                             | 27.69                              | 1.55                                      | 25.84                                   | NO                                    | 0.30                                      | NO                                       |
| 2016      | 247.43              | 2.34              | 219.64                             | 27.80                              | 1.61                                      | 25.90                                   | NO                                    | 0.29                                      | NO                                       |
| 2015      | 251.08              | 2.34              | 223.90                             | 27.18                              | 1.62                                      | 25.25                                   | NO                                    | 0.30                                      | NO                                       |
| 2014      | 254.73              | 2.34              | 228.70                             | 26.03                              | 1.67                                      | 23.94                                   | NO                                    | 0.42                                      | NO                                       |
| 2013      | 258.38              | 2.20              | 233.50                             | 24.88                              | 1.71                                      | 22.62                                   | NO                                    | 0.54                                      | NO                                       |
| 2012      | 262.03              | 2.20              | 238.30                             | 23.73                              | 1.76                                      | 21.31                                   | NO                                    | 0.66                                      | NO                                       |
| 2011      | 263.57              | 2.20              | 239.72                             | 23.84                              | 1.81                                      | 21.27                                   | NO                                    | 0.76                                      | NO                                       |
| 2010      | 265.10              | 2.14              | 241.14                             | 23.96                              | 1.87                                      | 21.23                                   | NO                                    | 0.87                                      | NO                                       |
| 2009      | 266.63              | 2.12              | 241.70                             | 24.93                              | 1.90                                      | 21.98                                   | NO                                    | 1.05                                      | NO                                       |
| 2008      | 268.17              | 2.11              | 242.27                             | 25.89                              | 1.93                                      | 22.73                                   | NO                                    | 1.23                                      | NO                                       |
| 2007      | 269.70              | 2.11              | 242.84                             | 26.86                              | 1.97                                      | 23.48                                   | NO                                    | 1.42                                      | NO                                       |
| 2006      | 271.23              | 2.11              | 243.40                             | 27.83                              | 2.00                                      | 24.23                                   | NO                                    | 1.60                                      | NO                                       |
| 2005      | 272.58              | 2.11              | 244.58                             | 28.00                              | 2.00                                      | 24.23                                   | NO                                    | 1.77                                      | NO                                       |
| 2004      | 273.90              | 2.11              | 245.72                             | 28.18                              | 2.00                                      | 24.23                                   | NO                                    | 1.95                                      | NO                                       |
| 2003      | 275.25              | 2.11              | 246.90                             | 28.35                              | 2.00                                      | 24.23                                   | NO                                    | 2.12                                      | NO                                       |
| 2002      | 276.60              | 2.11              | 248.07                             | 28.53                              | 2.00                                      | 24.23                                   | NO                                    | 2.30                                      | NO                                       |
| 2001      | 278.34              | 2.11              | 249.49                             | 28.85                              | 2.01                                      | 24.35                                   | NO                                    | 2.49                                      | NO                                       |
| 2000      | 280.08              | 2.11              | 250.91                             | 29.16                              | 2.03                                      | 24.46                                   | NO                                    | 2.67                                      | NO                                       |
| 1999      | 281.82              | 2.11              | 252.34                             | 29.48                              | 2.04                                      | 24.58                                   | NO                                    | 2.86                                      | NO                                       |
| 1998      | 283.56              | 2.11              | 253.76                             | 29.80                              | 2.06                                      | 24.70                                   | NO                                    | 3.04                                      | NO                                       |
| 1997      | 285.29              | 2.11              | 255.18                             | 30.12                              | 2.07                                      | 24.82                                   | NO                                    | 3.23                                      | NO                                       |
| 1996      | 287.03              | 2.11              | 256.60                             | 30.43                              | 2.09                                      | 24.93                                   | NO                                    | 3.41                                      | NO                                       |
| 1995      | 288.77              | 2.11              | 258.02                             | 30.75                              | 2.10                                      | 25.05                                   | NO                                    | 3.60                                      | NO                                       |
| 1994      | 292.10              | 2.11              | 260.50                             | 31.60                              | 2.08                                      | 25.84                                   | NO                                    | 3.68                                      | NO                                       |
| 1993      | 295.43              | 2.11              | 262.98                             | 32.45                              | 2.06                                      | 26.63                                   | NO                                    | 3.76                                      | NO                                       |
| 1992      | 298.75              | 2.11              | 265.45                             | 33.30                              | 2.04                                      | 27.42                                   | NO                                    | 3.84                                      | NO                                       |
| 1991      | 302.08              | 2.11              | 267.93                             | 34.15                              | 2.02                                      | 28.21                                   | NO                                    | 3.92                                      | NO                                       |
| 1990      | 305.41              | 2.11              | 270.41                             | 35.00                              | 2.00                                      | 29.00                                   | NO                                    | 4.00                                      | NO                                       |
| 1989      | 305.46              | 2.11              | 270.46                             | 35.00                              | 2.00                                      | 29.00                                   | NO                                    | 4.00                                      | NO                                       |
| 1988      | 305.51              | 2.11              | 270.51                             | 35.00                              | 2.00                                      | 29.00                                   | NO                                    | 4.00                                      | NO                                       |
| 1987      | 305.56              | 2.11              | 270.56                             | 35.00                              | 2.00                                      | 29.00                                   | NO                                    | 4.00                                      | NO                                       |
| 1986      | 305.61              | 2.11              | 270.61                             | 35.00                              | 2.00                                      | 29.00                                   | NO                                    | 4.00                                      | NO                                       |

Table 6.5.2: Emissions from Cropland (1986 – 2023) 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> |                     |                                    |                                   |   |   |                                       |   |  |
| 2023                                       | 122.75              | 60.38                              | 62.38                             | 12.53                                     | 46.28                                   | NA                                    | 3.57                                      | NA                                       |
| 2022                                       | 123.34              | 62.24                              | 61.10                             | 12.61                                     | 45.55                                   | NA                                    | 2.94                                      | NA                                       |
| 2021                                       | 123.00              | 63.45                              | 59.55                             | 12.65                                     | 44.47                                   | NA                                    | 2.42                                      | NA                                       |
| 2020                                       | 130.30              | 72.31                              | 57.99                             | 12.69                                     | 43.39                                   | NA                                    | 1.90                                      | NA                                       |
| 2019                                       | 128.06              | 71.63                              | 56.43                             | 12.73                                     | 42.32                                   | NA                                    | 1.38                                      | NA                                       |
| 2018                                       | 129.56              | 74.69                              | 54.87                             | 12.77                                     | 41.24                                   | NA                                    | 0.86                                      | NA                                       |
| 2017                                       | 127.83              | 74.39                              | 53.43                             | 12.93                                     | 40.16                                   | NA                                    | 0.34                                      | NA                                       |
| 2016                                       | 169.63              | 73.72                              | 95.91                             | 32.72                                     | 63.61                                   | NA                                    | -0.42                                     | NA                                       |
| 2015                                       | 166.37              | 72.64                              | 93.73                             | 32.85                                     | 61.45                                   | NA                                    | -0.57                                     | NA                                       |
| 2014                                       | 160.53              | 70.32                              | 90.21                             | 33.08                                     | 58.93                                   | NA                                    | -1.80                                     | NA                                       |
| 2013                                       | 151.31              | 64.61                              | 86.70                             | 33.32                                     | 56.42                                   | NA                                    | -3.04                                     | NA                                       |
| 2012                                       | 134.54              | 61.98                              | 72.56                             | 30.48                                     | 46.19                                   | NA                                    | -4.11                                     | NA                                       |
| 2011                                       | 131.45              | 61.15                              | 70.30                             | 30.22                                     | 45.68                                   | NA                                    | -5.60                                     | NA                                       |
| 2010                                       | 126.79              | 58.75                              | 68.04                             | 29.95                                     | 45.16                                   | NA                                    | -7.08                                     | NA                                       |
| 2009                                       | 124.47              | 57.74                              | 66.72                             | 29.63                                     | 46.48                                   | NA                                    | -9.39                                     | NA                                       |
| 2008                                       | 122.34              | 56.93                              | 65.41                             | 29.31                                     | 47.80                                   | NA                                    | -11.70                                    | NA                                       |
| 2007                                       | 120.52              | 56.42                              | 64.10                             | 28.99                                     | 49.11                                   | NA                                    | -14.00                                    | NA                                       |
| 2006                                       | 138.03              | 57.40                              | 80.63                             | 40.85                                     | 55.40                                   | NA                                    | -15.62                                    | NA                                       |
| 2005                                       | 135.69              | 56.34                              | 79.35                             | 40.24                                     | 56.53                                   | NA                                    | -17.42                                    | NA                                       |
| 2004                                       | 133.03              | 54.95                              | 78.08                             | 39.64                                     | 57.66                                   | NA                                    | -19.22                                    | NA                                       |
| 2003                                       | 130.70              | 53.89                              | 76.81                             | 39.04                                     | 58.79                                   | NA                                    | -21.03                                    | NA                                       |
| 2002                                       | 115.34              | 51.55                              | 63.78                             | 33.29                                     | 53.68                                   | NA                                    | -23.19                                    | NA                                       |
| 2001                                       | 117.05              | 54.18                              | 62.88                             | 32.82                                     | 55.16                                   | NA                                    | -25.10                                    | NA                                       |
| 2000                                       | 114.67              | 52.61                              | 62.06                             | 32.44                                     | 56.64                                   | NA                                    | -27.02                                    | NA                                       |
| 1999                                       | 114.46              | 53.22                              | 61.24                             | 32.05                                     | 58.12                                   | NA                                    | -28.93                                    | NA                                       |
| 1998                                       | 113.72              | 53.30                              | 60.42                             | 31.66                                     | 59.60                                   | NA                                    | -30.84                                    | NA                                       |
| 1997                                       | 111.69              | 52.09                              | 59.60                             | 31.27                                     | 61.08                                   | NA                                    | -32.75                                    | NA                                       |
| 1996                                       | 110.88              | 52.11                              | 58.78                             | 30.88                                     | 62.55                                   | NA                                    | -34.66                                    | NA                                       |
| 1995                                       | 115.87              | 52.19                              | 63.68                             | 41.64                                     | 55.01                                   | NA                                    | -32.97                                    | NA                                       |
| 1994                                       | 113.19              | 49.14                              | 64.05                             | 41.01                                     | 56.84                                   | NA                                    | -33.80                                    | NA                                       |
| 1993                                       | 111.76              | 47.34                              | 64.42                             | 40.37                                     | 58.67                                   | NA                                    | -34.62                                    | NA                                       |
| 1992                                       | 110.82              | 46.03                              | 64.79                             | 39.74                                     | 60.50                                   | NA                                    | -35.44                                    | NA                                       |
| 1991                                       | 111.99              | 46.82                              | 65.16                             | 39.11                                     | 62.33                                   | NA                                    | -36.27                                    | NA                                       |
| 1990                                       | 247.20              | 49.81                              | 197.39                            | 32.48                                     | 199.28                                  | NA                                    | -34.37                                    | NA                                       |
| 1989                                       | 247.95              | 51.02                              | 196.93                            | 32.01                                     | 199.28                                  | NA                                    | -34.37                                    | NA                                       |
| 1988                                       | 247.09              | 50.63                              | 196.46                            | 31.54                                     | 199.28                                  | NA                                    | -34.37                                    | NA                                       |
| 1987                                       | 245.77              | 49.78                              | 195.99                            | 31.07                                     | 199.28                                  | NA                                    | -34.37                                    | NA                                       |
| 1986                                       | 244.35              | 48.82                              | 195.52                            | 30.61                                     | 199.28                                  | NA                                    | -34.37                                    | NA                                       |



### **6.5.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

The information of cropland area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present cropland area in the period 1986-2001. The estimation of cropland area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing cropland areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to cropland is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of cropland areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Land-use database of the Statistical Yearbook of the Statistical Office RS,
- Agricultural Land Use Map and LPIS database of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

### **6.5.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories**

The cropland is not defined specifically in terms of national legislation or land-use classification. However, the Agricultural Land Act (2011) defines agricultural land as land suitable for the agricultural production. The Act refers to the national land-use classes determined by Article 6 of the Rules on the register of actual agricultural and forest land use (2006). For the need of the GHG reporting the Cropland category includes the following land-use classes (Table 6.2.1); arable land, including fields and gardens, hop fields, green houses, other permanent crops on arable land, vineyards, nursery, intensive and extensive orchards, olive groves, other permanent crops and forest plantation.

### **6.5.4 Methodological issues**

#### **6.5.4.1 Cropland remaining Cropland**

Annual emissions from cropland remaining cropland ranged from 48.82 Gg CO<sub>2</sub> in 1986 to 60.38 Gg CO<sub>2</sub> in 2022.

**Carbon stock changes in living biomass****Annual Cropland remaining annual Cropland**

According to the 2006 Guidelines, the increase in biomass stocks of annual crops in a year is assumed to be equal to the biomass losses due to harvest and mortality in the same year, so there is no net accumulation of biomass carbon stocks.

**Perennial Cropland remaining perennial Cropland****Table 6.5.3: Estimated area of perennial cropland in the period 1986-2023 in ha**

| Year | Intensive orchards | Extensive orchards | Vineyards | Olive groves | Other perennial crops | Total area |
|------|--------------------|--------------------|-----------|--------------|-----------------------|------------|
| 2023 | 2437               | 18112              | 15351     | 2437         | 487                   | 38824      |
| 2022 | 2413               | 17940              | 15205     | 2413         | 483                   | 38454      |
| 2021 | 2387               | 17745              | 15040     | 2387         | 477                   | 38037      |
| 2020 | 2361               | 17551              | 14875     | 2361         | 472                   | 37620      |
| 2019 | 2348               | 17409              | 14808     | 2271         | 408                   | 37245      |
| 2018 | 2335               | 17266              | 14738     | 2183         | 345                   | 36867      |
| 2017 | 2322               | 17121              | 14667     | 2096         | 284                   | 36489      |
| 2016 | 2308               | 16975              | 14592     | 2010         | 223                   | 36108      |
| 2015 | 2381               | 17268              | 14637     | 1962         | 257                   | 36505      |
| 2014 | 2478               | 17732              | 14822     | 1931         | 294                   | 37257      |
| 2013 | 2577               | 18203              | 15003     | 1897         | 332                   | 38013      |
| 2012 | 2679               | 18679              | 15182     | 1860         | 372                   | 38773      |
| 2011 | 2667               | 18831              | 15544     | 1790         | 372                   | 39204      |
| 2010 | 2655               | 18984              | 15912     | 1718         | 372                   | 39641      |
| 2009 | 2624               | 19009              | 16179     | 1633         | 369                   | 39815      |
| 2008 | 2593               | 19035              | 16446     | 1548         | 367                   | 39989      |
| 2007 | 2562               | 19061              | 16717     | 1461         | 364                   | 40165      |
| 2006 | 2530               | 19085              | 16989     | 1374         | 361                   | 40339      |
| 2005 | 2539               | 19327              | 17099     | 1378         | 345                   | 40688      |
| 2004 | 2545               | 19555              | 17195     | 1382         | 328                   | 41004      |
| 2003 | 2553               | 19800              | 17304     | 1386         | 310                   | 41353      |
| 2002 | 2561               | 20046              | 17412     | 1390         | 293                   | 41702      |
| 2001 | 2540               | 19883              | 17271     | 1379         | 290                   | 41363      |
| 2000 | 2519               | 19720              | 17129     | 1367         | 288                   | 41023      |
| 1999 | 2498               | 19557              | 16987     | 1356         | 286                   | 40684      |
| 1998 | 2477               | 19394              | 16846     | 1345         | 283                   | 40345      |
| 1997 | 2456               | 19231              | 16704     | 1334         | 281                   | 40006      |
| 1996 | 2436               | 19068              | 16563     | 1322         | 278                   | 39667      |
| 1995 | 2415               | 18905              | 16421     | 1311         | 276                   | 39327      |
| 1994 | 2448               | 19162              | 16644     | 1329         | 280                   | 39862      |
| 1993 | 2480               | 19419              | 16867     | 1347         | 283                   | 40396      |
| 1992 | 2513               | 19675              | 17090     | 1364         | 287                   | 40931      |
| 1991 | 2546               | 19932              | 17313     | 1382         | 291                   | 41465      |
| 1990 | 2579               | 20189              | 17537     | 1400         | 295                   | 41999      |
| 1989 | 2556               | 20011              | 17382     | 1388         | 292                   | 41628      |
| 1988 | 2533               | 19832              | 17227     | 1375         | 290                   | 41257      |
| 1987 | 2511               | 19654              | 17072     | 1363         | 287                   | 40886      |
| 1986 | 2488               | 19476              | 16917     | 1350         | 284                   | 40515      |

Aggregate data for perennial cropland (orchards and vineyards) are available from the Statistical Office of the Republic of Slovenia as of 1956. For the calculation of the annual change of carbon stock in the living biomass of perennial cropland remaining perennial Cropland, Tier 1 (Gain-Loss) method was used, which is well described in the Austrian 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 2002 to 2020 ranged from 75 to 117 ha.

For the calculation of annual change in carbon stocks in living biomass of perennial cropland converted to annual cropland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

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

$\Delta C_B$  – 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>

$\Delta C_{CONVERSION}$  – 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>

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

$\Delta C_{CONVERSION}$  – initial change in biomass carbon stocks on land converted to annual cropland, 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 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 ( $C_{BEFORE} = 15.77$  t C ha<sup>-1</sup>) was used. The biomass stock immediately after conversion is zero.

### Annual Cropland converted to perennial Cropland

The average annual land-use change from annual cropland to perennial cropland from 2002 to 2020 ranged from 16 to 100 ha.

For the calculation of annual change in carbon stocks in living biomass of annual cropland converted to perennial cropland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

The country-specific value for carbon accumulation rate of perennial crops ( $\Delta C_G = 0.789$  t C ha<sup>-1</sup> yr<sup>-1</sup>) was estimated as a weighted average of perennial crops based on national and published data (Table 6.5.4). The country-specific value for carbon stock in annual crops before conversion ( $C_{BEFORE} = 2.76$  t C ha<sup>-1</sup>) 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****Annual Cropland remaining annual Cropland and Perennial Cropland remaining perennial Cropland**

Emissions from arable mineral soils were estimated using Tier 1 because there is currently no regular soil monitoring to estimate emission from the remaining land in this category. Equation 2.25 (IPCC 2006) was used and the approach suggested by Hiederer et al. (2016). Stratification of cropland and preparation of vector layers for stock change factors was performed by Agricultural Institute of Slovenia. It is assumed that the change in management regime has occurred since 2007. Therefore, emissions and removals from arable mineral soils are reported only from 2007. Note that the same method was used for annual cropland remaining annual cropland and perennial cropland remaining perennial cropland to estimate SOC stock changes.

There are two main reasons why carbon stock change in mineral soils for annual cropland remaining annual cropland (also for annual grassland remaining annual grassland) was estimated using a Tier 1 method for the period 2007-2018. First, in order to generate vector maps for comparing the stocks of SOC in 2007 and 2016, a number of input data (i.e. vector layers) were obtained from different institutions, such as land-use map from ICAS/LPIS system, Agri-Environment-Climate payments requirement map (major crops, all crops), gross nitrogen input map from livestock manure, and soil map (mineral, organic). Based on these data, 4 different vector layers were created for land use, management, input and reference stock, for 2007 and 2006, respectively. Input data have only been available since 2007, so it was not technically possible to stratify properly because land use, management and input data were not available. Second, based on discussion with experts from Agricultural Institute of Slovenia, it can be assumed that the change in management by farmers in 2007 was due to external stimuli, such as Rural Development Programme 2007-2013 (e.g. different subsidy payment schemes, a change in cropping patterns and/or different management technologies), especially the Agri-Environment-Climate measure, which included many more operations

related to land management, compared to the previous RDP. Permanent soil monitoring on agricultural land is expected, but we cannot say when. However, it seems that the reform of the EU CAP and related new legislative proposals will require member states to monitor indicators of progress, including soil quality.

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

$$SOC = \sum_{c,s,i} (SOC_{REF_{c,s,i}} \cdot F_{LU_{c,s,i}} \cdot F_{MG_{c,s,i}} \cdot F_{I_{c,s,i}} \cdot A_{c,s,i})$$

(Equation 19)

$\Delta C_{\text{CCmineral}}$  – 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>]

$D$  – time [default 20 years]

$A$  – land area [ha]

$SOC_{REF}$  – default reference value for soil organic carbon stock (i.e. 88 t C ha<sup>-1</sup>) for mineral soil according to Table 2.3 of the 2006 IPCC guidelines (Warm temperate, moist, HAC soils)

$F_{LU}$ ,  $F_{MG}$ ,  $F_I$  – relative stock change factors for different management activities on cropland according to Table 5.5 of the 2006 IPCC guidelines (Temperate, Moist/Wet;  $F_{LU} = 0.69$  for arable land and  $F_{LU} = 1$  for perennial crops;  $F_{MG} = 1$  for regularly tilled arable land,  $F_{MG} = 1.05$  for reduced tillage, and  $F_{MG} = 1.15$  for no-till;  $F_I = 1.0$  for medium input,  $F_I = 1.11$  for high input with organic manure, and  $F_I = 1.44$  for high input without organic manure)

## Organic soils

The total area of (cultivated) organic soils in the cropland category was 2,309 ha in 2022. According to expert opinion, the arable land on organic soils has been relatively constant since 1995 (Agricultural institute of Slovenia, 2006).

For the calculations of emissions from organic soils, the Tier 1/Tier 2 method and Equation 2.26 from the 2006 Guidelines were used. Default emission factor ( $EF = 10$  t ha<sup>-1</sup>) for warm temperate climatic temperature regime) from Table 5.6 (IPCC 2006) was used.

$$\Delta C = \sum (A * EF)$$

(Equation 20)

$A$  – land area of organic soils

$EF$  – emission factor for climate type (10 t ha<sup>-1</sup>)

## Annual Cropland converted to perennial Cropland

For calculations of carbon stock changes in mineral soils from annual cropland to perennial cropland and the Tier 2 method was applied, using equation 2.25 (IPCC 2006). Net emissions were calculated by country-specific average carbon stocks in mineral soils of annual and perennial cropland (Table 6.3.12).

$$\Delta C_{\text{Mineral}} = \text{conversion area for a transition period of 20 years} * \Delta C_{\text{SOC}} \quad (\text{Equation 21})$$

$$\Delta C_{\text{SOC}} = \frac{(SOC_n - SOC_o)}{T}$$

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

$SOC_n$  – average carbon stock of soils in perennial cropland, tonnes C ha<sup>-1</sup>

$SOC_o$  – average carbon stock of soils in annual cropland, tonnes C ha<sup>-1</sup>

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

### Perennial Cropland converted to annual Cropland

Emissions/removals were calculated by country specific values for carbon stocks in mineral soils of perennial cropland and annual cropland, respectively. Calculation steps and input data follow the equation 21, where  $SOC_n$  is average carbon stock of annual cropland and  $SOC_o$  is average carbon stock of perennial cropland.

### 6.5.4.2 Land converted to Cropland

The average annual area converted from other land uses to cropland during 2002-2020 was between 1,600 and 1,750 ha according to the land-use change matrices. However, there are also conversions of forest land to cropland and grassland to cropland. There are no conversions of wetlands and other land to cropland, and conversions of settlements to cropland are also rare.

#### 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.

$$\Delta C_B = \Delta C_G + \Delta C_{\text{CONVERSION}} - \Delta C_L \quad (\text{Equation 22})$$

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

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

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

$$\Delta C_{\text{CONVERSION}} = \sum [(B_{\text{AFTER}} - B_{\text{BEFORE}}) \times \Delta A] \times CF \quad (\text{Equation 23})$$

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

$B_{\text{AFTER}}$  – biomass stock immediately after the conversion is 0, t d.m. ha<sup>-1</sup>

$B_{\text{BEFORE}}$  – biomass stock 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 average carbon stocks in living biomass under the previous land-use

categories are the same as those in Table 6.3.10. It is assumed that the carbon stock in biomass immediately after conversion ( $B_{AFTER}$ ) is zero, since the land is cleared of all vegetation before planting crops (Tier 1). The same assumption was made for annual and perennial cropland.

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

Carbon stock changes in dead organic matter were calculated for dead wood and litter pool in conversion from Forest land to Cropland. The following equation was used:

$$\Delta C_{LC_{DOM}} = \Delta C_{LC_{DW}} + \Delta C_{LC_{LT}} \quad \text{(Equation 24)}$$

$\Delta C_{LC_{DOM}}$  – annual change in carbon stock in dead organic matter [ $t\ C\ yr^{-1}$ ]

$\Delta C_{LC_{DW}}$  – change in carbon stock in dead wood [ $t\ C\ yr^{-1}$ ]

$\Delta C_{LC_{LT}}$  – change in carbon stock in litter [ $t\ C\ yr^{-1}$ ]

For calculations of annual change in carbon stocks in dead wood the following equation was used:

$$\Delta C_{LC_{DW}} = \text{annual area of converted land} * \Delta C_{DW} \quad \text{(Equation 25)}$$

$$\Delta C_{DW} = \frac{(C_n - C_o)}{T}$$

$C_n$  – dead wood stock under the new land-use category [ $t\ C\ ha^{-1}$ ]

$C_o$  – dead wood stock under the old land-use category [ $t\ C\ ha^{-1}$ ]

$T$  – time period of the transition from old to new land-use category [ $yr$ ]

Dead wood carbon stocks ( $C_o$ ) were calculated from FECS 2007, FECS 2012 and FECS 2018 data. The Tier 1 default transition period is 1 year for carbon losses.

For calculations of annual change in carbon stocks in litter the following equation was used:

$$\Delta C_{LC_{LT}} = \text{annual area of converted land} * \Delta C_{LT} \quad \text{(Equation 26)}$$

$$\Delta C_{LT} = \frac{(C_n - C_o)}{T}$$

$C_n$  – litter stock under the new land-use category [ $t\ C\ ha^{-1}$ ]

$C_o$  – litter stock under the old land-use category [ $t\ C\ ha^{-1}$ ]

$T$  – time period of the transition from old to new land-use category [ $yr$ ]



The value for carbon stock in litter ( $C_{\text{before}} = 10.41 \text{ t C ha}^{-1}$ ) 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.

$$\Delta C_{LC\text{mineral}} = \frac{[SOC_0 - SOC_{0-T}]}{T} \quad (\text{Equation 27})$$

$\Delta C_{LC\text{mineral}}$  – 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:  $SOC_{CL\text{annual}} = 86.00 \text{ t C ha}^{-1}$ ; perennial cropland:  $SOC_{CL\text{perennial}} = 77.80 \text{ t C ha}^{-1}$ ) are presented in Table 6.3.12.

#### **Organic soils**

Activity data for organic soils was revised using area data from the Pedology Map, which is consistent with the areas in the Agriculture sector. It is assumed that no land with organic soils is converted to forest land. Therefore, emissions from organic soils on land converted to forest land were not reported. For 70% of the national land-use classes that have organic soils, the annual difference in land use change is less than 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 28)

$$N_2O_{Ninputs} - N = EF_1 * F_{SOM}$$

$N_2O - N_{Direct}$  – annual direct  $N_2O$ –N emissions produced from managed soils (kg  $N_2O$ –N  $yr^{-1}$ )

$F_{SOM}$  – annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N  $yr^{-1}$ )

$EF_1$  – IPCC default emission factor used to estimate direct  $N_2O$  emissions from managed soils [kg  $N_2O$ –N (kg N) $^{-1}$ ]. The default value is 0.01 kg  $N_2O$ –N (kg N) $^{-1}$

According to 2006 Guidelines conversion of  $N_2O$ –N emissions to  $N_2O$  emissions for reporting purposes is performed by using the following equation:  $N_2O = N_2O\text{--}N * 44/28$ .

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:

$$F_{SOM} = \sum_{LU} \left[ \left( \Delta C_{Mineral, LU} * \frac{1}{R} \right) * 1000 \right] \quad \text{(Equation 29)}$$

$F_{SOM}$  – annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management (kg N  $yr^{-1}$ )

$\Delta C_{Mineral, LU}$  – average annual loss of soil carbon for each land-use type (t C)

R – C:N ratio of soil organic matter. Default value for the C:N ratio is 15.

Values for annual carbon stock change in soils ( $\Delta C_{Mineral, LU}$ ) were taken from calculations of carbon stock changes in soils for Land converted to Cropland (Forest land and Grassland to Cropland). For emission factor ( $EF_1$ ), the default value (0.01 kg  $N_2O$ –N/kg N) was used.

### **Indirect $N_2O$ emissions from N leaching and run-off**

For estimation of indirect  $N_2O$  emissions from managed soils arising from N mineralization due to change of land use or management on mineral soils through leaching/runoff were estimated by applying Tier 1 method (Equation 11.10) and default emission factors from the Table 11.3 of GPG (IPCC 2006). However, these emissions are partly reported under Agriculture sector (CRF sector 3).

## **6.5.5 Uncertainties and time-series consistency**

Uncertainties were analysed as uncertainty in activity data (Table 6.3.8) and uncertainty in variables such as emission factors, growth rates, effects of land management factors, etc. Uncertainties were determined from empirical data, IPCC default values and expert judgement.

**Table 6.5.5: Uncertainties for emission factors**

| Variable       | Cropland remaining cropland (95 % CI) | Land converted to cropland (95% CI) |
|----------------|---------------------------------------|-------------------------------------|
| Living biomass | 85 %                                  | 202 %                               |
| Litter         | 40 %                                  | 40 %                                |
| Mineral soil   | 16 %                                  | 65 %                                |
| Organic soil   | 90 %                                  | NA                                  |

### 6.5.6 Category-specific QA/QC and verification

There were no category-specific QA/QC and verification in this annual submission. However, general QA/QC, taking into account the figures check, correctness of the calculation used, data sources etc., were performed in the category, as it was subject to source specific recalculation.

### 6.5.7 Category-specific recalculations

Recalculations have been undertaken for the period 1986-2022 concerning land converted to cropland, incorporating updated emission factors for living biomass and dead organic matter (conversions from forest land to cropland) and updated emission factors for mineral soil (conversions from settlements to cropland).

### 6.5.8 Source-specific planned improvements

No major improvements are planned for this category in the next annual submission.

## **6.6 Grassland (4C)**

### **6.6.1 Source category description**

Grassland category includes CO<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 19.97 % of country total area in 2023.

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 -281.44 to -246.57 Gg CO<sub>2</sub> between 1986 and 2023. 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 – 2023 in kha

| Year      | 4.C. Total Grassland | 4.C. Organic soil | 4.C.1. Grassland remaining<br>Grassland | 4.C.2. Land converted<br>to Grassland | 4.C.2.1 Forest Land<br>converted to Grassland | 4.C.2.2 Cropland converted<br>to Grassland | 4.C.2.3 Wetlands converted<br>to Grassland | 4.C.2.4 Settlements<br>converted to Grassland | 4.C.2.5 Other Land<br>converted to Grassland |
|-----------|----------------------|-------------------|---|---------------------------------------|---|--|--|---|--|
| Area, kha |                      |                   |   |                                       |   |  |  |   |  |
| 2023      | 404.95               | 4.48              | 343.32                                  | 61.63                                 | 9.22  | 51.58                                      | 0.08                                       | 0.67  | 0.08   |
| 2022      | 405.40               | 4.48              | 342.25                                  | 63.15                                 | 9.55  | 52.60                                      | 0.10                                       | 0.80  | 0.10   |
| 2021      | 405.85               | 4.47              | 340.96                                  | 64.89                                 | 9.55  | 53.81                                      | 0.14                                       | 0.87  | 0.51   |
| 2020      | 406.30               | 4.43              | 339.66                                  | 66.64                                 | 9.56  | 55.03                                      | 0.19                                       | 0.94  | 0.92   |
| 2019      | 406.75               | 4.43              | 338.37                                  | 68.38                                 | 9.56  | 56.24                                      | 0.23                                       | 1.01  | 1.33   |
| 2018      | 407.20               | 4.31              | 337.08                                  | 70.12                                 | 9.56  | 57.46                                      | 0.27                                       | 1.09  | 1.74   |
| 2017      | 407.65               | 4.30              | 335.79                                  | 71.86                                 | 9.57  | 58.67                                      | 0.31                                       | 1.16  | 2.15   |
| 2016      | 408.10               | 4.31              | 334.49                                  | 73.61                                 | 9.57  | 59.89                                      | 0.36                                       | 1.23  | 2.56   |
| 2015      | 405.40               | 4.31              | 334.15                                  | 71.25                                 | 9.75  | 56.82                                      | 0.40                                       | 1.30  | 2.97   |
| 2014      | 402.70               | 4.35              | 331.93                                  | 70.77                                 | 10.08   | 54.70                                      | 0.42                                       | 2.30  | 3.27   |
| 2013      | 400.00               | 4.29              | 329.71                                  | 70.29                                 | 10.41   | 52.57                                      | 0.44                                       | 3.30  | 3.57   |
| 2012      | 397.30               | 4.29              | 327.49                                  | 69.81                                 | 10.74   | 50.44                                      | 0.46                                       | 4.30  | 3.87   |
| 2011      | 396.80               | 4.28              | 324.05                                  | 72.75                                 | 10.82   | 52.02                                      | 0.48                                       | 5.25  | 4.17   |
| 2010      | 396.30               | 4.38              | 320.62                                  | 75.68                                 | 10.90   | 53.60                                      | 0.50                                       | 6.20  | 4.47   |
| 2009      | 395.80               | 4.39              | 318.09                                  | 77.71                                 | 10.77   | 53.26                                      | 0.53                                       | 7.42  | 5.72   |
| 2008      | 395.30               | 4.39              | 315.56                                  | 79.74                                 | 10.65   | 52.92                                      | 0.55                                       | 8.65  | 6.97   |
| 2007      | 394.80               | 4.38              | 313.02                                  | 81.78                                 | 10.52   | 52.58                                      | 0.58                                       | 9.87  | 8.22   |
| 2006      | 394.30               | 4.38              | 310.49                                  | 83.81                                 | 10.40   | 52.24                                      | 0.60                                       | 11.10   | 9.47   |
| 2005      | 393.52               | 4.38              | 308.52                                  | 85.01                                 | 10.02   | 51.44                                      | 0.60                                       | 12.25   | 10.70  |
| 2004      | 392.75               | 4.38              | 306.54                                  | 86.21                                 | 9.65  | 50.64                                      | 0.60                                       | 13.40   | 11.92  |
| 2003      | 391.98               | 4.38              | 304.57                                  | 87.41                                 | 9.27  | 49.84                                      | 0.60                                       | 14.55   | 13.15  |
| 2002      | 391.20               | 4.38              | 302.59                                  | 88.61                                 | 8.90  | 49.04                                      | 0.60                                       | 15.70   | 14.37  |
| 2001      | 406.08               | 4.38              | 316.49                                  | 89.59                                 | 8.85  | 48.05                                      | 0.58                                       | 16.90   | 15.21  |
| 2000      | 420.96               | 4.38              | 330.39                                  | 90.57                                 | 8.79  | 47.06                                      | 0.56                                       | 18.11   | 16.05  |
| 1999      | 435.84               | 4.38              | 344.29                                  | 91.56                                 | 8.74  | 46.07                                      | 0.55                                       | 19.31   | 16.89  |
| 1998      | 450.73               | 4.38              | 358.19                                  | 92.54                                 | 8.69  | 45.08                                      | 0.53                                       | 20.51   | 17.73  |
| 1997      | 465.61               | 4.38              | 372.09                                  | 93.52                                 | 8.63  | 44.09                                      | 0.51                                       | 21.72   | 18.57  |
| 1996      | 480.49               | 4.38              | 385.99                                  | 94.50                                 | 8.58  | 43.10                                      | 0.49                                       | 22.92   | 19.41  |
| 1995      | 495.37               | 4.38              | 399.88                                  | 95.49                                 | 8.53  | 42.11                                      | 0.48                                       | 24.12   | 20.25  |
| 1994      | 508.32               | 4.38              | 413.73                                  | 94.59                                 | 8.32  | 40.19                                      | 0.48                                       | 24.40   | 21.20  |
| 1993      | 521.28               | 4.38              | 427.58                                  | 93.69                                 | 8.12  | 38.27                                      | 0.49                                       | 24.67   | 22.15  |
| 1992      | 534.23               | 4.38              | 441.43                                  | 92.79                                 | 7.91  | 36.34                                      | 0.49                                       | 24.95   | 23.10  |
| 1991      | 547.18               | 4.38              | 455.28                                  | 91.90                                 | 7.70  | 34.42                                      | 0.50                                       | 25.22   | 24.05  |
| 1990      | 560.13               | 4.38              | 469.13                                  | 91.00                                 | 7.50  | 32.50                                      | 0.50                                       | 25.50   | 25.00  |
| 1989      | 560.63               | 4.38              | 469.63                                  | 91.00                                 | 7.50  | 32.50                                      | 0.50                                       | 25.50   | 25.00  |
| 1988      | 561.13               | 4.38              | 470.13                                  | 91.00                                 | 7.50  | 32.50                                      | 0.50                                       | 25.50   | 25.00  |
| 1987      | 561.63               | 4.38              | 470.63                                  | 91.00                                 | 7.50  | 32.50                                      | 0.50                                       | 25.50   | 25.00  |
| 1986      | 562.13               | 4.38              | 471.13                                  | 91.00                                 | 7.50  | 32.50                                      | 0.50                                       | 25.50   | 25.00  |

Table 6.6.2: Emissions from Grassland (1986 – 2023) 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> |                      |                                      |                                    |  |   |  |  |   |
| 2023                                       | -246.57              | -320.22                              | 73.66                              | 164.27                                     | -80.37                                  | -1.66                                  | -8.71                                      | 0.13                                      |
| 2022                                       | -269.54              | -336.64                              | 67.09                              | 162.68                                     | -83.41                                  | -2.21                                  | -10.20                                     | 0.23                                      |
| 2021                                       | -316.87              | -364.65                              | 47.78                              | 159.77                                     | -91.55                                  | -3.16                                  | -11.05                                     | -6.24                                     |
| 2020                                       | -358.81              | -391.76                              | 32.94                              | 157.73                                     | -96.23                                  | -4.10                                  | -11.90                                     | -12.55                                    |
| 2019                                       | -397.08              | -417.76                              | 20.68                              | 156.16                                     | -99.05                                  | -5.05                                  | -12.75                                     | -18.63                                    |
| 2018                                       | -437.72              | -445.10                              | 7.37                               | 154.42                                     | -102.67                                 | -6.00                                  | -13.60                                     | -24.79                                    |
| 2017                                       | -470.30              | -470.40                              | 0.10                               | 155.17                                     | -103.37                                 | -6.94                                  | -14.45                                     | -30.31                                    |
| 2016                                       | -400.06              | -360.72                              | -39.35                             | 88.99                                      | -67.93                                  | -7.89                                  | -15.30                                     | -37.22                                    |
| 2015                                       | -413.26              | -371.73                              | -41.53                             | 88.93                                      | -62.15                                  | -8.84                                  | -16.15                                     | -43.33                                    |
| 2014                                       | -427.85              | -370.90                              | -56.95                             | 88.83                                      | -61.74                                  | -9.28                                  | -28.07                                     | -46.69                                    |
| 2013                                       | -428.93              | -368.91                              | -60.01                             | 89.16                                      | -50.68                                  | -9.72                                  | -39.99                                     | -48.79                                    |
| 2012                                       | -394.81              | -384.31                              | -10.50                             | 187.96                                     | -85.39                                  | -10.16                                 | -50.43                                     | -52.48                                    |
| 2011                                       | -446.42              | -406.18                              | -40.24                             | 184.85                                     | -95.91                                  | -10.60                                 | -61.69                                     | -56.89                                    |
| 2010                                       | -492.91              | -425.95                              | -66.96                             | 182.07                                     | -104.45                                 | -11.05                                 | -72.91                                     | -60.62                                    |
| 2009                                       | -522.37              | -423.30                              | -99.06                             | 179.48                                     | -105.48                                 | -11.60                                 | -87.40                                     | -74.06                                    |
| 2008                                       | -548.89              | -420.05                              | -128.84                            | 177.08                                     | -105.38                                 | -12.15                                 | -101.88                                    | -86.52                                    |
| 2007                                       | -574.22              | -416.72                              | -157.50                            | 174.72                                     | -104.99                                 | -12.70                                 | -116.35                                    | -98.18                                    |
| 2006                                       | -537.83              | -455.77                              | -82.06                             | 259.64                                     | -91.85                                  | -11.71                                 | -128.89                                    | -109.25                                   |
| 2005                                       | -539.14              | -420.35                              | -118.79                            | 255.14                                     | -93.20                                  | -11.71                                 | -142.77                                    | -126.24                                   |
| 2004                                       | -529.39              | -383.41                              | -145.99                            | 251.40                                     | -91.01                                  | -11.71                                 | -156.44                                    | -138.23                                   |
| 2003                                       | -495.62              | -343.68                              | -151.94                            | 249.07                                     | -82.37                                  | -11.71                                 | -169.74                                    | -137.19                                   |
| 2002                                       | -682.41              | -357.77                              | -324.64                            | 138.60                                     | -109.27                                 | -10.61                                 | -185.23                                    | -158.14                                   |
| 2001                                       | -694.69              | -361.80                              | -332.89                            | 136.83                                     | -104.33                                 | -10.21                                 | -199.46                                    | -155.72                                   |
| 2000                                       | -720.52              | -366.90                              | -353.61                            | 134.98                                     | -103.30                                 | -9.82                                  | -213.80                                    | -161.67                                   |
| 1999                                       | -759.52              | -372.90                              | -386.63                            | 132.77                                     | -105.47                                 | -9.42                                  | -228.25                                    | -176.26                                   |
| 1998                                       | -789.02              | -378.20                              | -410.82                            | 130.84                                     | -105.16                                 | -9.03                                  | -242.61                                    | -184.86                                   |
| 1997                                       | -815.58              | -383.31                              | -432.28                            | 128.99                                     | -104.13                                 | -8.63                                  | -256.96                                    | -191.54                                   |
| 1996                                       | -830.51              | -387.73                              | -442.79                            | 127.41                                     | -100.61                                 | -8.24                                  | -271.24                                    | -190.11                                   |
| 1995                                       | -398.07              | -38.69                               | -359.38                            | 170.81                                     | -60.04                                  | -9.26                                  | -260.22                                    | -200.67                                   |
| 1994                                       | -434.71              | -62.11                               | -372.60                            | 168.29                                     | -54.04                                  | -9.37                                  | -263.94                                    | -213.55                                   |
| 1993                                       | -405.61              | -75.33                               | -330.28                            | 167.30                                     | -36.14                                  | -9.48                                  | -263.41                                    | -188.55                                   |
| 1992                                       | -438.92              | -98.39                               | -340.52                            | 164.84                                     | -29.73                                  | -9.59                                  | -266.98                                    | -199.06                                   |
| 1991                                       | -503.61              | -126.03                              | -377.59                            | 161.69                                     | -28.65                                  | -9.70                                  | -272.46                                    | -228.46                                   |
| 1990                                       | -255.56              | 234.90                               | -490.46                            | 101.84                                     | -80.94                                  | -9.50                                  | -268.35                                    | -233.50                                   |
| 1989                                       | -265.96              | 226.06                               | -492.02                            | 100.28                                     | -80.94                                  | -9.50                                  | -268.35                                    | -233.50                                   |
| 1988                                       | -263.25              | 220.39                               | -483.64                            | 98.90                                      | -79.99                                  | -9.50                                  | -267.42                                    | -225.63                                   |
| 1987                                       | -284.14              | 209.02                               | -493.16                            | 97.19                                      | -80.75                                  | -9.50                                  | -268.16                                    | -231.93                                   |
| 1986                                       | -281.44              | 203.34                               | -484.78                            | 95.80                                      | -79.80                                  | -9.50                                  | -267.23                                    | -224.05                                   |

### **6.6.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

The information of grassland area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present grassland area in the period 1986-2001. The estimation of area of Grassland for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing grassland areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to grassland is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of grassland areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Land-use database of the Statistical Yearbook of the Statistical Office RS,
- Agricultural Land Use Map and LPIS database of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

### **6.6.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories**

The grassland is not defined specifically in terms of national legislation. However, the Agricultural Land Act (2011) defines agricultural land as land suitable for the agricultural production. The Act refers to the national land-use classes determined by Article 6 of the Rules on the register of actual agricultural and forest land use (2006). For the need of the GHG reporting the Grassland category includes the following land-use classes (Table 6.2.1); meadows and pastures, swampy meadows and pastures, uncultivated agriculture land, overgrown areas, mixed land use, and forest trees on agricultural land.

### **6.6.4 Methodological issues**

#### **6.6.4.1 Grassland remaining grassland**

##### **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 includes Overgrown areas, Trees and shrubs and Forest trees on agricultural land (see Table 6.2.1). Although these lands are considered to be managed, the woody vegetation on these lands is considered to have resulted primarily from the abandonment of agricultural activity. Harvesting or gathering of wood for fuel purposes is assumed to predominate on forest land, while losses on the remaining perennial grassland are assumed to be primarily due to natural mortality and removal (which is assumed to be minor). The latter also occur naturally, of course, but no country-specific data are available because there is currently no continuous monitoring.

### Perennial Grassland converted to Annual Grassland

For the calculation of annual change in carbon stocks in living biomass of perennial grassland converted to annual grassland the Tier 1/Tier 2 method was applied and equations 2.15 and 2.16 (IPCC 2006) were used.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \quad \text{(Equation 30)}$$

$\Delta C_B$  – 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>

$$\Delta C_{CONVERSION} = \sum [(B_{AFTER} - B_{BEFORE}) \times \Delta A] \times CF \quad \text{(Equation 31)}$$

$\Delta C_{CONVERSION}$  – 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**

#### **Annual Grassland remaining annual Grassland**

For calculations of carbon stock changes in soils in grassland remaining grassland, the equation 2.24 (IPCC 2006) was used.

$$\Delta C_{GGsoils} = \Delta C_{GGmineral} - L_{GGorganic} + \Delta C_{inorganic} \quad \text{(Equation 32)}$$

$\Delta C_{GGsoils}$  - 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. The reasons for using the Tier 1 method in grassland remaining grassland are the same as for cropland remaining cropland and are described in more detail in subsection 6.5.4.1.

It should be noted that the change in net carbon stock in mineral soils per area appears incorrect for category 4.C.1 (grassland remaining grassland). The change in carbon stock in mineral soils for the subcategory “GL\_a to GL\_a” reported under 4.C.1 was estimated for 2007–2018 only, causing a trend change in mineral soil carbon stock change per area. In addition, the changes in land-use management occurred in 2007 following the introduction of initiatives such as the Rural Development Programme 2007–2013, which resulted in, for example, a range of subsidy payment regimes and incentives to change crop types and/or adopt different management technologies and agri-environment-climate policy measures (which provided for additional activities to be undertaken in the country related to soil management).

### **Organic soils**

The total area of organic soils of grassland was 4.477 kha in 2023. Emissions from organic soils are not reported 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.

### **Perennial Grassland remaining perennial Grassland**

At the country level, there is no permanent soil monitoring on areas of perennial grassland remaining perennial grassland. However, because this category includes land that is predominantly uncultivated, it is assumed that the soils are not subject to disturbance. Therefore, the carbon stock of perennial grassland remaining perennial grassland is conservatively assumed to be in equilibrium.

### **Annual Grassland converted to Perennial Grassland**

For calculations of carbon stock changes in mineral soils from annual grassland to perennial grassland the Tier 2 method was applied, using equation 2.25 (IPCC 2006). Net emissions were calculated by country-specific average carbon stocks in mineral soils of annual and perennial grassland (Table 6.3.12).

$$\Delta C_{\text{Mineral}} = \text{conversion area for a transition period of 20 years} * \Delta C_{\text{SOC}} \quad (\text{Equation 33})$$

$$\Delta C_{\text{SOC}} = \frac{(SOC_n - SOC_o)}{T}$$

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

$SOC_n$  – average carbon stock of soils in perennial grassland, tonnes C ha<sup>-1</sup>

$SOC_o$  – average carbon stock of soils in annual grassland, tonnes C ha<sup>-1</sup>

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

### Perennial Grassland converted to Annual Grassland

Emissions/removals were calculated by country specific values for carbon stocks in mineral soils of perennial grassland and annual grassland, respectively. Calculation steps and input data follow the equation 3, where  $SOC_n$  is average carbon stock of annual grassland and  $SOC_o$  is average carbon stock of perennial grassland.

#### 6.6.4.2 Land converted to Grassland

According to the results from the point sampling conversions from all categories to Grassland occur, although conversions from Wetlands are very rare. The average annual area converted from other land uses to Grassland in the period 2002-2020 ranged between 3,525 and 8,200 ha.

#### Carbon stock changes in living biomass

For the calculations of the annual change in carbon stocks in living biomass on land converted to grassland the Tier 2 methodology and equations 2.15 and 2.16 (IPCC 2006) were used.

A country-specific value for the annual accumulation rate of perennial grassland ( $\Delta C_G = 0.994$  t C ha<sup>-1</sup>) was used. The average carbon stocks in living biomass under the previous land-use categories are the same as those in Table 6.3.10. It is assumed that the carbon stock in biomass immediately after conversion ( $B_{\text{AFTER}}$ ) is zero, since the land is cleared of all vegetation before planting vegetation (Tier 1). The same assumption was made for annual and perennial grassland.

#### Carbon stock changes in dead organic matter

Carbon stock changes in dead organic matter were calculated for dead wood and litter pool in conversion from forest land to grassland. The following equation was used:

$$\Delta C_{\text{LG}_{\text{DOM}}} = \Delta C_{\text{LG}_{\text{DW}}} + \Delta C_{\text{LG}_{\text{LT}}} \quad (\text{Equation 34})$$

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

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

$\Delta C_{LG_{LT}}$  – 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:

$$\Delta C_{LG_{DW}} = \text{annual area of converted land} * \Delta C_{\text{conversion}} \quad (\text{Equation 35})$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is 2.27 t C ha<sup>-1</sup>

$C_{\text{before}}$  – 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, 2012 and 2018.

For calculations of annual change in carbon stocks in litter the following equation was used:

$$\Delta C_{LG_{LT}} = \text{annual area of converted land} * \Delta C_{\text{conversion}} \quad (\text{Equation 36})$$

$$\Delta C_{\text{conversion}} = C_{\text{after}} - C_{\text{before}}$$

$C_{\text{after}}$  – carbon after conversion is 7.58 t C ha<sup>-1</sup>

$C_{\text{before}}$  – carbon stock in litter [t C ha<sup>-1</sup>]

The value for carbon stock in litter ( $C_{\text{before}} = 10.41$  t C ha<sup>-1</sup>) 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.

$$\Delta C_{LG_{\text{mineral}}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad (\text{Equation 37})$$

$\Delta C_{LG_{\text{mineral}}}$  – 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]

$$SOC = SOC_{GL}$$

$SOC_{GL}$  – country-specific value for organic carbon stock in mineral soil

Slovenian national value for organic carbon stock in mineral soil for grassland (grassland annual:  $SOC_{GLannual} = 94.86 \text{ t ha}^{-1}$ ; grassland perennial:  $SOC_{GLperennial} = 101.53 \text{ t ha}^{-1}$ ) are presented in Table 6.3.12.

### Organic soil

Activity data for organic soils were revised using area data from Pedology Map, which are consistent with those of the agricultural sector. However, emissions from organic soils were not estimated. For explanation, see subsection 6.5.4.1.

### **$N_2O$ emissions from N mineralization/immobilization**

Equations 11.1 and 11.8 and the default emission factors from Table 11.1 (IPCC 2006) were used for the calculations of  $N_2O$  emissions associated with land conversion to grassland. The Tier 1 method was used to estimate direct  $N_2O$  emissions due to land use conversions from forest land and cropland to grassland. Additionally, the same approach was used to estimate direct  $N_2O$  emissions from the conversion of perennial grassland to annual grassland.

### **Indirect $N_2O$ emission from N leaching and run-off**

For the estimation of indirect  $N_2O$  emissions from N mineralization due to land use change in mineral soils through leaching/runoff, the Tier 1 method was applied using Equation 11.10 and default emission factors from Table 11.3 of the 2006 Guidelines. Indirect  $N_2O$  emissions are estimated due to land use changes from forest land and cropland to grassland and from perennial grassland to annual grassland.

## 6.6.5 Uncertainties and time-series consistency

Uncertainties were analysed as uncertainty in activity data (Table 6.3.8) and uncertainty in variables such as emission factors, growth rates, effects of land management factors, etc. Uncertainties were determined from empirical data, IPCC default values and expert judgement.

**Table 6.6.3: Uncertainties for emission factors**

| Variable            | Grassland remaining grassland (95 % CI) | Land converted to grassland (95% CI) |
|---------------------|---|--------------------------------------|
| Living biomass      | 85 %                                    | 189 %                                |
| Dead organic matter | 54 %                                    | 60 %                                 |
| Mineral soil        | 100 %                                   | 65 %                                 |

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

No specific QA/QC and verification for grassland was used in the 2023 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**

Recalculations for the period 1986-2022 for land converted to grassland were made based on updated emission factors for living biomass and dead organic matter (conversions from forest land to grassland) and updated emission factors for mineral soil (conversions from settlements to grassland and from wetlands to grassland).

### **6.6.8 Source-specific planned improvements**

No major improvements are planned for this category in the next annual submission.

## **6.7 Wetlands (4D)**

### **6.7.1 Source category description**

Wetlands are defined under the 2006 Guidelines as land that is covered or saturated by water all or part of the year and does not fall into the categories of forest land, cropland, 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 0.75% of the country's area in 2023. Wetlands include: swamps, reeds, other marshy areas and water bodies (inland water bodies). Emissions from wetlands ranged from 39.41 Gg CO<sub>2</sub> in 1986 to 45.98 Gg CO<sub>2</sub> in 2023.

Table 6.7.1: Activity data of Wetlands 1986 – 2023 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 |                    |                                   |                                  |                                      |  |   |   |  |
| 2023      | 15.23              | 13.78                             | 1.45                             | 0.83                                 | 0.35                                   | 0.27                                    | NO  | NO                                       |
| 2022      | 15.10              | 13.75                             | 1.35                             | 0.80                                 | 0.3                                    | 0.25                                    | NO  | NO                                       |
| 2021      | 14.97              | 13.74                             | 1.24                             | 0.76                                 | 0.25                                   | 0.22                                    | NO  | NO                                       |
| 2020      | 14.85              | 13.72                             | 1.13                             | 0.73                                 | 0.2                                    | 0.20                                    | NO  | NO                                       |
| 2019      | 14.72              | 13.71                             | 1.02                             | 0.69                                 | 0.15                                   | 0.17                                    | NO  | NO                                       |
| 2018      | 14.60              | 13.69                             | 0.91                             | 0.66                                 | 0.1                                    | 0.15                                    | NO  | NO                                       |
| 2017      | 14.47              | 13.68                             | 0.80                             | 0.62                                 | 0.05                                   | 0.12                                    | NO  | NO                                       |
| 2016      | 14.35              | 13.66                             | 0.69                             | 0.59                                 | NO                                     | 0.10                                    | NO  | NO                                       |
| 2015      | 14.35              | 13.65                             | 0.70                             | 0.60                                 | NO                                     | 0.10                                    | NO  | NO                                       |
| 2014      | 14.35              | 13.55                             | 0.80                             | 0.62                                 | NO                                     | 0.18                                    | NO  | NO                                       |
| 2013      | 14.35              | 13.45                             | 0.90                             | 0.64                                 | NO                                     | 0.26                                    | NO  | NO                                       |
| 2012      | 14.35              | 13.35                             | 1.00                             | 0.66                                 | NO                                     | 0.34                                    | NO  | NO                                       |
| 2011      | 14.27              | 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                             | 0.53                                 | NO                                     | 0.53                                    | 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              | 12.73                             | 1.17                             | 0.40                                 | NO                                     | 0.77                                    | 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                                     | 1.22                                    | 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                                     | 1.53                                    | NO  | NO                                       |
| 1994      | 14.89              | 12.89                             | 2.00                             | 0.48                                 | NO                                     | 1.52                                    | NO  | NO                                       |
| 1993      | 14.87              | 12.87                             | 2.00                             | 0.49                                 | 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 – 2023) 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> |                                      |  |   |   |  |
| 2023 | 45.98              | NE                                | 45.98                                      | 36.23                                | 5.33                                   | 4.41                                    | NO  | NO                                       |
| 2022 | 44.30              | NE                                | 44.30                                      | 35.63                                | 4.64                                   | 4.03                                    | NO  | NO                                       |
| 2021 | 42.44              | NE                                | 42.44                                      | 34.84                                | 3.95                                   | 3.64                                    | NO  | NO                                       |
| 2020 | 40.58              | NE                                | 40.58                                      | 34.06                                | 3.27                                   | 3.26                                    | NO  | NO                                       |
| 2019 | 38.73              | NE                                | 38.73                                      | 33.28                                | 2.58                                   | 2.87                                    | NO  | NO                                       |
| 2018 | 36.87              | NE                                | 36.87                                      | 32.49                                | 1.89                                   | 2.49                                    | NO  | NO                                       |
| 2017 | 35.25              | NE                                | 35.25                                      | 31.95                                | 1.2                                    | 2.10                                    | NO  | NO                                       |
| 2016 | 11.48              | NE                                | 11.48                                      | 9.94                                 | NO                                     | 1.54                                    | NO  | NO                                       |
| 2015 | 11.72              | NE                                | 11.72                                      | 10.18                                | NO                                     | 1.54                                    | NO  | NO                                       |
| 2014 | 13.29              | NE                                | 13.29                                      | 10.52                                | NO                                     | 2.78                                    | NO  | NO                                       |
| 2013 | 14.87              | NE                                | 14.87                                      | 10.86                                | NO                                     | 4.01                                    | NO  | NO                                       |
| 2012 | 45.16              | NE                                | 45.16                                      | 39.80                                | NO                                     | 5.36                                    | NO  | NO                                       |
| 2011 | 44.95              | NE                                | 44.95                                      | 38.62                                | NO                                     | 6.33                                    | NO  | NO                                       |
| 2010 | 44.74              | NE                                | 44.74                                      | 37.43                                | NO                                     | 7.31                                    | NO  | NO                                       |
| 2009 | 44.54              | NE                                | 44.54                                      | 36.33                                | NO                                     | 8.21                                    | NO  | NO                                       |
| 2008 | 44.34              | NE                                | 44.34                                      | 35.23                                | NO                                     | 9.11                                    | NO  | NO                                       |
| 2007 | 44.14              | NE                                | 44.14                                      | 34.13                                | NO                                     | 10.01                                   | NO  | NO                                       |
| 2006 | 27.42              | NE                                | 27.42                                      | 16.63                                | NO                                     | 10.79                                   | NO  | NO                                       |
| 2005 | 28.42              | NE                                | 28.42                                      | 16.47                                | NO                                     | 11.95                                   | NO  | NO                                       |
| 2004 | 29.43              | NE                                | 29.43                                      | 16.32                                | NO                                     | 13.11                                   | NO  | NO                                       |
| 2003 | 30.43              | NE                                | 30.43                                      | 16.17                                | NO                                     | 14.26                                   | NO  | NO                                       |
| 2002 | 27.48              | NE                                | 27.48                                      | 12.06                                | NO                                     | 15.42                                   | NO  | NO                                       |
| 2001 | 28.74              | NE                                | 28.74                                      | 12.16                                | NO                                     | 16.57                                   | NO  | NO                                       |
| 2000 | 30.00              | NE                                | 30.00                                      | 12.27                                | NO                                     | 17.73                                   | NO  | NO                                       |
| 1999 | 31.27              | NE                                | 31.27                                      | 12.38                                | NO                                     | 18.89                                   | NO  | NO                                       |
| 1998 | 32.54              | NE                                | 32.54                                      | 12.49                                | NO                                     | 20.04                                   | NO  | NO                                       |
| 1997 | 33.80              | NE                                | 33.80                                      | 12.60                                | NO                                     | 21.20                                   | NO  | NO                                       |
| 1996 | 35.07              | NE                                | 35.07                                      | 12.71                                | NO                                     | 22.36                                   | NO  | NO                                       |
| 1995 | 38.80              | NE                                | 38.80                                      | 14.73                                | NO                                     | 24.07                                   | NO  | NO                                       |
| 1994 | 38.71              | NE                                | 38.71                                      | 14.72                                | NO                                     | 23.99                                   | NO  | NO                                       |
| 1993 | 38.62              | NE                                | 38.62                                      | 14.71                                | NO                                     | 23.91                                   | NO  | NO                                       |
| 1992 | 38.54              | NE                                | 38.54                                      | 14.70                                | NO                                     | 23.84                                   | NO  | NO                                       |
| 1991 | 38.45              | NE                                | 38.45                                      | 14.69                                | NO                                     | 23.76                                   | NO  | NO                                       |
| 1990 | 39.88              | NE                                | 39.88                                      | 16.23                                | NO                                     | 23.65                                   | NO  | NO                                       |
| 1989 | 39.76              | NE                                | 39.76                                      | 16.11                                | NO                                     | 23.65                                   | NO  | NO                                       |
| 1988 | 39.64              | NE                                | 39.64                                      | 16.00                                | NO                                     | 23.65                                   | NO  | NO                                       |
| 1987 | 39.52              | NE                                | 39.52                                      | 15.88                                | NO                                     | 23.65                                   | NO  | NO                                       |
| 1986 | 39.41              | NE                                | 39.41                                      | 15.76                                | NO                                     | 23.65                                   | NO  | NO                                       |

### **6.7.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

The information of wetlands area is based on multiple data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present wetlands area in the period 1986-2001. Besides, data on area of Wetlands until 2001 were complemented by the information from the land cover map (based on Landsat TM, ETM – EURIMAGE, Eurostat/CESD), being available for the years 1993, 1997 and 2001 and officially published (SORS 2005). The estimation of wetlands area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project “Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry”.

The estimation of cropland area and annual land-use changes for the years 2013, 2014 and 2015 were extrapolated. The approach used for representing areas of Wetlands follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to wetlands is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of wetlands areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

### **6.7.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories**

The wetlands are not defined specifically in terms of national legislation. However, the Rules on delineation of surface water bodies (2005) defines that detached surface water bodies are determined for large streams, natural lakes, sea and brackish water, artificial channels, water reservoirs on rivers and artificial lakes.

For the need of the GHG reporting the Wetlands category includes the following land-use classes (Table 6.2.1); swamps, reeds, other marshy areas, and waters (inland water bodies). In line with the land-use classification (Identification key 2013) waters (class 7000) includes running and standing waters, channels, temporarily dry riverbeds, sandy beaches and dunes, gravel areas along or in the streams, river islands covered with vegetation, running waters in the forest (if recognizable from the map), capture and reservoirs, and fishponds.

## 6.7.4 Methodological issues

### 6.7.4.1 Wetlands remaining wetlands

Slovenia has not reported emissions from flooded land remaining flooded land due to lack of data. As the Ljubljana marsh, the largest Slovenian and southernmost European wetland (area of about 160 km<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.

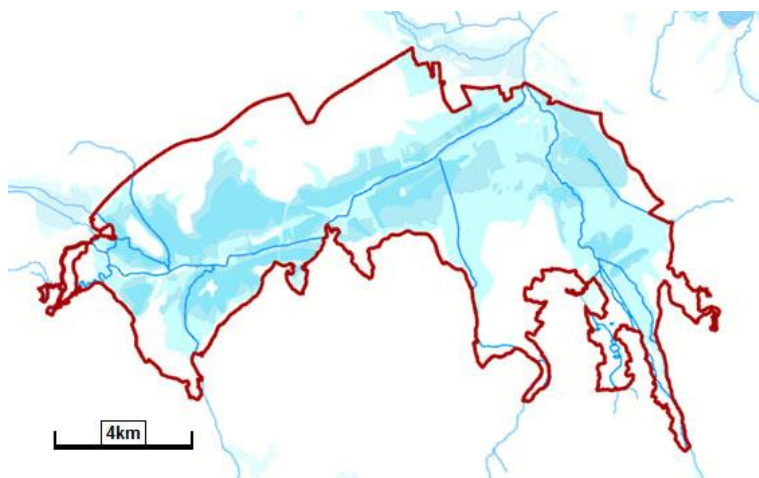


Figure 6.7.1 : Ljubljana Marsh and the Ljubljanica river basin with floodwater area (shaded)

### 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:

$$\Delta C_{LWflood, LB} = \left[ \sum_i A_i * (B_{After} - B_{Before}) \right] * CF \quad \text{(Equation 38)}$$

$A_i$  – area of land converted annually to Flooded land from original land use (from Forest land and from Grassland) (ha yr<sup>-1</sup>)

$B_{After}$  – biomass immediately following conversion to flooded land, tonnes d. m. ha<sup>-1</sup> (default = 0)

$B_{Before}$  – biomass in land immediately before conversion to flooded land, tonnes d.m. ha<sup>-1</sup>

CF – carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)<sup>-1</sup>

### **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

$$\Delta C_{LG\text{ mineral}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad \text{(Equation 39)}$$

$\Delta C_{LG\text{ mineral}}$  – 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]

The country-specific value for organic carbon stock in mineral soil for wetlands:  $SOC_{WL} = 10.76 \text{ t ha}^{-1}$  is presented in Table 6.3.12.

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 6.3.8.

## **6.7.5 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.

## **6.7.6 Category-specific recalculations**

Recalculations have been made for the period 1986-2022 concerning land converted to wetlands based on updated emission factors for living biomass and dead organic matter (conversions from forest land to wetlands) and updated emission factors for mineral soil (conversions from forest land to wetlands and from grassland to wetlands).

## **6.7.7 Source-specific planned improvements**

No major improvements are planned for this category in the next annual submission.

## 6.8 Settlements (4E)

### 6.8.1 Source category description

Settlements covered 6.09% of country area in 2023. 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 413.32 to 170.02 Gg CO<sub>2</sub> between 1986 and 2023.

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 (1986-2023) 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                          |  |  |   |   |   |
| 2023 | 123.55               | 103.55                                   | 20.00                              | 3.83                                   | 4.58                                     | 11.45                                     | 0.15                                    | NO  |
| 2022 | 122.65               | 101.90                                   | 20.75                              | 4.30                                   | 4.95                                     | 11.30                                     | 0.20                                    | NO  |
| 2021 | 121.75               | 100.19                                   | 21.56                              | 4.54                                   | 5.38                                     | 11.34                                     | 0.29                                    | NO  |
| 2020 | 120.85               | 98.49                                    | 22.36                              | 4.77                                   | 5.81                                     | 11.39                                     | 0.39                                    | NO  |
| 2019 | 119.95               | 96.78                                    | 23.17                              | 5.01                                   | 6.25                                     | 11.43                                     | 0.48                                    | NO  |
| 2018 | 119.05               | 95.07                                    | 23.98                              | 5.24                                   | 6.68                                     | 11.48                                     | 0.58                                    | NO  |
| 2017 | 118.15               | 93.36                                    | 24.79                              | 5.48                                   | 7.11                                     | 11.52                                     | 0.67                                    | NO  |
| 2016 | 117.25               | 91.66                                    | 25.59                              | 5.71                                   | 7.54                                     | 11.57                                     | 0.77                                    | NO  |
| 2015 | 116.70               | 89.93                                    | 26.77                              | 5.80                                   | 8.07                                     | 12.04                                     | 0.86                                    | NO  |
| 2014 | 116.15               | 87.79                                    | 28.36                              | 5.78                                   | 8.73                                     | 12.93                                     | 0.92                                    | NO  |
| 2013 | 115.60               | 85.65                                    | 29.95                              | 5.76                                   | 9.38                                     | 13.83                                     | 0.98                                    | NO  |
| 2012 | 115.05               | 83.51                                    | 31.54                              | 5.74                                   | 10.04                                    | 14.72                                     | 1.04                                    | NO  |
| 2011 | 114.07               | 81.43                                    | 32.63                              | 5.74                                   | 10.37                                    | 15.42                                     | 1.10                                    | NO  |
| 2010 | 113.08               | 79.36                                    | 33.72                              | 5.73                                   | 10.70                                    | 16.13                                     | 1.16                                    | NO  |
| 2009 | 112.10               | 77.55                                    | 34.55                              | 5.70                                   | 10.53                                    | 17.11                                     | 1.21                                    | NO  |
| 2008 | 111.12               | 75.74                                    | 35.37                              | 5.67                                   | 10.35                                    | 18.09                                     | 1.26                                    | NO  |
| 2007 | 110.13               | 73.93                                    | 36.20                              | 5.63                                   | 10.18                                    | 19.08                                     | 1.31                                    | NO  |
| 2006 | 109.15               | 72.13                                    | 37.02                              | 5.60                                   | 10.00                                    | 20.06                                     | 1.36                                    | NO  |
| 2005 | 107.65               | 70.43                                    | 37.22                              | 5.22                                   | 9.68                                     | 20.96                                     | 1.36                                    | NO  |
| 2004 | 106.15               | 68.73                                    | 37.42                              | 4.85                                   | 9.35                                     | 21.86                                     | 1.36                                    | NO  |
| 2003 | 104.65               | 67.03                                    | 37.62                              | 4.47                                   | 9.03                                     | 22.76                                     | 1.36                                    | NO  |
| 2002 | 103.15               | 65.33                                    | 37.82                              | 4.10                                   | 8.70                                     | 23.66                                     | 1.36                                    | NO  |
| 2001 | 101.57               | 63.60                                    | 37.97                              | 3.96                                   | 8.32                                     | 24.37                                     | 1.32                                    | NO  |
| 2000 | 99.99                | 61.88                                    | 38.11                              | 3.83                                   | 7.94                                     | 25.07                                     | 1.27                                    | NO  |
| 1999 | 98.42                | 60.16                                    | 38.25                              | 3.69                                   | 7.55                                     | 25.78                                     | 1.23                                    | NO  |
| 1998 | 96.84                | 58.44                                    | 38.40                              | 3.56                                   | 7.17                                     | 26.48                                     | 1.18                                    | NO  |
| 1997 | 95.26                | 56.72                                    | 38.54                              | 3.42                                   | 6.79                                     | 27.19                                     | 1.14                                    | NO  |
| 1996 | 93.68                | 55.00                                    | 38.68                              | 3.29                                   | 6.41                                     | 27.89                                     | 1.09                                    | NO  |
| 1995 | 92.10                | 53.28                                    | 38.82                              | 3.15                                   | 6.02                                     | 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                                   | 5.01                                     | 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 – 2023) 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> |  |  |   |   |   |
| 2023 | 170.02               | -99.93                                   | 269.95                                     | 69.39                                  | 44.56                                    | 156.69                                    | -0.70                                   | NO  |
| 2022 | 178.63               | -98.34                                   | 276.97                                     | 75.07                                  | 47.84                                    | 154.98                                    | -0.93                                   | NO  |
| 2021 | 186.83               | -96.69                                   | 283.52                                     | 77.80                                  | 51.75                                    | 155.34                                    | -1.37                                   | NO  |
| 2020 | 195.03               | -95.05                                   | 290.07                                     | 80.53                                  | 55.65                                    | 155.70                                    | -1.81                                   | NO  |
| 2019 | 203.22               | -93.40                                   | 296.62                                     | 83.25                                  | 59.55                                    | 156.06                                    | -2.25                                   | NO  |
| 2018 | 211.42               | -91.75                                   | 303.17                                     | 85.98                                  | 63.46                                    | 156.42                                    | -2.69                                   | NO  |
| 2017 | 219.86               | -90.10                                   | 309.96                                     | 88.95                                  | 67.36                                    | 156.78                                    | -3.13                                   | NO  |
| 2016 | 265.13               | -88.46                                   | 353.58                                     | 156.34                                 | 67.18                                    | 133.62                                    | -3.57                                   | NO  |
| 2015 | 277.48               | -86.78                                   | 364.26                                     | 157.65                                 | 71.93                                    | 138.69                                    | -4.01                                   | NO  |
| 2014 | 294.88               | -84.72                                   | 379.60                                     | 157.66                                 | 77.89                                    | 148.33                                    | -4.29                                   | NO  |
| 2013 | 312.28               | -82.65                                   | 394.94                                     | 157.67                                 | 83.86                                    | 157.97                                    | -4.57                                   | NO  |
| 2012 | 351.41               | -80.59                                   | 432.00                                     | 149.43                                 | 96.18                                    | 191.23                                    | -4.85                                   | NO  |
| 2011 | 362.52               | -78.59                                   | 441.11                                     | 148.31                                 | 99.25                                    | 198.67                                    | -5.12                                   | NO  |
| 2010 | 373.63               | -76.59                                   | 450.22                                     | 147.19                                 | 102.32                                   | 206.11                                    | -5.40                                   | NO  |
| 2009 | 382.62               | -74.84                                   | 457.46                                     | 145.70                                 | 100.79                                   | 216.61                                    | -5.63                                   | NO  |
| 2008 | 391.61               | -73.10                                   | 464.71                                     | 144.20                                 | 99.26                                    | 227.11                                    | -5.87                                   | NO  |
| 2007 | 400.60               | -71.35                                   | 471.96                                     | 142.71                                 | 97.73                                    | 237.61                                    | -6.10                                   | NO  |
| 2006 | 539.52               | -69.61                                   | 609.13                                     | 275.65                                 | 103.85                                   | 231.54                                    | -1.91                                   | NO  |
| 2005 | 540.32               | -67.97                                   | 608.29                                     | 267.85                                 | 101.10                                   | 241.24                                    | -1.91                                   | NO  |
| 2004 | 541.13               | -66.32                                   | 607.45                                     | 260.07                                 | 98.35                                    | 250.94                                    | -1.91                                   | NO  |
| 2003 | 541.94               | -64.68                                   | 606.62                                     | 252.29                                 | 95.60                                    | 260.65                                    | -1.91                                   | NO  |
| 2002 | 451.91               | -63.04                                   | 514.95                                     | 156.11                                 | 89.49                                    | 267.29                                    | 2.06                                    | NO  |
| 2001 | 454.66               | -61.38                                   | 516.04                                     | 152.73                                 | 86.12                                    | 274.92                                    | 2.27                                    | NO  |
| 2000 | 457.70               | -59.72                                   | 517.42                                     | 149.63                                 | 82.75                                    | 282.55                                    | 2.48                                    | NO  |
| 1999 | 460.73               | -58.06                                   | 518.79                                     | 146.54                                 | 79.38                                    | 290.19                                    | 2.69                                    | NO  |
| 1998 | 463.77               | -56.40                                   | 520.16                                     | 143.44                                 | 76.02                                    | 297.82                                    | 2.89                                    | NO  |
| 1997 | 466.80               | -54.74                                   | 521.54                                     | 140.33                                 | 72.65                                    | 305.45                                    | 3.10                                    | NO  |
| 1996 | 469.83               | -53.08                                   | 522.90                                     | 137.23                                 | 69.28                                    | 313.09                                    | 3.31                                    | NO  |
| 1995 | 432.95               | -51.42                                   | 484.37                                     | 98.91                                  | 63.12                                    | 321.91                                    | 0.43                                    | NO  |
| 1994 | 430.95               | -50.69                                   | 481.64                                     | 97.67                                  | 58.53                                    | 324.96                                    | 0.48                                    | NO  |
| 1993 | 428.96               | -49.96                                   | 478.92                                     | 96.44                                  | 53.94                                    | 328.02                                    | 0.52                                    | NO  |
| 1992 | 426.96               | -49.23                                   | 476.19                                     | 95.20                                  | 49.34                                    | 331.07                                    | 0.57                                    | NO  |
| 1991 | 424.96               | -48.50                                   | 473.46                                     | 93.97                                  | 44.75                                    | 334.13                                    | 0.62                                    | NO  |
| 1990 | 414.58               | -47.77                                   | 462.35                                     | 83.46                                  | 33.82                                    | 345.29                                    | -0.22                                   | NO  |
| 1989 | 414.26               | -47.39                                   | 461.65                                     | 82.76                                  | 33.82                                    | 345.29                                    | -0.22                                   | NO  |
| 1988 | 413.95               | -47.00                                   | 460.95                                     | 82.06                                  | 33.82                                    | 345.29                                    | -0.22                                   | NO  |
| 1987 | 413.63               | -46.61                                   | 460.25                                     | 81.36                                  | 33.82                                    | 345.29                                    | -0.22                                   | NO  |
| 1986 | 413.32               | -46.23                                   | 459.54                                     | 80.65                                  | 33.82                                    | 345.29                                    | -0.22                                   | NO  |

### **6.8.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

The information of settlements area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present settlements area in the period 1986-2001. The estimation of settlements area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The approach used for representing settlements areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to settlements is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of settlements areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

### **6.8.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories**

The settlements is not defined specifically in terms of national legislation. However, the Rules on recording land use data in the land cadaster (1982) specified land use related to man-made objects and properties, such as residential and industry buildings, outbuildings, garage, functional objects, monuments, roads, railways, market squares, parking places, waste dumps, open warehouses etc. For the need of the GHG reporting the Settlements category includes the land-use class 3000 (Table 6.2.1), i.e. built-up areas and related surfaces. According to Interpretation key (2013) the latter includes all lands associated with buildings, roads, settlements, houses, parking places, mines and quarries and other infrastructure related to human activities.

### **6.8.4 Methodological issues**

#### **6.8.4.1 Settlements remaining Settlements**

##### **Carbon stock changes in living biomass**

The 2006 Guidelines defined methods for estimating changes in carbon stock in biomass, dead organic matter, and soil carbon stock changes in settlements remaining settlements. The estimation of carbon stock changes in living biomass is based on crown cover area, using a Tier 2a approach. The country-specific value for crown cover (AT) is 9.4% was used from the WISDOM study (2006). During the informal recommendation of the EU review (i.e. Trial review of the 2021 greenhouse gas inventory for the LULUCF sector of Slovenia) the reviewer recommended Slovenia to use this value as it refers to tree cover in settlements.



Equation 8.2 of the 2006 Guidelines was used to estimate the annual carbon accumulation attributed to biomass increment. A default value of 2.8 t C ha crown cover<sup>-1</sup> year<sup>-1</sup> was used (IPCC 2019). Urban trees are assumed to be net sinks as the active growing period (AGP) was estimated to be less than 20 years.

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

In line with 2006 Guidelines the Tier 1 default assumes all carbon contained in dead wood and litter is lost during conversion and does not take account of any subsequent accumulation. Therefore, changes in carbon stocks of DOM are assumed zero.

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

The Tier 1 method assumes that inputs equal outputs, so that C stocks in the settlement soil do not change.

### **6.8.4.2 Land converted to Settlements**

The average annual area converted from other land uses to Settlements in the period 2002-2020 is in the range between 925 and 1,675 ha.

#### **Carbon stock changes in living biomass**

The fundamental equation for estimating changes in carbon stocks associated with land-use conversions is the same as applied for other areas of land-use conversion (land converted to forest land, cropland or grassland). The default assumption for Tier 2 estimate is that all living biomass present before conversion to Settlement will be lost in the same year as the conversion takes place, and that carbon stocks following conversion are equal to zero. For calculations of emissions from other land uses converted to settlements Tier 2 methodology and equations 2.15 and 2.16 (IPCC 2006) were used.

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

In line with 2006 Guidelines the Tier 1 default assumes all carbon contained in dead wood and litter is lost during conversion and does not take account of any subsequent accumulation. Therefore, changes in carbon stocks of DOM are assumed zero.

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

For calculations of emissions from soils in land converted to Settlements Tier 2 methodology and equation 2.25 (IPCC 2006) were used.

$$\Delta C_{LS\text{mineral}} = \frac{[SOC_0 - SOC_{0-T}] * A}{T} \quad \text{(Equation 40)}$$

$\Delta C_{LG\text{mineral}}$  – annual change in carbon stock in mineral soils [t C yr<sup>-1</sup>]

$SOC_0$  – soil organic carbon stock in the inventory year [ $t\ C\ ha^{-1}$ ]

$SOC_{0-T}$  – soil organic carbon stock  $T$  years prior to the inventory [ $t\ C\ ha^{-1}$ ]

$T$  – time [default 20 years],  $A$  – land area [ha]

$SOC_{SL}$  – country-specific value for organic carbon stock in mineral soil (see Table 6.2.8.)

In 2022, the Slovenian Forestry Institute estimated the proportion of unsealed settlement areas on the basis of a visual analysis of digital orthophotos. In this study, 1,000 sample plots were randomly distributed at country level, taking into account the area of settlements. The estimated proportion of unsealed settlement area equals to 33.86%. In 2023, the average SOC stock for urban areas was reported as  $88.14\ t\ C\ ha^{-1}$ , based on the findings of Marinšek et al. (2023).

### **$N_2O$ emissions from N mineralization/immobilization**

For calculations of  $N_2O$  emissions associated with land conversion to settlements, the Tier 1 methodology was used, using Equations 11.1 and 11.8 and default emission factors from the Table 11.1 (IPCC 2006). Direct  $N_2O$  emissions are estimated due to land use conversions from forest land, cropland, grassland and wetlands to settlements.

### **Indirect $N_2O$ emission from N leaching and run-off**

The Tier 1 method (Equation 11.10) and default emission factors from Table 11.3 of the 2006 Guidelines were used to estimate indirect  $N_2O$  emissions from N mineralization due land use changes in mineral soils through leaching/runoff. Indirect  $N_2O$  emissions are estimated due to land use changes from forest land, cropland, grassland and wetlands to settlements.

## **6.8.5 Uncertainties and time-series consistency**

The uncertainty estimates are not reported here.

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

No specific QA/QC and verification for grassland was used in the 2022 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**

Recalculations have been made for the period 1986-2022 for land converted to settlements based on updated emission factors for living biomass, dead organic matter and mineral soil.

## **6.8.8 Category-specific planned improvements**

There are no specific planned improvements in this category in the near future.

## **6.9 Other land (4F)**

### **6.9.1 Source category description**

Under the 2006 Guidelines, other land is defined as a category that includes bare soil, rock, ice and any unmanaged land areas that does not fall into any of the other five categories. This land use category is included so that the sum of identified land is consistent with the national land area.

Other land took up 1.59% of the national land area in 2022. Other land includes: open areas with little or no vegetation and dried open areas with special vegetation.

Emissions in other land decreased by 75% (i.e. from 13.71 to 3.49 Gg CO<sub>2</sub>) between 1986 and in 2023.

Table 6.9.1: Activity data of other land (1986-2023) in kha

| Year | 4.F Other land | 4.F.1. Other land remaining<br>other land | Land converted to other land           |  |   |  |   |  |
|------|----------------|---|--|--|---|--|---|--|
|      |                |   | 4.F.2. Land converted<br>to other land | 4.F.2.1 Forest Land<br>converted to other land | 4.F.2.2 Cropland<br>converted to other land | 4.F.2.3 Grassland<br>converted to other land | 4.F.2.4 Wetlands<br>converted to other land | 4.F.2.5 Settlements<br>converted to other land |
|      |                |   | Area, kha                              |  |   |  |   |  |
| 2023 | 32.15          | 31.80                                     | 0.35                                   | 0.27   | NO  | NO   | NO  | 0.08   |
| 2022 | 32.15          | 31.75                                     | 0.40                                   | 0.30   | NO  | NO   | NO  | 0.1  |
| 2021 | 32.15          | 31.68                                     | 0.47                                   | 0.30   | NO  | NO   | NO  | 0.17   |
| 2020 | 32.15          | 31.61                                     | 0.54                                   | 0.30   | NO  | NO   | NO  | 0.24   |
| 2019 | 32.15          | 31.55                                     | 0.60                                   | 0.30   | NO  | NO   | NO  | 0.3  |
| 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                                   | 0.43   | 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  | 0.5  |
| 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                                   | 0.47   | NO  | NO   | NO  | 0.27   |
| 1998 | 33.32          | 32.61                                     | 0.70                                   | 0.50   | NO  | NO   | NO  | 0.2  |
| 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                                     | 0.55                                   | 0.55   | 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 (1986-2023) 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> |                |  |                                     |   |  |   |  |   |
| 2023                                       | 3.49           | NA                                     | 3.49                                | 3.54  | NO                                       | NO  | NO                                       | -0.05                                       |
| 2022                                       | 3.80           | NA                                     | 3.80                                | 3.86  | NO                                       | NO  | NO                                       | -0.06                                       |
| 2021                                       | 3.75           | NA                                     | 3.75                                | 3.86  | NO                                       | NO  | NO                                       | -0.1  |
| 2020                                       | 3.71           | NA                                     | 3.71                                | 3.86  | NO                                       | NO  | NO                                       | -0.14                                       |
| 2019                                       | 3.67           | NA                                     | 3.67                                | 3.86  | NO                                       | NO  | NO                                       | -0.19                                       |
| 2018                                       | 3.63           | NA                                     | 3.63                                | 3.86  | NO                                       | NO  | NO                                       | -0.23                                       |
| 2017                                       | 3.59           | NA                                     | 3.59                                | 3.86  | NO                                       | NO  | NO                                       | -0.27                                       |
| 2016                                       | 3.55           | NA                                     | 3.55                                | 3.86  | NO                                       | NO  | NO                                       | -0.31                                       |
| 2015                                       | 3.50           | NA                                     | 3.50                                | 3.86  | NO                                       | NO  | NO                                       | -0.35                                       |
| 2014                                       | 4.02           | NA                                     | 4.02                                | 4.37  | NO                                       | NO  | NO                                       | -0.35                                       |
| 2013                                       | 4.53           | NA                                     | 4.53                                | 4.89  | NO                                       | NO  | NO                                       | -0.35                                       |
| 2012                                       | 19.35          | NA                                     | 19.35                               | 19.70                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2011                                       | 19.24          | NA                                     | 19.24                               | 19.59                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2010                                       | 19.13          | NA                                     | 19.13                               | 19.48                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2009                                       | 18.82          | NA                                     | 18.82                               | 19.18                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2008                                       | 18.52          | NA                                     | 18.52                               | 18.87                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2007                                       | 18.22          | NA                                     | 18.22                               | 18.57                                       | NO                                       | NO  | NO                                       | -0.35                                       |
| 2006                                       | 15.48          | NA                                     | 15.48                               | 14.98                                       | NO                                       | NO  | NO                                       | 0.5   |
| 2005                                       | 15.34          | NA                                     | 15.34                               | 14.83                                       | NO                                       | NO  | NO                                       | 0.51  |
| 2004                                       | 15.21          | NA                                     | 15.21                               | 14.68                                       | NO                                       | NO  | NO                                       | 0.53  |
| 2003                                       | 15.07          | NA                                     | 15.07                               | 14.53                                       | NO                                       | NO  | NO                                       | 0.54  |
| 2002                                       | 7.18           | NA                                     | 7.18                                | 5.14  | NO                                       | NO  | NO                                       | 2.03  |
| 2001                                       | 7.54           | NA                                     | 7.54                                | 5.46  | NO                                       | NO  | NO                                       | 2.08  |
| 2000                                       | 7.90           | NA                                     | 7.90                                | 5.79  | NO                                       | NO  | NO                                       | 2.12  |
| 1999                                       | 8.27           | NA                                     | 8.27                                | 6.11  | NO                                       | NO  | NO                                       | 2.16  |
| 1998                                       | 8.63           | NA                                     | 8.63                                | 6.43  | NO                                       | NO  | NO                                       | 2.2   |
| 1997                                       | 8.99           | NA                                     | 8.99                                | 6.75  | NO                                       | NO  | NO                                       | 2.24  |
| 1996                                       | 9.36           | NA                                     | 9.36                                | 7.07  | NO                                       | NO  | NO                                       | 2.28  |
| 1995                                       | 20.74          | NA                                     | 20.74                               | 20.74                                       | NO                                       | NO  | NO                                       | NO  |
| 1994                                       | 20.36          | NA                                     | 20.36                               | 20.36                                       | NO                                       | NO  | NO                                       | NO  |
| 1993                                       | 19.97          | NA                                     | 19.97                               | 19.97                                       | NO                                       | NO  | NO                                       | NO  |
| 1992                                       | 19.59          | NA                                     | 19.59                               | 19.59                                       | NO                                       | NO  | NO                                       | NO  |
| 1991                                       | 19.20          | NA                                     | 19.20                               | 19.20                                       | NO                                       | NO  | NO                                       | NO  |
| 1990                                       | 14.17          | NA                                     | 14.17                               | 14.17                                       | NO                                       | NO  | NO                                       | NO  |
| 1989                                       | 14.06          | NA                                     | 14.06                               | 14.06                                       | NO                                       | NO  | NO                                       | NO  |
| 1988                                       | 13.94          | NA                                     | 13.94                               | 13.94                                       | NO                                       | NO  | NO                                       | NO  |
| 1987                                       | 13.82          | NA                                     | 13.82                               | 13.82                                       | NO                                       | NO  | NO                                       | NO  |
| 1986                                       | 13.71          | NA                                     | 13.71                               | 13.71                                       | NO                                       | NO  | NO                                       | NO  |

### **6.9.2 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

The information of other land area is based on two data sources. Data from Statistical Yearbook of the Statistical Office RS (SORS) was used to present other land area in the period 1986-2001. The estimation of other land area for the period 2002-2012 was provided by the Slovenian Forestry Institute through targeted research project "Bases for improving the reporting methodology of greenhouse gas emissions in relation to land use, land use change and forestry". The approach used for representing other land areas follows the principle of estimation of areas via proportions, where the total area of the inventory region is known (IPCC 2006). The methodology of data acquisition as well as detection of land use changes from and to other land is described in the sub-chapter 6.3.1. The following maps and databases were used in the assessment of other land areas:

- Digital orthophotos of the Surveying and Mapping Authority RS,
- Agricultural Land Use Map of the Ministry of Agriculture, Forestry and Food,
- Land cover map of Slovenia from Landsat satellite imagery (images for the period 1984-2014 collected by ZRC SAZU).

### **6.9.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories**

The other land is not defined specifically in terms of national legislation. This category includes all land areas that do not fall into any of the other five top-level land-use categories which is in line with the 2006 Guidelines. For the need of the GHG reporting the Other Land category includes the following land-use classes (Table 6.2.1); dried open areas with special vegetation and open areas with little or no vegetation.

### **6.9.4 Methodological issues**

#### **6.9.4.1 Other land remaining Other land**

Consistent with the IPCC Guidelines, change in carbon stocks and non-CO<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**

Recalculations have been made for the period 1986-2022 for land converted to other land based on updated emission factors for living biomass and dead organic matter (conversions from forest land to other land) and updated emission factors for mineral soil (conversions from settlements to other land).

Direct N<sub>2</sub>O emissions from N mineralization/immobilization and indirect N<sub>2</sub>O emissions from managed soils (nitrogen leaching and run-off

Recalculations were made on the basis of updated emission factors for all land use changes where the change in soil organic carbon stocks is negative.

#### **6.9.8 Category-specific planned improvements**

No category-specific improvement are planned in the near future.



## 6.10 Harvested wood products (4G)

### 6.10.1 Source category description

Harvested wood products (HWP) include all wood materials leaving the harvest sites. Typically, HWP is sawnwood, 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 2023, HWP contributed to a net removals of -270.71 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.

Time series start with 1900 using all available sources of information (historical records, official statistics, independent studies). E.g.: for fibreboard production, annual data are used from the year 1946 (one of the first companies to produce fibreboard in Europe).

The product group “plywood” was not included in our calculations because these products are derived from sawnwood and veneer and would therefore cause double counting of carbon inflow. The carbon input from domestic pulpwood in paper and paperboard production was estimated using data for the production of wood pulp (mechanical and chemical pulp).

The revised first order decay method (FOD) according to the 2006 Guidelines and Pingoud and Wagner (2006) was used. The calculation of net emissions follows the recommended method according to IPCC 2006 (Equation 12.1). The estimate uses the product categories, half-lives and methodologies as proposed in paragraph 27, page 31 of FCCC/KP/AWG/2010/CRP.4/Rev.4:

- Sawnwood: 35 years,
- WBP (Particle boards, Fibreboards, Veneer): 25 years,
- Paper and Paperboard: 2 years.

**Table 6.10.1: Emissions from Harvested wood products (1986-2023) 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> |                             |              |                 |                          |                 |
| 2023                                       | -270.71                     | -244.15      | -39.42          | 12.86                    | NO              |
| 2022                                       | -304.87                     | -272.71      | -48.70          | 16.54                    | NO              |
| 2021                                       | -195.13                     | -177.40      | -30.89          | 13.17                    | NO              |
| 2020                                       | -142.18                     | -110.58      | -25.47          | -6.13                    | NO              |
| 2019                                       | -252.87                     | -195.82      | -52.22          | -4.82                    | NO              |
| 2018                                       | -125.92                     | -115.05      | -16.65          | 5.79                     | NO              |
| 2017                                       | -85.75                      | -50.63       | -39.28          | 4.17                     | NO              |
| 2016                                       | -101.84                     | -44.27       | -42.87          | -14.70                   | NO              |
| 2015                                       | -129.04                     | -45.76       | -67.41          | -15.87                   | NO              |
| 2014                                       | -112.83                     | -22.26       | -72.23          | -18.34                   | NO              |
| 2013                                       | -25.38                      | -3.84        | -39.30          | 17.77                    | NO              |
| 2012                                       | -64.02                      | -16.38       | -63.54          | 15.89                    | NO              |
| 2011                                       | -74.55                      | -36.81       | -58.72          | 20.97                    | NO              |
| 2010                                       | -128.97                     | -91.59       | -46.58          | 9.20                     | NO              |
| 2009                                       | -182.54                     | -137.60      | -65.77          | 20.83                    | NO              |
| 2008                                       | -228.47                     | -181.82      | -76.42          | 29.76                    | NO              |
| 2007                                       | -310.86                     | -264.98      | -86.26          | 40.38                    | NO              |
| 2006                                       | -218.65                     | -216.44      | -33.58          | 31.38                    | NO              |
| 2005                                       | -184.59                     | -146.23      | -24.86          | -13.50                   | NO              |
| 2004                                       | -164.13                     | -124.48      | -33.38          | -6.27                    | NO              |
| 2003                                       | -128.98                     | -94.23       | -28.53          | -6.22                    | NO              |
| 2002                                       | -97.97                      | -39.40       | -48.95          | -9.63                    | NO              |
| 2001                                       | -77.69                      | -28.51       | -40.10          | -9.08                    | NO              |
| 2000                                       | -85.11                      | -39.91       | -29.88          | -15.32                   | NO              |
| 1999                                       | -39.82                      | 3.26         | -24.95          | -18.13                   | NO              |
| 1998                                       | -71.50                      | -19.78       | -38.64          | -13.08                   | NO              |
| 1997                                       | 24.01                       | 56.12        | -17.67          | -14.45                   | NO              |
| 1996                                       | -42.77                      | -28.35       | -20.27          | 5.86                     | NO              |
| 1995                                       | 28.38                       | 49.81        | -25.23          | 3.81                     | NO              |
| 1994                                       | 45.38                       | 39.66        | -21.91          | 27.63                    | NO              |
| 1993                                       | 105.98                      | 67.82        | -11.95          | 50.11                    | NO              |
| 1992                                       | 76.88                       | 28.62        | -3.34           | 51.60                    | NO              |
| 1991                                       | 39.54                       | 15.65        | -25.45          | 49.34                    | NO              |
| 1990                                       | -67.01                      | -67.54       | -35.04          | 35.56                    | NO              |
| 1989                                       | -328.98                     | -212.43      | -109.99         | -6.56                    | NO              |
| 1988                                       | -415.72                     | -293.15      | -99.95          | -22.62                   | NO              |
| 1987                                       | -459.61                     | -319.71      | -102.37         | -37.53                   | NO              |
| 1986                                       | -457.00                     | -352.78      | -82.16          | -22.07                   | NO              |

**Table 6.10.2: Production of harvested wood products based on domestic harvest in Slovenia for the period 1986-2023 in m<sup>3</sup> or tons**

|      | Sawnwood<br>[m <sup>3</sup> ] | Wood panels<br>[m <sup>3</sup> ] | Paper and paperboard<br>[tonnes] |
|------|-------------------------------|----------------------------------|----------------------------------|
| 2023 | 962196                        | 87375                            | 17995                            |
| 2022 | 992175                        | 91031                            | 18831                            |
| 2021 | 868257                        | 82791                            | 24018                            |
| 2020 | 782054                        | 81300                            | 36566                            |
| 2019 | 881149                        | 96656                            | 34619                            |
| 2018 | 782239                        | 72861                            | 28225                            |
| 2017 | 707180                        | 84610                            | 30260                            |
| 2016 | 700541                        | 84782                            | 40704                            |
| 2015 | 697811                        | 101935                           | 38210                            |
| 2014 | 669790                        | 103335                           | 36130                            |
| 2013 | 651929                        | 78239                            | 13966                            |
| 2012 | 667112                        | 92610                            | 18647                            |
| 2011 | 695278                        | 85295                            | 19410                            |
| 2010 | 762470                        | 73943                            | 29785                            |
| 2009 | 817691                        | 83108                            | 25819                            |
| 2008 | 874273                        | 83190                            | 25666                            |
| 2007 | 972061                        | 84990                            | 26533                            |
| 2006 | 903769                        | 53530                            | 39579                            |
| 2005 | 815842                        | 47701                            | 68925                            |
| 2004 | 784960                        | 53975                            | 62427                            |
| 2003 | 746175                        | 50551                            | 61084                            |
| 2002 | 673782                        | 66994                            | 61504                            |
| 2001 | 654539                        | 64366                            | 59201                            |
| 2000 | 661304                        | 61318                            | 60459                            |
| 1999 | 608371                        | 58574                            | 58667                            |
| 1998 | 635299                        | 66929                            | 52298                            |
| 1997 | 541906                        | 55617                            | 50246                            |
| 1996 | 644400                        | 55565                            | 36914                            |
| 1995 | 554245                        | 56764                            | 39184                            |
| 1994 | 567618                        | 54014                            | 27904                            |
| 1993 | 535902                        | 47028                            | 22307                            |
| 1992 | 582496                        | 42082                            | 32075                            |
| 1991 | 602282                        | 53315                            | 44064                            |
| 1990 | 699876                        | 59277                            | 61410                            |
| 1989 | 867718                        | 106562                           | 90240                            |
| 1988 | 957877                        | 97978                            | 97006                            |
| 1987 | 979935                        | 99317                            | 99820                            |
| 1986 | 1016771                       | 80863                            | 84093                            |

**Table 6.10.3: Conversion factors and primary product groups used in calculation**

| Classifi-<br>cation | Description<br>of commodity | Air dry<br>density   | C conv.<br>factor        | C conv.<br>factor             | Source  |
|---------------------|-----------------------------|----------------------|--------------------------|-------------------------------|---|
| UNECE               |                             | [g/cm <sup>3</sup> ] | [Gg<br>C/1000<br>tonnes] | [Gg<br>C/1000m <sup>3</sup> ] |   |
| 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.

$$Inflow\ HWP = \sum_i^n (F_{DPPA\ i} \times HWP_i) \quad \text{(Equation 41)}$$

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)

$$F_{DPPA\ i} = \frac{Domestic\ INDRW\ Consumption_i}{WOOD\ Consumption_i} \quad \text{(Equation 42)}$$

HWP are calculated separately for sawnwood, veneer, particle board, fibreboard and virgin pulp with time series starting from year 1900 using all existing sources of information (historical records, official statistics independent studies). The domestic share of roundwood is calculated separately for product group sawnwood and veneer and product group consisting of WBP and product group virgin pulp.

As the production process of sawnwood and veneer use logs as input material and to be as close to real roundwood flows from domestic sources the FDPPA is the same for both products. However, the calculation for sawnwood uses HL 35 y and calculation for veneer uses HL 25 y. Product groups: sawnwood, WBP and paper and paperboard are calculated and reported separately.

### Factors and data sources for primary product groups

#### 1. $F_{DPPAi}$ for sawn wood and veneer ( $F_{SW+V}$ )

$$F_{SW+V} = \frac{\text{Production LOGS} - \text{Export LOGS}}{\text{Production LOGS} + \text{Import LOGS} - \text{Export LOGS}} \quad (\text{Equation 43})$$

Data sources for calculation of amounts of domestic round wood accounted in product group sawn wood and veneer are based on data from Statistical Office of the Republic of Slovenia (SORS), industrial reports and independent national studies. Due to changes in statistical data collection amounts of produced sawn wood in period 1996-2009 are calculated using conversion factors and mass balance of logs consumption.

#### 2. $F_{DPPAi}$ for particle boards and fibreboards ( $F_{WBP}$ )

$$F_{WBP} = \frac{\text{Domestic INDRW Consumption}_{WBP}}{\text{WOOD Consumption}_{WBP}} \quad (\text{Equation 44})$$

Data sources for calculation of  $F_{WBP}$  until 2009 are official data and industry reports. From 2010 onwards, data were obtained directly from producers and included in calculations (data from companies: production, input material, type of input material (roundwood, wood residues), quantities from import and from domestic sources). Due to small number of companies to obtain realistic figures and confidential data of national statistics covering industry we suppose our direct full coverage of production is, despite time-consuming process, precise and unbiased.

#### 3. $F_{DPPAi}$ for wood pulp ( $F_{WP}$ )

$$F_{WP} = \frac{\text{Domestic INDRW Consumption}_{WP}}{\text{WOOD Consumption}_{WP}} \quad (\text{Equation 45})$$

Data sources for calculation of  $F_{WP}$  are based on industry reports for years before 1990, interpolation for missing years and direct full data coverage obtained from domestic producers (production, input material, type of input material: roundwood, wood residues quantities of input material originating from import and from domestic sources, percentage of pulp in production process) was used for the period 2004-2016.

### 6.10.3 Uncertainties and time-series consistency

The expert estimate for the uncertainty of the activity data was 30% in 1986 and is 25% in recent years while uncertainty of the emission factors is 50%.

### 6.10.4 Category-specific QA/QC and verification

The methodology used in the submission of information on reference levels for forest management by Slovenia (FMRL Submission) and updated for this report is based on Equation 12.1 from the 2006 Guidelines. Some country-specific methodologies are also described in the FMRL Submission (MAFF, SFI, SFS 2011).

In the category, a general QA/QC was performed considering 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 (CRT sector 5)

### 7.1 Overview of sector

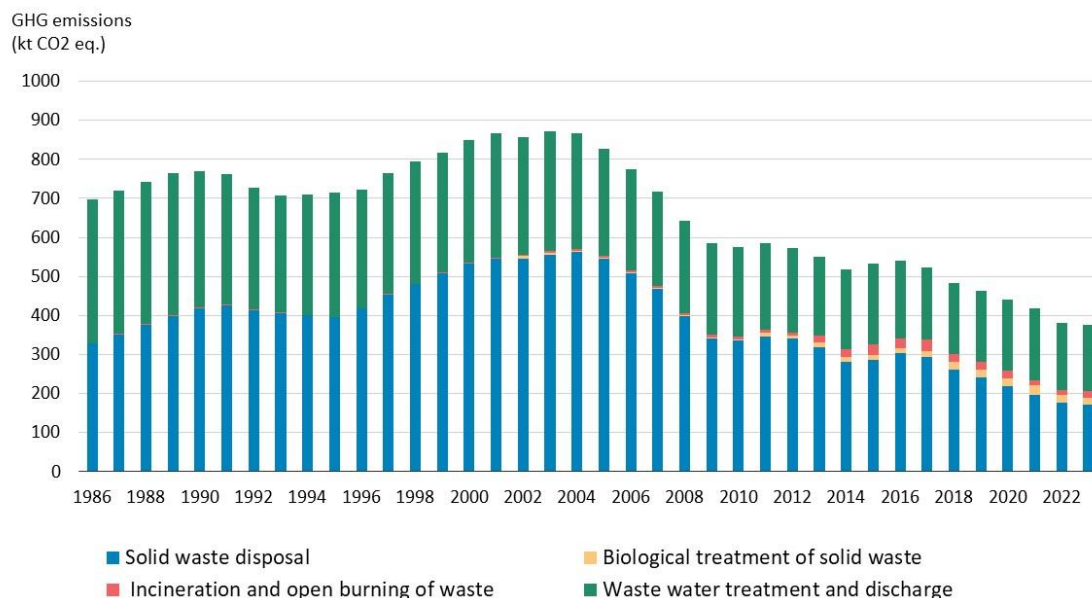
In this chapter the following sources are presented:

- Solid waste disposal (5.A),
- Biological treatment of solid waste – composting (CRT 5.B),
- Incineration of waste (CRT 5.C), and
- Wastewater treatment and discharge (CRT 5.D).

**Table 7.1.1: Methods, EFs used and key categories indications for the year 2023 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, T         | 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).



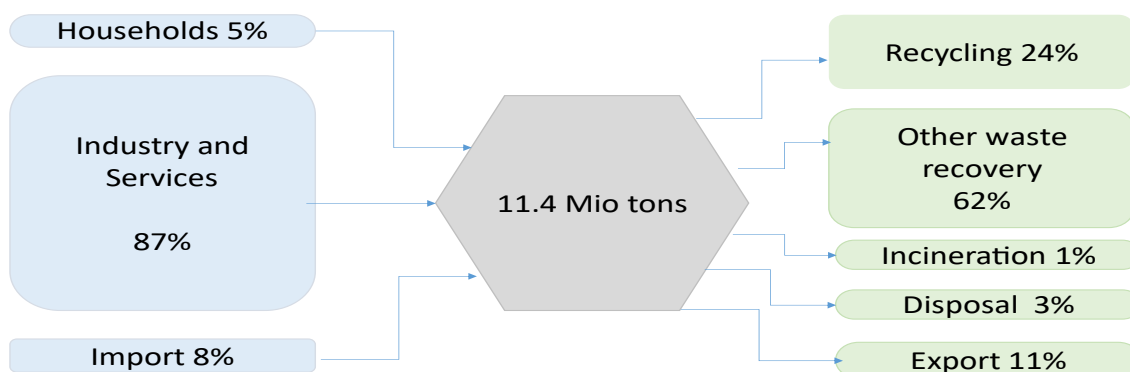
**Figure 7.1.1: Emissions from solid waste disposal on land and from wastewater handling in Gg CO<sub>2</sub> eq.**

In 2023, emissions from the waste sector amounted to 377 Gg CO<sub>2</sub> eq, or 2.5 per cent of the total GHG emissions. Since 1986 emissions decreased by 45.9 per cent. The key driver for the decline of emissions is the decrease of biodegradable part of the municipal waste deposited on the SWD sites and increase of gas recovery on the SWD sites and in the wastewater treatment plants. (Figure 7.1.1).

Methane emissions from the Waste sector are the second largest source of methane and represents 17.4% of the all methane emissions in Slovenia in 2023. The fraction of methane emissions in this sector amounts to 85.2%, while the remaining part represent N<sub>2</sub>O (10.4%) and CO<sub>2</sub> emissions (4.5%). Solid waste handling contributes 45.7% to the total emissions from this sector, wastewater handling 45.1%, composting 4.7%, and incineration of waste 4.5%.

Emissions from solid waste disposal started to decline in 2005 and since then emissions decreased by 68.4% due to the strong decrease of deposited biodegradable part of municipal waste and gas recovery. Emissions from waste waters were by 53.8% lower than in the base year what is mostly due to recovery of gas in wastewater treatment plants and the decrease in industrial production.

In Slovenia, 9.4 million tonnes of waste was generated, almost quarter more than in 2020. Almost two-thirds (6 million tonnes) of total waste generated was construction and demolition waste, dominated by soil and stones, followed by municipal waste with 12% and by waste from thermal processes with 8% of total waste generated.



**Figure 7.1.2: Waste stream in Slovenia in 2023**

In 2023, approximately 384 kt of waste was disposed of; 163 kt tonnes of waste was landfilled, of which 93% on municipal waste landfill sites, 5% on industrial waste landfill sites and 2% on hazardous waste landfill sites. Mixed fractions of municipal waste and residues after mechanical and biological waste treatment dominated among the landfilled waste (42%), followed by construction and demolition waste (28%), and waste from mechanical treatment of other waste (18%). Other types of waste were landfilled in smaller amounts.



The waste regulations have introduced a 5-stage waste hierarchy, according to which the top priority is given to the prevention of waste generation, followed by preparing for reuse, recycling, other recovery procedures (e.g. energy recovery), whereas waste disposal (e.g. landfilling, incineration without energy recovery) is deemed to be the least preferred option.

The volume of separately collected fractions of municipal waste has been increasing in recent years. The system of door-to-door separate collection of waste facilitates further processing of separately collected waste (recycling and recovery). In this way we contribute to the conservation of natural resources and to a decrease in the negative environmental impacts of waste deposited in landfills (e.g. CH<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 kt), compared to 7.3% in 2021 (76 kt).

Waste management pays particular attention to packaging waste, not so much because of the generated quantities and risk potential, but primarily because of its enormous volume, short life cycle and substantial portion of organic matter. Up to 2004, the majority of Slovenian packaging waste ended up in landfills. With the introduction of regulations providing for the payment of an environmental tax on packaging, the separate collection of packaging waste, the establishment of a system for processing packaging waste, and by focusing on achieving the objectives set for the recovery and recycling of packaging waste, packaging waste management has seen substantial improvement.

### **Relevant legislation**

The Decree on the landfill of waste is the main act in which the EU Landfill Directive was transposed. Thus in 2006, when Decree on the landfill of waste cancelled the mentioned Rules on the landfill of waste, Slovenia fully complied with the requirements of the Landfill Directive.

On the political level Slovenia started with the activities on the field of waste management in 1996, when also strategic orientations for waste management were prepared. On this basis National environmental action Programme was adopted in 2006 and set the enforcement of modern forms of waste management as priority objective. A period of systematic regulation in the field of waste management followed, with the adoption of implementing acts on the basis of EPA.

The National environmental action Programme formed the basis for the Operational Programme for waste disposal and its goal was the reduction of deposited biodegradable waste for the period 2009-2013; it was adopted by the government in 2008. However, the Rules on the landfill of waste adopted in 2000 had already comprised provisions regarding reduction of biodegradable waste and these were also included in the Decree on the treatment of biodegradable waste, which was adopted in 2008 and repealed the mentioned Rules.

The Operational Programme from 2008 was project oriented, focusing on goals:

- at least 65% or more of the produced municipal waste should be redirected in other type of treatment and at least 42% of them should be reused;
- all kitchen waste should be extracted and biologically processed;
- the remainder of waste should be processed in a way that the content of organic carbon will not exceed 5%;
- in the structure of the whole deposited waste 47% of the deposited biodegradable waste should be reduced to 16% until 2013 or 2015 that means in average 5% per year.

Measures for achieving the listed goals are also a part of the Operational Programme:

- the existing landfills should be closed down, if the adjustment to the existing provisions were too expensive or technically difficult to manage;
- reconstruction and enlargement of the existing landfills, which will be operating until the end of 2008;
- construction of a new infrastructure for treatment, recovery and disposal of waste for regional centres for waste management and national centres for thermal treatment.

Decree on the landfill of waste also includes annex 4. It specifies the volume of biodegradable substance in municipal waste, which can be deposited in all landfills in the territory of Slovenia per year. It also sets that the amount of deposited biodegradable waste should be decreased:

- by 10% in years 2008-2009,
- by 5% in years 2009 – 2010, 2011– 2012 and 2013 – 2015 in accordance with the 1995 amount.

A new strategic document, Operational Programme from 2013 adopted in this area provides the certain measures for achieving the following targets by 2020:

- increasing the recycling rate of municipal waste to 61–64%;
- increasing the incineration rate to approximately 25%; and
- decreasing the disposal of municipal waste in landfills to 11–15%.

In December 2015, the European Commission presented an ambitious package of measures aimed at achieving a transition to a circular and thus more competitive economy with a more sustainable use of resources. The package also includes amended legislative proposals on waste with ambitious targets: the EU's common goal by 2030 is 65% of municipal waste recycling, 75% of packaging waste recycling, and a binding target of reducing the amount of waste that ends up at landfills to a maximum of 10% of municipal waste.

In 2016, Slovenia adopted the Waste Management Plan as well as the Waste Prevention Programme, which serve as a basis for achieving ambitious objectives by 2030.

Main measures, which already in the past contributed to reducing the quantities of deposited biodegradable waste, are waste separation at source and mechanical biological treatment of mixed municipal waste. In most municipalities, door-to-door collection systems are used for waste packaging, bio-waste, and paper.

Since 2016, the mechanical biological treatment of mixed municipal waste prior to disposal in municipal waste management centres has been mandatory. That is why all facilities for mechanical and biological treatment of mixed municipal waste in Slovenia had to be upgraded in order to meet the country's needs.

**Biological treatment of solid waste** in Slovenia covers composting and anaerobic digestion. The only GHG emissions included in the inventory are emissions from composting. In 2022 emissions from this source (CH<sub>4</sub> and N<sub>2</sub>O) amounted only 19.1 kt CO<sub>2</sub> eq. There are no CH<sub>4</sub> emissions from the anaerobic digestion in the MB treatment plant because the generated CH<sub>4</sub> is fully recovered. 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 2022 were 14.0 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 2022 emissions from this source amounted to 170.6 kt CO<sub>2</sub> eq. The majority (96%) of this emissions arose from domestic waste waters and remaining 4% from industrial waste water. Waste water is treated in municipal waste-water treatment plants classified by level of treatment as specified in regulations. As a rule, primary treatment is defined as the mechanical or chemical elimination of a smaller quantity of organic loading and some suspended substances. Secondary treatment is a process of biological purification. It removes a large amount of organic substances and nutrients (20%-30%). Tertiary treatment eliminates organic matter and a large amount of nutrients (nitrogen, phosphors). According to the 2022 data approximately 71% of population in Slovenia was connected to waste-water treatment plants and nearly 29% of the population still uses septic tanks.

## 7.2 Solid Waste Disposal Sites (CRT 5.A)

### 7.2.1 Category description

Methane is emitted during anaerobic fermentation of degradable organic substances in solid waste disposal sites in processes, which may last several decades. If waste were not disposed of on solid waste disposal sites, the degradation would take place in aerobic conditions without methane formation. Methane emissions from waste disposal are thus of anthropogenic origin and, consequently, a constituent part of national GHG inventories in accordance with IPCC methodology.

### 7.2.2 Methodological issues

The IPCC methodology for estimating CH<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 – 2023

Since 2002 all data from waste collection system in Slovenia are very detailed and are also publicly available from the SORS database [SI-STAT](#).

**Table 7.2.3: Quantities of landfilled waste in the period 2001 - 2022.**

| year | Urban population | Waste gen. rate in kg/cap/y. | Fraction landfilled | Deposited MSW (kt) | Industrial waste (kt) | Deposited Industrial waste (kt) |
|------|------------------|------------------------------|---------------------|--------------------|-----------------------|---------------------------------|
| 2002 | 1,842,447        | 426.3                        | 0.84                | 712.471            | 4,067.315             | 108.965                         |
| 2003 | 1,847,015        | 440.6                        | 0.79                | 692.880            | 4,570.267             | 127.252                         |
| 2004 | 1,857,214        | 417.0                        | 0.75                | 625.062            | 5,634.562             | 102.402                         |
| 2005 | 1,881,047        | 422.2                        | 0.78                | 658.367            | 5,170.200             | 94.179                          |
| 2006 | 1,879,971        | 431.0                        | 0.84                | 725.074            | 5,693.728             | 115.264                         |
| 2007 | 1,878,048        | 438.5                        | 0.78                | 688.617            | 5,916.184             | 123.057                         |
| 2008 | 1,921,498        | 456.3                        | 0.74                | 679.603            | 5,904.332             | 143.119                         |
| 2009 | 1,981,065        | 447.0                        | 0.69                | 631.082            | 5,580.967             | 119.661                         |
| 2010 | 2,028,768        | 421.6                        | 0.65                | 562.722            | 5,441.859             | 60.502                          |
| 2011 | 2,052,496        | 351.7                        | 0.58                | 419.228            | 5,330.250             | 85.769                          |
| 2012 | 2,056,262        | 361.8                        | 0.42                | 314.952            | 3,722.431             | 73.413                          |
| 2013 | 2,059,114        | 414.4                        | 0.26                | 224.001            | 3,779.395             | 50.723                          |
| 2014 | 2,061,623        | 432.5                        | 0.23                | 207.676            | 3,785.627             | 50.238                          |
| 2015 | 2,063,077        | 450.5                        | 0.22                | 208.618            | 4,242.916             | 52.202                          |
| 2016 | 2,064,241        | 464.8                        | 0.06                | 54.885             | 4,516.811             | 58.131                          |
| 2017 | 2,066,161        | 477.8                        | 0.07                | 67.011             | 5,185.112             | 75.611                          |
| 2018 | 2,070,050        | 495.2                        | 0.06                | 57.276             | 7,363.418             | 87.769                          |
| 2019 | 2,089,310        | 509.4                        | 0.07                | 76.387             | 7,349.537             | 79.720                          |
| 2020 | 2,100,126        | 487.6                        | 0.07                | 76.148             | 6,643.101             | 75.844                          |
| 2021 | 2,107,007        | 517.9                        | 0.05                | 55.368             | 8,344.150             | 78.609                          |
| 2022 | 2,108,732        | 495.9                        | 0.07                | 76.285             | 10,613.540            | 118.129                         |
| 2023 | 2,120,937        | 517.6                        | 0.07                | 77.989             | 11,659.227            | 97.489                          |



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 7.2.4: Quantities of landfilled waste (MSW and industrial) and amount of biodegradable waste in the period 1964 - 2023.**

| Year | Deposited waste (kt) | Biodegradable waste (kt) | Year | Deposited waste (kt) | Biodegradable waste (kt) |
|------|----------------------|--------------------------|------|----------------------|--------------------------|
| 1964 | 140.078              | 39.937                   | 1994 | 543.898              | 273.651                  |
| 1965 | 143.769              | 41.671                   | 1995 | 707.000              | 384.817                  |
| 1966 | 147.497              | 43.424                   | 1996 | 748.916              | 412.092                  |
| 1967 | 149.941              | 44.572                   | 1997 | 717.364              | 394.242                  |
| 1968 | 157.867              | 48.297                   | 1998 | 750.236              | 414.317                  |
| 1969 | 159.872              | 49.240                   | 1999 | 759.614              | 420.654                  |
| 1970 | 162.444              | 50.288                   | 2000 | 707.444              | 391.818                  |
| 1971 | 171.634              | 54.310                   | 2001 | 696.624              | 361.557                  |
| 1972 | 177.511              | 56.928                   | 2002 | 821.436              | 409.880                  |
| 1973 | 211.165              | 71.491                   | 2003 | 820.132              | 366.094                  |
| 1974 | 266.869              | 95.608                   | 2004 | 727.464              | 304.019                  |
| 1975 | 293.386              | 107.228                  | 2005 | 752.546              | 299.099                  |
| 1976 | 325.486              | 121.309                  | 2006 | 840.338              | 311.707                  |
| 1977 | 384.435              | 147.072                  | 2007 | 811.674              | 293.262                  |
| 1978 | 449.343              | 175.532                  | 2008 | 822.722              | 289.315                  |
| 1979 | 551.571              | 220.293                  | 2009 | 750.743              | 265.102                  |
| 1980 | 570.646              | 228.975                  | 2010 | 623.224              | 187.146                  |
| 1981 | 569.486              | 228.822                  | 2011 | 504.997              | 176.665                  |
| 1982 | 529.545              | 211.648                  | 2012 | 388.365              | 130.324                  |
| 1983 | 544.817              | 218.577                  | 2013 | 274.724              | 93.320                   |
| 1984 | 567.106              | 228.599                  | 2014 | 257.914              | 56.831                   |
| 1985 | 591.036              | 239.518                  | 2015 | 260.820              | 85.583                   |
| 1986 | 620.640              | 252.774                  | 2016 | 113.016              | 5.182                    |
| 1987 | 642.930              | 262.844                  | 2017 | 142.622              | 0.125                    |
| 1988 | 651.626              | 266.960                  | 2018 | 145.045              | 0.004                    |
| 1989 | 672.902              | 298.917                  | 2019 | 156.107              | 0.007                    |
| 1990 | 620.726              | 279.192                  | 2020 | 198.631              | 0.085                    |
| 1991 | 474.293              | 211.861                  | 2021 | 133.974              | 0.004                    |
| 1992 | 473.673              | 226.963                  | 2022 | 194.414              | 0.028                    |
| 1993 | 483.100              | 236.035                  | 2023 | 175.477              | 0.003                    |

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.

### Composition of waste

The following data on composition of waste have been estimated:

A = fraction of waste that is paper and textiles

B = fraction of waste that is garden waste, park waste or other non-food waste

C = fraction of waste that is food waste

D = fraction of waste that is wood or straw

The fractions used for GHG emission calculations are presented in the table 7.2.8.

For the mixed MS waste, which represents the major part of municipal and similar types of waste, we have assumed the composition or fractions A, B, C in D, as stated in the Operational programme of waste disposal to be the same for the entire period 1964 to 1988: A:12%, B:5%, C:25%, D:5%.

These values have been changed to A: 15%, B: 8%, C: 32%, D: 8% for 1995 (the base year for the Operational programme) and to determine values in between and for the period 1996 to 2004 the expert estimates which are based on the periodic sample analyses have been used.

In 2005 and partly in 2006, new screening analyses of mixed municipal waste were performed. The results were as followed: 22.1% A, 17.5% C and 7.5% D, or, together, 47% of all degradable wastes. Considering all waste disposed of in SWDS and fraction of degradable waste in other types of disposed wastes, we have estimated the following composition of waste for 2005: A: 20.4%, C: 16.5% and D: 7.1%. The fraction of waste "garden waste or park waste" is zero because since 2004 a legislation prohibits deposition of such a type of waste on SWDS. For the industrial waste the same composition have been assumed for the entire period 1964 to 2007; A: 5%, C: 0.5%, and D: 4.5%. In the period 2008-2015 the screening analyses have been done for the mixed part of municipal solid waste (code 20 03 01) for every landfill many times per year and results are presented in the table 7.2.5.

**Table 7.2.5: Amounts of wastes deposited on municipal SWDS and results for screening analyzes for the mixed MSW (code from LoW 20 03 01) for the period 2008 to 2015.**

| year | All waste deposited on the SWDS (t) | Municipal solid waste – MSW (t) | Mixed fraction of MSW – code 20 03 01 (t) | A paper textiles % | C food waste % | D wood straw % |
|------|-------------------------------------|---------------------------------|---|--------------------|----------------|----------------|
| 2008 | 822,722                             | 684,719                         | 616,588                                   | 20.2               | 13.5           | 9.2            |
| 2009 | 750,743                             | 627,686                         | 524,734                                   | 14.8               | 14.4           | 11.1           |
| 2010 | 623,224                             | 557,901                         | 516,502                                   | 14.0               | 13.8           | 5.6            |
| 2011 | 504,997                             | 419,228                         | 380,414                                   | 19.9               | 16.6           | 5.2            |
| 2012 | 388,365                             | 314,952                         | 290,284                                   | 18.9               | 17.2           | 4.5            |
| 2013 | 274,724                             | 224,001                         | 203,945                                   | 18.9               | 17.2           | 4.5            |
| 2014 | 257,914                             | 207,676                         | 188,387                                   | 17.9               | 17.7           | 3.8            |
| 2015 | 260,820                             | 208,618                         | 188,638                                   | 17.9               | 17.7           | 3.8            |

For all other types of MSW and for the industrial waste the composition as presented on table 7.2.6 has been used. The data on amount of waste are available according to the classification in the List of waste (LoW). LoW is a list of hazardous and non-hazardous waste listed in the Annex 4 of the Decree on Waste (OJ RS, No 103/2011) and is available on the web site:

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000D0532:20020101:EN:PDF>

Waste is classified into groups according to the origin. In addition to the name, each waste has a six-digit classification number.

**Table 7.2.6: A composition data for the different types of biodegradable waste used in the period 2008-2015**

| Main code | Type of wastes   | Additional code    | A paper and textile | C food      | D wood      |
|-----------|--|--------------------|---------------------|-------------|-------------|
| 02 01     | wastes from agriculture, horticulture, forestry, hunting and fishing       | 01, 02, 03, 99     |                     | 100%        |             |
| 02 01     | wastes from agriculture, horticulture, forestry, hunting and fishing       | 07                 |                     |             | 100%        |
| 02 02     | wastes from the preparation and processing of meat, fish and other foods   | 01, 02, 03, 99     |                     | 100%        |             |
| 02 03     | wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea... | 01, 02, 03, 04, 99 |                     | 100%        |             |
| 02 04     | wastes from sugar processing   | 99                 |                     | 100%        |             |
| 02 05     | wastes from the dairy products industry                                    | 01, 99             |                     | 100%        |             |
| 02 06     | wastes from the baking and confectionery industry                          | 01, 02             |                     | 100%        |             |
| 02 07     | wastes from the production of alcoholic and non-alcoholic beverages        | 01, 02, 04         |                     |             |             |
| 03 01     | wastes from wood processing and the production of panels and furniture     | 01, 05, 99         |                     |             | 100%        |
| 03 03     | wastes from pulp, paper and cardboard production and processing            | 01                 |                     |             | 100%        |
| 03 03     | wastes from pulp, paper and cardboard production and processing            | 07, 10, 99         | 100%                |             |             |
| 04 02     | wastes from the textile industry   | 09, 10, 21, 22, 99 | 50%                 |             |             |
| 15 01     | packaging  | 01                 | 100%                |             |             |
| 15 01     | packaging  | 03                 |                     |             | 100%        |
| 15 01     | packaging  | 09                 | 100%                |             |             |
| 15 02     | other  | 03                 | 50%                 |             |             |
| 17 02     | wood, glass and plastic  | 01                 |                     |             | 100%        |
| 17 09     | Mixed constriction waste   | 04                 |                     |             | 20%         |
| 19 08     | wastes from waste water treatment plants                                   | 01, 02             | 10%                 |             | 5%          |
| 19 12     | wastes from the mechanical treatment of waste                              | 01                 | 100%                |             |             |
| 19 12     | wastes from the mechanical treatment of waste                              | 07                 |                     |             | 100%        |
| 19 12     | wastes from the mechanical treatment of waste                              | 08                 | 50%                 |             |             |
| 19 12     | wastes from the mechanical treatment of waste                              | 12                 | 10%                 |             | 5%          |
| 20 01     | separately collected fractions   | 08, 25             |                     | 100%        |             |
| 20 01     | separately collected fractions   | 10, 11             | 50%                 |             |             |
| 20 01     | separately collected fractions   | 38                 |                     |             | 100%        |
| 20 02     | garden and park wastes   | 01                 |                     |             | 100%        |
| 20 03     | other municipal wastes - mixed municipal wastes                            | 01, 99             | Table 7.2.5         | Table 7.2.5 | Table 7.2.5 |
| 20 03     | other municipal wastes   | 03                 | 20%                 | 10%         | 5%          |
| 20 03     | Bulky waste  | 07                 |                     |             | 35%         |

Since 2016, the mechanical biological treatment (MBT) of mixed municipal waste prior to disposal in municipal waste management centres has been mandatory. That is why all facilities for mechanical and biological treatment of mixed municipal waste in Slovenia had to be upgraded in order to meet the country's needs. The treated municipal waste has to fulfil the following restrictions before they are allowed to be disposed on the SWDS.

heating value: does not exceed 6 MJ / kg of dry matter,

TOC: does not exceed 18% by weight of dry MB treated municipal waste and

AT4: does not exceed 10 mg O<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 2022 the composition presented in the table 7.2.7. have been used.

**Table 7.2.7: Composition of deposited biodegradable waste in 2023**

| Main code | Type of wastes  | Additional code | A paper and textile | D wood |
|-----------|---|-----------------|---------------------|--------|
| 15 02     | absorbents, filter materials, wiping cloths and protective clothing | 03              | 50%                 |        |
| 17 02     | wood, glass and plastic   | 01              |                     | 100%   |
| 17 09     | mixed constriction waste  | 04              |                     | 10%    |
| 19 08     | wastes from waste water treatment plants                            | 02              | 2%                  | 3%     |

The average yearly values of fractions of degradable waste as used for GHG emission calculations for the period 1964 to 2023 are presented in the table 7.2.8.

**Table 7.2.8: Fractions of degradable waste in deposited MSW and industrial waste.**

| year      | Municipal solid waste |                |              |              |                     | Industrial waste |              |              |                                  |
|-----------|-----------------------|----------------|--------------|--------------|---------------------|------------------|--------------|--------------|----------------------------------|
|           | A paper textiles      | B garden waste | C food waste | D wood straw | Degradable MSW in % | A paper textiles | C food waste | D wood straw | Degradable industrial waste in % |
| 1964-1988 | 12                    | 5              | 25           | 5            | 47                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1989      | 13                    | 6              | 26           | 6            | 51                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1990      | 13                    | 6              | 27           | 6            | 52                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1991      | 13                    | 6              | 28           | 6            | 53                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1992      | 14                    | 7              | 29           | 7            | 57                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1993      | 14                    | 7              | 30           | 7            | 58                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1994      | 14                    | 7              | 31           | 7            | 59                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1995      | 15                    | 8              | 32           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1996      | 15                    | 8              | 32           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1997      | 15                    | 8              | 32           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1998      | 16                    | 8              | 31           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 1999      | 16                    | 8              | 31           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 2000      | 17                    | 8              | 30           | 8            | 63                  | 5.0              | 0.5          | 4.5          | 10                               |
| 2001      | 17                    | 6              | 28           | 8            | 59                  | 5.0              | 0.5          | 4.5          | 10                               |
| 2002      | 18                    | 4              | 26           | 8            | 56                  | 5.0              | 0.5          | 4.5          | 10                               |

| year | Municipal solid waste  |                      |                    |                    |                           | Industrial waste       |                    |                    |   |
|------|------------------------|----------------------|--------------------|--------------------|---------------------------|------------------------|--------------------|--------------------|---|
|      | A<br>paper<br>textiles | B<br>garden<br>waste | C<br>food<br>waste | D<br>wood<br>straw | Degradable<br>MSW<br>in % | A<br>paper<br>textiles | C<br>food<br>waste | D<br>wood<br>straw | Degradable<br>industrial<br>waste<br>in % |
| 2003 | 18                     | 2                    | 23                 | 8                  | 51                        | 5.0                    | 0.5                | 4.5                | 10  |
| 2004 | 19                     | NO                   | 21                 | 7                  | 47                        | 5.0                    | 0.5                | 4.5                | 10  |
| 2005 | 20.4                   | NO                   | 16.5               | 7.1                | 44                        | 5.0                    | 0.5                | 4.5                | 10  |
| 2006 | 20.8                   | NO                   | 14.2               | 6.4                | 41.4                      | 5.0                    | 0.5                | 4.5                | 10  |
| 2007 | 19.7                   | NO                   | 13.2               | 7.9                | 40.8                      | 5.0                    | 0.5                | 4.5                | 10  |
| 2008 | 18.6                   | NO                   | 12.4               | 9.5                | 40.5                      | 5.1                    | 0.4                | 4.3                | 9.8                                       |
| 2009 | 13.1                   | NO                   | 16.8               | 10.0               | 39.9                      | 1.3                    | 0.6                | 9.1                | 11.0                                      |
| 2010 | 13.2                   | NO                   | 13.0               | 6.2                | 32.4                      | 7.5                    | 0.6                | 0.0                | 8.1                                       |
| 2011 | 18.4                   | NO                   | 15.2               | 7.3                | 40.9                      | 1.8                    | 0.1                | 4.4                | 6.2                                       |
| 2012 | 17.8                   | NO                   | 16.0               | 6.1                | 39.9                      | 3.0                    | 0.0                | 3.3                | 6.3                                       |
| 2013 | 17.7                   | NO                   | 15.9               | 6.1                | 39.7                      | 4.0                    | 0.0                | 4.6                | 8.7                                       |
| 2014 | 9.5                    | NO                   | 13.3               | 4.3                | 27.1                      | 0.8                    | 0.1                | 0.2                | 1.1                                       |
| 2015 | 16.6                   | NO                   | 16.2               | 5.5                | 38.4                      | 5.5                    | 0.0                | 5.0                | 10.6                                      |
| 2016 | NO                     | NO                   | NO                 | NO                 | NO                        | 5.9                    | NO                 | 3.0                | 8.9                                       |
| 2017 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.028                  | NO                 | 0.138              | 0.166                                     |
| 2018 | 0.002                  | NO                   | NO                 | 0.002              | 0.004                     | 0.000                  | NO                 | 0.002              | 0.002                                     |
| 2019 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.005                  | NO                 | 0.001              | 0.006                                     |
| 2020 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.012                  | NO                 | 0.073              | 0.085                                     |
| 2021 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.004                  | NO                 | 0.000              | 0.004                                     |
| 2022 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.005                  | NO                 | 0.022              | 0.028                                     |
| 2023 | NO                     | NO                   | NO                 | NO                 | NO                        | 0.003                  | NO                 | 0.000              | 0.003                                     |

### 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<br>from 25 % to 0 % | Linear interpolation<br>from 75 to 100 % | Linear interpolation        | Linear<br>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.

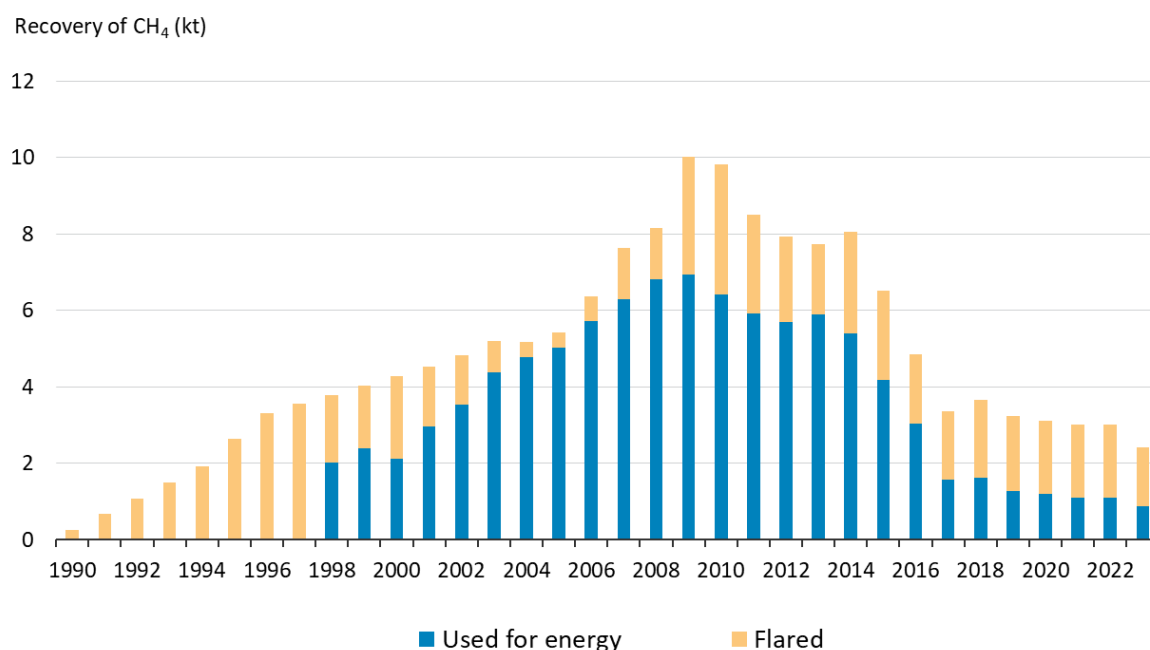
The oxidation value of 0.1 is justified for well-managed landfills which are covered with soil or other material. In the past very few SWDSs in Slovenia, although they were managed, use the cover material. In 2006 Slovenia started to implement EU legislation and until 2008 all SWDSs became well managed (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  $\text{DOC}_m$  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.



**Figure 7.2.1: Methane recovery in tons.**

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 from the disposal sites. This reports have to be prepared according to the Slovenian legislation. Data are available

separately for flaring and for energy use. Emissions from the energy use of methane are reported in the Energy sector in 1.A.4.a Commercial and Institutional, while emissions from flaring are not included in the inventory. A detailed data on methane recovery are presented in the Figure 7.2.1 and Table 7.2.11.

**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  | 2021  |
| Recovery             | t CH <sub>4</sub> | 8,054 | 6,517 | 4,860 | 3,808  | 3,664 | 3,246 | 3,123 | 3,024 |
| flared               | t CH <sub>4</sub> | 2,660 | 2,341 | 1,824 | 2,245  | 2,042 | 1,961 | 1,931 | 1,926 |
| used for electricity | t CH <sub>4</sub> | 5,394 | 4,176 | 3,036 | 1,563  | 1,622 | 1,285 | 1,193 | 1,098 |
| used for electricity | TJ                | 272   | 210   | 153   | 79     | 82    | 65    | 60    | 55    |
|                      | Unit              | 2022  | 2023  |       |        |       |       |       |       |
| Recovery             | t CH <sub>4</sub> | 3,008 | 2,420 |       |        |       |       |       |       |
| flared               | t CH <sub>4</sub> | 1,903 | 1,550 |       |        |       |       |       |       |
| used for electricity | t CH <sub>4</sub> | 1,105 | 870   |       |        |       |       |       |       |
| used for electricity | TJ                | 56    | 44    |       |        |       |       |       |       |

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.

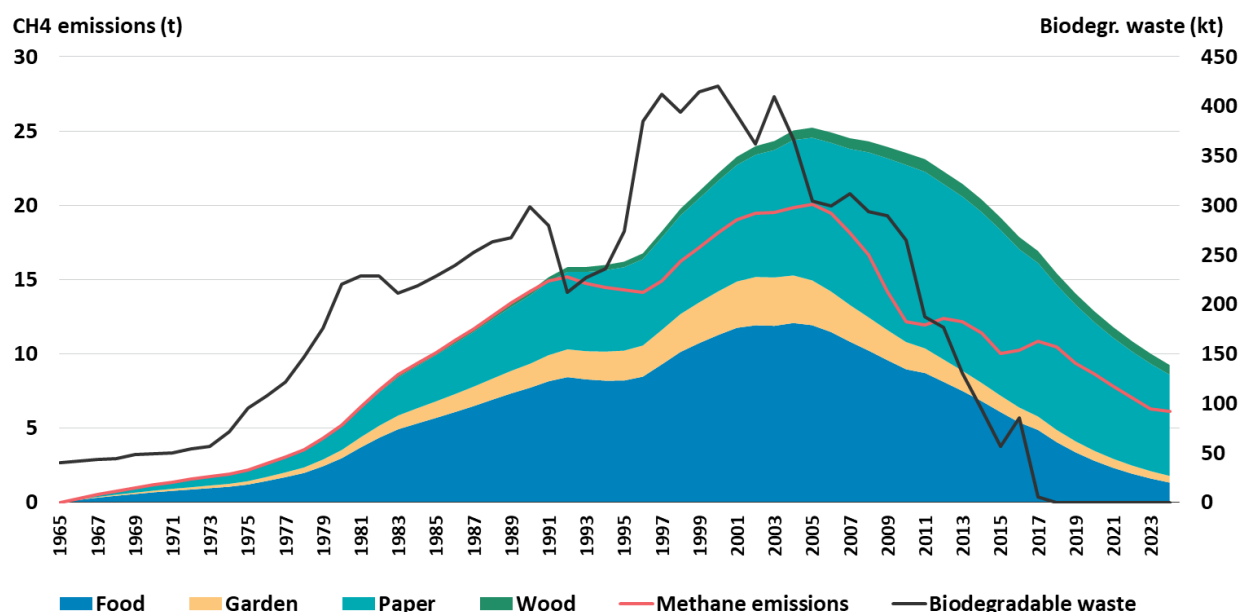
#### CH<sub>4</sub> Emissions

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 NID.

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 have 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 2023 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 recalculations have been performed in this category.

## 7.2.6 Category-specific planned improvements

No improvements are planned for the next submission.

## 7.3 Biological Treatment of Solid Waste (CRT 5.B)

Biological treatment of solid waste in Slovenia covers composting and anaerobic digestion. The only GHG emissions included in the inventory are emissions from composting.

### 7.3.1 Composting

#### 7.3.1.1 Category description

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste is converted into CO<sub>2</sub>. Composting can also produce emissions of N<sub>2</sub>O and CH<sub>4</sub>.

#### 7.3.1.2 Methodological issues

Amount of composted waste on the wet weight have been obtained from SORS for all years since 2002. In 2022 108.545 kt of wet waste have been composted. A household composting is not included in these data, because there is no data on the amount of composted waste and also no IPCC default EFs which are appropriate for home composting. No data prior 2002 is available.

In the CRT tables amount of composted waste is presented in kt of dry matter because the unit cannot be changed. For this reason the dry amount composted waste is calculated from the wet weight assuming a moisture content of 60% in wet waste as recommended in the 2006 IPCC GL. On the figure 7.3.1 amount on composted waste is presented, while a nominal data are available in the CRT tables.

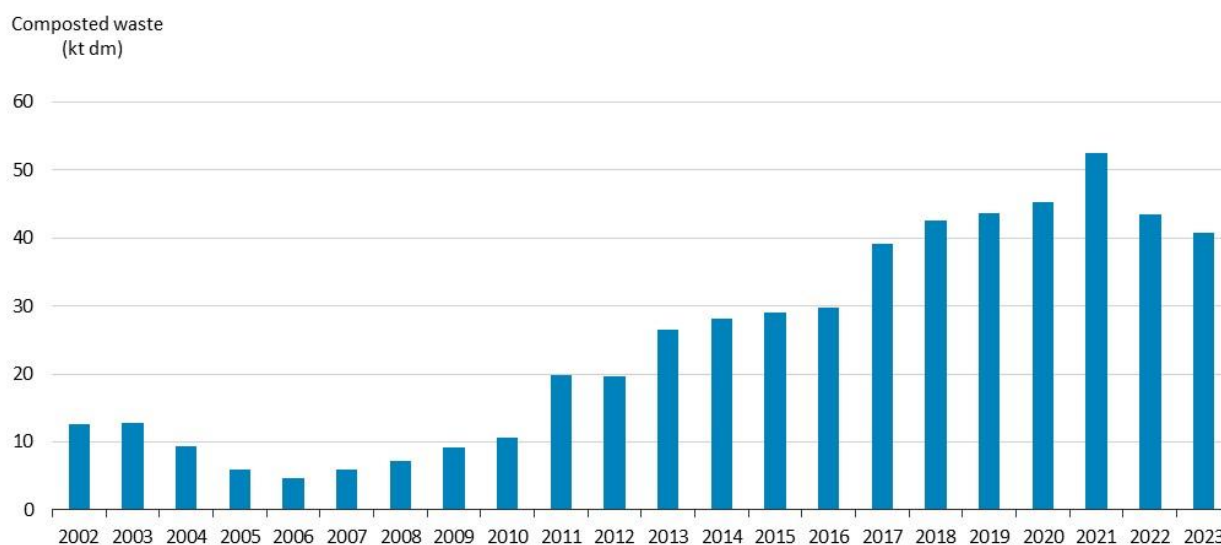


Figure 7.3.1: Amount of composted waste in kt of dry weight.

Emission factors have been taken from 2006 IPCC GL, Vol. 5 Table 4.1 for dry weight: 10 g CH<sub>4</sub> / kg waste and 0.6 g N<sub>2</sub>O / kg waste.

### **7.3.1.3 Uncertainty and time series consistency**

The composted waste is weighted and uncertainty is 10%. It is the same value as used for the deposited waste since 2002 and is recommended in the 2006 IPCC GL.

Uncertainties in the default emission factors can be estimated using the ranges given in Table 4.1. in the Waste chapter of 2006 IPCC GL. We have used the highest value; it is 100% for CH<sub>4</sub> EF and 150% for N<sub>2</sub>O EF.

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

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

### **7.3.1.5 Category-specific recalculations**

No recalculation have been performed.

### **7.3.1.6 Category-specific planned improvements**

No improvements are planned for the next submission

## **7.3.2 Anaerobic Digestion at Biogas Facilities**

The treatment of waste in the anaerobic digesters can be divided into two periods. Before 2015 the waste which has been treated in the biogas facilities was only the waste with the waste code 02 01 06 "Animal faeces, urine and manure (including spoiled straw), and effluent, collected separately and treated off-site". Emissions from this source were not included in the previous submissions. For the present submission emissions from the treatment of this type of waste in anaerobic digesters have been calculated for the first time, however, these emissions are reported in the Agriculture sector.

Waste treatment in the anaerobic digesters of other types of waste only started in 2015 with new legislation. This prohibits the disposal of biodegradable waste without prior MBT treatment. For this reason, all devices used for this purpose are very new and practically emission-free. All anaerobic digestion facilities are using gas detection sensors, to monitor the levels of methane and other gases within the facility. These sensors can detect any potential gas leaks or other issues that could affect the safety and efficiency of the anaerobic digestion process. The digestion process is also continuously monitored to maintain the appropriate temperature and pH conditions for optimal digestion, and properly manage the digestate.

In the period 2015-2022 between 85 and 158 kt of waste was treated in these facilities. If IPCC default EF of 0.8 g CH<sub>4</sub>/kg of wet waste is used, the highest emissions would be 0.126 kt CH<sub>4</sub> or 3.5 kt CO<sub>2</sub> eq in the year 2019. This value is below our threshold of significance (8 kt CO<sub>2</sub> eq). However, the experts assume that these emissions are close to zero. For these reason notation key NE is used in the CRT category 5B2. As well the notation key NE is also used for N<sub>2</sub>O emissions which are negligible according to the IPCC GL.

## 7.4 Waste incineration (CRT 5.C)

### 7.4.1 Category description

The purpose of waste incineration until 2008 in Slovenia was to remove waste which was not allowed to be deposited on the SWDS, the amount of incinerated waste was small and emissions from this source were less than 5 Gg CO<sub>2</sub> eq. Since 2009 the incinerated amount of waste has increased and emissions in 2022 were 14.0 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.

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 7.4.1: Amount of waste incinerated in tons in Slovenia in the period 1986 – 2023.**

| Year        | biogenic | municipal solid waste | clinical waste | hazardous waste |
|-------------|----------|-----------------------|----------------|-----------------|
| 1986 – 1993 | 0        | 0                     | 0              | 815             |
| 1994        | 0        | 0                     | 132            | 456             |
| 1995        | 0        | 0                     | 0              | 268             |
| 1996        | 0        | 0                     | 0              | 389             |
| 1997        | 0        | 0                     | 214            | 73              |
| 1998        | 10       | 0                     | 205            | 335             |
| 1999        | 0        | 0                     | 85             | 1,031           |
| 2000        | 0        | 0                     | 109            | 1,261           |
| 2001        | 0        | 0                     | 280            | 1,190           |
| 2002        | 260      | 0                     | 441            | 946             |
| 2003        | 235      | 0                     | 534            | 1,382           |
| 2004        | 110      | 15                    | 138            | 1,366           |
| 2005        | 291      | 2                     | 113            | 1,325           |
| 2006        | 345      | 4                     | 108            | 1,616           |
| 2007        | 676      | 9                     | 160            | 1,987           |
| 2008        | 533      | 33                    | 148            | 2,091           |
| 2009        | 630      | 19                    | 193            | 2,585           |
| 2010        | 31       | 21                    | 671            | 2,836           |
| 2011        | 251      | 9                     | 660            | 2,860           |
| 2012        | 221      | 11                    | 578            | 7,714           |
| 2013        | 132      | 10                    | 524            | 6,883           |
| 2014        | 29       | 10                    | 267            | 8,235           |
| 2015        | 41       | 12                    | 195            | 11,110          |
| 2016        | 71       | 1                     | 299            | 8,993           |
| 2017        | 133      | 2                     | 247            | 10,906          |
| 2018        | 98       | 2                     | 238            | 8,310           |
| 2019        | 171      | 1                     | 276            | 8,215           |
| 2020        | 271      | NO                    | 266            | 7,703           |
| 2021        | 247      | NO                    | 467            | 5,553           |
| 2022        | 284      | NO                    | 386            | 5,841           |
| 2023        | 461      | NO                    | 303            | 6,655           |

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  | 65             | NA                  | 50               |
| TCC    | %    | 50             | 3   | 60             | 80                  | 50               |
| FCF    | %    | 0              | 100 | 40             | 100                 | 90               |
| OF     | %    | 100            | 100 | 100            | 100                 | 100              |

**Table 7.4.3: Emission factors used in the period 1986 – 2023**

|                  | Unit        | Wood and paper | MSW   | Clinical waste | Fossil liquid waste | Other industrial |
|------------------|-------------|----------------|-------|----------------|---------------------|------------------|
| CO <sub>2</sub>  | t / t waste | 0              | 0.099 | 0.572          | 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  | 2021  | 2022  | 2023  |
|------------------|-------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| liquid           | %           | 77         | 84.4  | 79.7  | 78.1  | 78.7  | 80.7  | 77.8  | 72.5  | 79.7  |
| CO <sub>2</sub>  | t / t waste | 2.448      | 2.604 | 2.505 | 2.472 | 2.484 | 2.525 | 2.466 | 2.354 | 2.505 |
| N <sub>2</sub> O | g/ t waste  | 30.55      | 23.87 | 28.11 | 29.55 | 29.04 | 27.25 | 29.83 | 34.57 | 28.13 |



### 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 recalculations have been performed in this category.

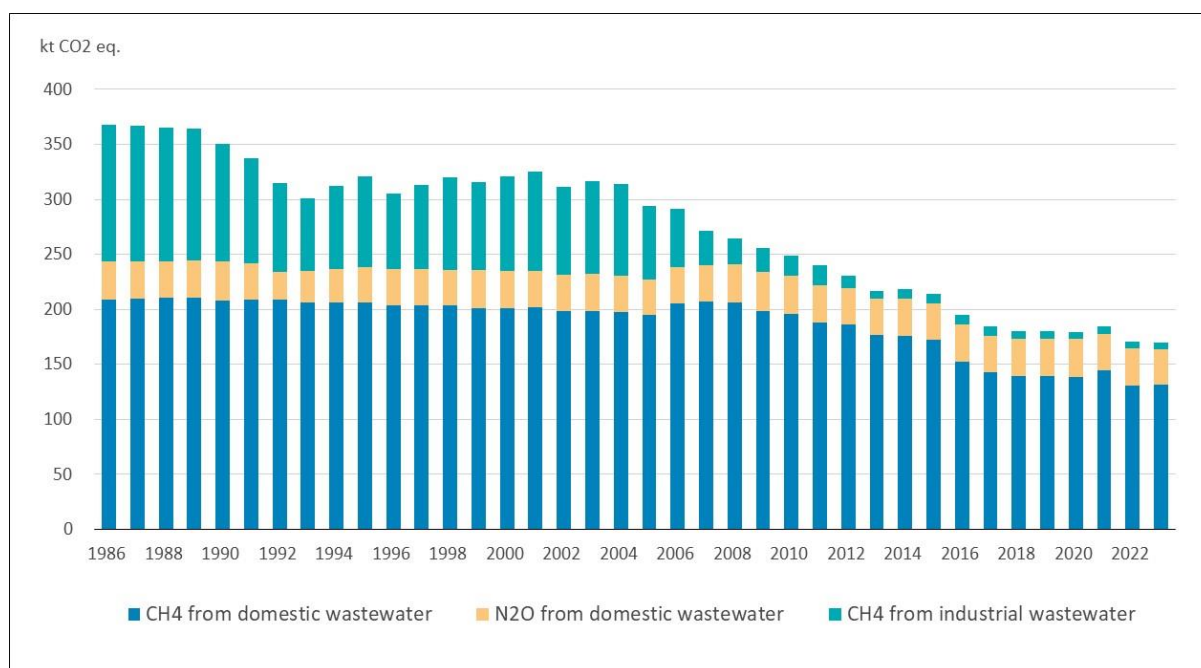
### 7.4.6 Category-specific planned improvements

No improvements are planned for this category.

## 7.5 Emissions from Wastewater Treatment and Discharge (CRT 5.D)

### 7.5.1 Category description

Wastewater could be a source of methane ( $\text{CH}_4$ ) when treated or disposed anaerobically. It can also be a source of nitrous oxide ( $\text{N}_2\text{O}$ ) emissions. Carbon dioxide ( $\text{CO}_2$ ) emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions. Wastewater originates from a variety of domestic and industrial sources and may be treated on site (uncollected), 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.



**Figure 7.5.1: Emissions of methane and nitrous oxide from wastewater treatment.**

Wastewater as well as its sludge components can produce  $\text{CH}_4$  if it degrades anaerobically. The extent of  $\text{CH}_4$  production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. With increases in temperature, the rate of  $\text{CH}_4$  production increases. This is especially important in uncontrolled systems and in warm climates. Below  $15^\circ\text{C}$ , significant  $\text{CH}_4$  production is unlikely because methanogens are not active.

$\text{N}_2\text{O}$  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                            | 4.42                           | 209.1  | 34.6  | 123.9  |
| 1987 | 7.48                           | 0.13                            | 4.41                           | 209.4  | 34.0  | 123.6  |
| 1988 | 7.48                           | 0.13                            | 4.34                           | 209.6  | 33.6  | 121,5  |
| 1989 | 7.49                           | 0.13                            | 4.30                           | 209.6  | 33.6  | 120.4  |
| 1990 | 7.39                           | 0.13                            | 3.84                           | 207.0  | 35.0  | 107,6  |
| 1991 | 7.39                           | 0.12                            | 3.44                           | 206.9  | 32.9  | 96.3   |
| 1992 | 7.37                           | 0.09                            | 2.89                           | 206.4  | 25.1  | 80,8   |
| 1993 | 7.27                           | 0.11                            | 2.38                           | 203.6  | 28.8  | 66.5   |
| 1994 | 7.27                           | 0.11                            | 2.70                           | 203.5  | 30.3  | 75,6   |
| 1995 | 7.27                           | 0.12                            | 2.96                           | 203.5  | 31.9  | 82.8   |
| 1996 | 7.15                           | 0.13                            | 2.45                           | 200.2  | 33.2  | 68,7   |
| 1997 | 7.14                           | 0.12                            | 2.74                           | 200.0  | 32.5  | 76.6   |
| 1998 | 6.98                           | 0.12                            | 3.03                           | 195.3  | 31.8  | 84,8   |
| 1999 | 6.85                           | 0.13                            | 2.87                           | 191.8  | 34.4  | 80.3   |
| 2000 | 6.99                           | 0.13                            | 3.04                           | 195.9  | 34.1  | 85,2   |
| 2001 | 6.95                           | 0.13                            | 3.21                           | 194.5  | 33.3  | 90.0   |
| 2002 | 6.80                           | 0.12                            | 2.86                           | 190.4  | 32.9  | 80.0   |
| 2003 | 6.77                           | 0.13                            | 3.01                           | 189.5  | 33.4  | 84.2   |
| 2004 | 6.42                           | 0.13                            | 3.00                           | 179.9  | 33.2  | 83,9   |
| 2005 | 6.32                           | 0.12                            | 2.38                           | 176.9  | 32.9  | 66.6   |
| 2006 | 6.27                           | 0.12                            | 1.88                           | 175.6  | 33.0  | 52.6   |
| 2007 | 6.38                           | 0.13                            | 1.09                           | 178.5  | 33.3  | 30,5   |
| 2008 | 6.37                           | 0.13                            | 0.83                           | 178.4  | 34.5  | 23.4   |
| 2009 | 6.36                           | 0.13                            | 0.79                           | 178.0  | 34.9  | 22.2   |
| 2010 | 6.21                           | 0.13                            | 0.67                           | 173.9  | 34.4  | 18.9   |
| 2011 | 6.10                           | 0.13                            | 0.65                           | 170.8  | 34.0  | 18.3   |
| 2012 | 6.13                           | 0.13                            | 0.40                           | 171.5  | 33.8  | 11.1   |
| 2013 | 5.82                           | 0.13                            | 0.25                           | 163.0  | 33.1  | 7.1  |
| 2014 | 5.81                           | 0.13                            | 0.31                           | 162.8  | 34.1  | 8.6  |
| 2015 | 5.84                           | 0.13                            | 0.30                           | 163.4  | 33.6  | 8.4  |
| 2016 | 5.59                           | 0.13                            | 0.30                           | 156.5  | 34.1  | 8.5  |
| 2017 | 5.08                           | 0.13                            | 0.30                           | 142.3  | 33.7  | 8.4  |
| 2018 | 5.01                           | 0.13                            | 0.25                           | 140.2  | 33.6  | 7.0  |
| 2019 | 4.99                           | 0.13                            | 0.25                           | 139.6  | 34.3  | 7.1  |
| 2020 | 5.05                           | 0.13                            | 0.22                           | 141.5  | 34.1  | 6.2  |
| 2021 | 5.17                           | 0.12                            | 0.24                           | 144.7  | 33.0  | 6.7  |
| 2022 | 4.68                           | 0.12                            | 0.23                           | 131.0  | 33.0  | 6.6  |
| 2023 | 4.68                           | 0.12                            | 0.22                           | 131.1  | 32.5  | 6.2  |

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 1986-2022. Emissions in Figure 7.5.1 are expressed in kt CO<sub>2</sub> equivalent.

## 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)

$MCF_j$  - methane correction factor for each discharge pathway, j (fraction)

In the third step, emission for each domestic wastewater treatment and discharge pathways have to be estimated.

$$CH_4 \text{ Emissions}_{-j} = ((TOW_j - S_j) * EF_j) - R_j$$

$CH_4 \text{ Emissions}_{-j}$  -  $CH_4$  emissions for each discharge pathway (kg  $CH_4$ /year)

$TOW_j$  - total organics in wastewater for each discharge pathway, j (kg BOD/year)

$S_j$  - organic component removed as sludge for each discharge pathway (kg BOD/year)

$R_j$  - amount of  $CH_4$  recovered for each discharge pathway (kg  $CH_4$ /year)

In the end, the total national emission of methane from domestic wastewater is estimated. Individual emission estimates for each discharge pathway are sum up.

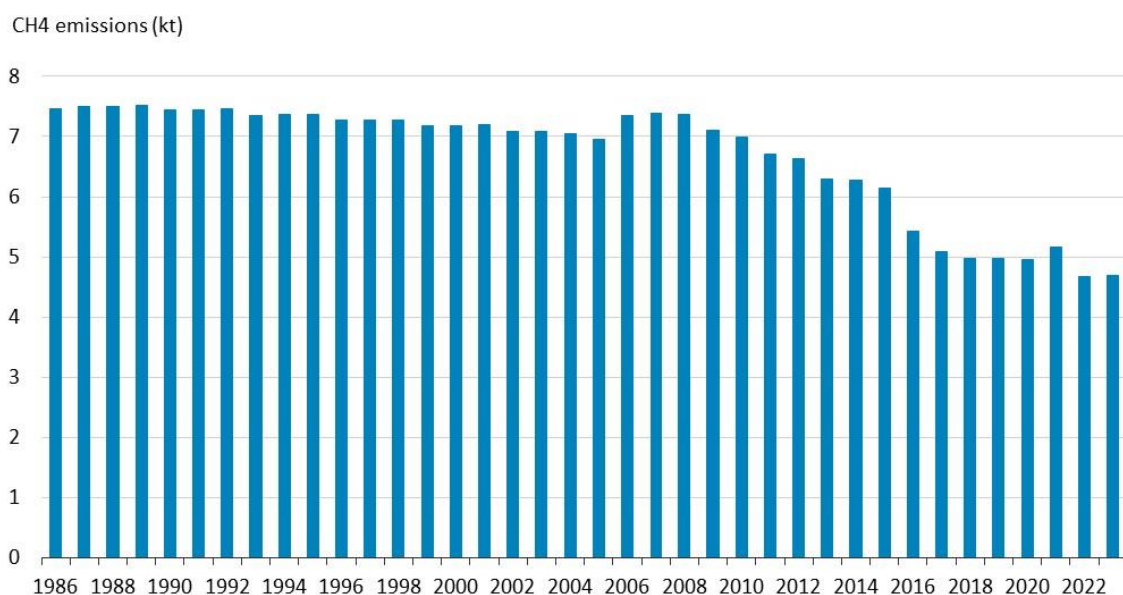
The equation for the calculation of annual  $CH_4$  emissions is as follows:

$$CH_4 \text{ emissions} = \sum_j CH_4 \text{ Emissions}_{-j}$$

$CH_4 \text{ Emissions}$  - total annual  $CH_4$  emissions in the country (kg  $CH_4$ /year)

$CH_4 \text{ Emissions}_{-j}$  -  $CH_4$  emissions for each discharge pathway (kg  $CH_4$ /year)

$CH_4$  emissions from domestic wastewater treatment and discharge for the period 1986 - 2023 are shown in Figure 7.5.2. Emissions were decreased in 2016 - 2023 due to a smaller share of the population connected to septic tanks.



**Figure 7.5.2:  $CH_4$  emissions from domestic wastewater treatment.**

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<br>in domestic<br>wastewater<br>(kt BOD) | Year | Total organics<br>in domestic<br>wastewater<br>(kt BOD) | Year | Total organics<br>in domestic<br>wastewater<br>(kt BOD) | Year | Total organics<br>in domestic<br>wastewater<br>(kt BOD) |
|------|---|------|---|------|---|------|---|
| 1986 | 46.78   | 1996 | 47.47   | 2006 | 49.15   | 2016 | 52.40   |
| 1987 | 47.03   | 1997 | 47.49   | 2007 | 49.63   | 2017 | 52.73   |
| 1988 | 47.15   | 1998 | 47.41   | 2008 | 49.82   | 2018 | 53.21   |
| 1989 | 47.21   | 1999 | 47.68   | 2009 | 50.48   | 2019 | 53.63   |
| 1990 | 47.36   | 2000 | 47.80   | 2010 | 50.68   | 2020 | 54.01   |
| 1991 | 47.40   | 2001 | 47.95   | 2011 | 51.09   | 2021 | 53.84   |
| 1992 | 47.36   | 2002 | 48.04   | 2012 | 51.26   | 2022 | 54.32   |
| 1993 | 47.33   | 2003 | 48.14   | 2013 | 51.47   | 2023 | 54.66   |
| 1994 | 47.39   | 2004 | 48.91   | 2014 | 51.55   |      |   |
| 1995 | 47.48   | 2005 | 49.22   | 2015 | 51.71   |      |   |

#### Wastewater treatment and discharge pathways

Dispersed settlements and a large number of communities with less than 2000 inhabitants exert a strong influence on the extent and structure of municipal infrastructure as well as on the organisation of municipal activities. Domestic wastewater has been treated in centralized aerobic wastewater plants, septic tanks and latrines.

In 2022, about 70.5% of the population was connected to centralized aerobic wastewater treatment plants (secondary and tertiary treatment). 29.3% of the population use septic tanks and only 0.2% use latrines. The number of inhabitants included in various types of domestic wastewater treatment is shown in Table 7.5.3.

Data on inhabitants included in various types of domestic wastewater treatment and the database on municipal wastewater treatment plants are obtained by the Slovenian Environment Agency (SEA).

5.D.1 Domestic Wastewater CRT subcategory comprises emissions from all types of wastewater treatment, wastewater sewerred 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).

**Table 7.5.3: Number of inhabitants included in various types of domestic wastewater treatment.**

| Year | Number of inhabitants (in 1000) |                                  |              |          |                    |
|------|---------------------------------|----------------------------------|--------------|----------|--------------------|
|      | Primary treatment               | Secondary and tertiary treatment | Septic tanks | Latrines | Country population |
| 1986 | 307                             | 295                              | 905          | 483      | 1985               |
| 1987 | 313                             | 303                              | 911          | 478      | 1994               |
| 1988 | 319                             | 312                              | 913          | 467      | 1996               |
| 1989 | 325                             | 320                              | 909          | 453      | 1996               |
| 1990 | 331                             | 328                              | 913          | 443      | 2000               |
| 1991 | 337                             | 336                              | 917          | 428      | 1999               |
| 1992 | 343                             | 345                              | 916          | 409      | 1994               |
| 1993 | 349                             | 353                              | 911          | 390      | 1989               |
| 1994 | 355                             | 361                              | 910          | 377      | 1989               |
| 1995 | 361                             | 370                              | 914          | 364      | 1990               |
| 1996 | 367                             | 378                              | 912          | 347      | 1987               |
| 1997 | 373                             | 386                              | 916          | 331      | 1985               |
| 1998 | 547                             | 253                              | 872          | 310      | 1978               |
| 1999 | 499                             | 309                              | 885          | 306      | 1988               |
| 2000 | 531                             | 274                              | 901          | 294      | 1990               |
| 2001 | 479                             | 348                              | 895          | 284      | 1994               |
| 2002 | 438                             | 406                              | 892          | 271      | 1995               |
| 2003 | 438                             | 425                              | 1014         | 259      | 1996               |
| 2004 | 420                             | 630                              | 867          | 120      | 1998               |
| 2005 | 394                             | 689                              | 860          | 80       | 2003               |
| 2006 | 78                              | 1038                             | 854          | 60       | 2010               |
| 2007 | 78                              | 1056                             | 872          | 41       | 2026               |
| 2008 | 27                              | 1108                             | 879          | 20       | 2032               |
| 2009 | 9                               | 1145                             | 876          | 18       | 2047               |
| 2010 | 10                              | 1174                             | 852          | 16       | 2050               |
| 2011 | 9                               | 1201                             | 833          | 14       | 2055               |
| 2012 | 9                               | 1201                             | 838          | 12       | 2059               |
| 2013 | 9                               | 1224                             | 819          | 10       | 2061               |
| 2014 | 9                               | 1230                             | 818          | 8        | 2063               |
| 2015 | 0                               | 1238                             | 822          | 6        | 2064               |
| 2016 | 0                               | 1281                             | 780          | 4        | 2066               |
| 2017 | 0                               | 1364                             | 699          | 4        | 2067               |
| 2018 | 0                               | 1391                             | 685          | 4        | 2081               |
| 2019 | 0                               | 1410                             | 681          | 4        | 2096               |
| 2020 | 0                               | 1413                             | 691          | 4        | 2109               |
| 2021 | 0                               | 1405                             | 698          | 4        | 2107               |
| 2022 | 0                               | 1487                             | 618          | 4        | 2109               |
| 2023 | 0                               | 1499                             | 618          | 4        | 2117               |

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 sewerage, 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 1 was used for emission calculations.

#### Maximum methane producing capacity ( $B_0$ ):

The methane producing potential ( $B_0$ ) is the maximum amount of  $CH_4$  that can be produced from a given quantity of organics (as expressed in BOD) in the wastewater. The  $CH_4$  producing potential varies according to the composition of the wastewater and its degradability, but the IPCC Guidelines provide only one default value of  $B_0$ . The IPCC default of 0.6 kg  $CH_4$ /kg BOD was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.12, Table 6.2).

#### Methane conversion factor (MCF):

The calculated amount of generated methane depends on the methane conversion factor, which tells us which fraction is actually transformed into methane. The MCF indicates the extent to which the  $CH_4$  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  $CH_4$  can be emitted from settling basins and other pockets. The share of well managed aerobic treatment plants was estimated from information on the implementation of the Urban Waste Water Treatment Directive. In 2023 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:

$$N_{\text{EFFLUENT}} = (P * \text{Protein} * F_{\text{NPR}} * F_{\text{NON-CON}} * F_{\text{IND-COM}}) - N_{\text{SLUDGE}}$$

|                       |  |
|-----------------------|--|
| $N_{\text{EFFLUENT}}$ | - total annual amount of nitrogen in the wastewater effluent (kg N/year)           |
| P                     | - human population   |
| Protein               | - annual per capita protein consumption (kg/person/year)                           |
| $F_{\text{NPR}}$      | - fraction of nitrogen in protein  |
| $F_{\text{NON-CON}}$  | - factor for non-consumed protein added to the wastewater                          |
| $F_{\text{IND-COM}}$  | - factor for industrial and commercial co-discharged protein into the sewer system |
| $N_{\text{SLUDGE}}$   | - nitrogen removed with sludge (kg N/year)   |

Finally, emissions of N<sub>2</sub>O from wastewater effluent are calculated as follows:

$$N_2O \text{ emissions} = N_{\text{EFFLUENT}} * EF_{\text{EFFLUENT}} * 44 / 28$$

|                            |   |
|----------------------------|---|
| N <sub>2</sub> O emissions | - N <sub>2</sub> O emissions in inventory year (kg N <sub>2</sub> O/year)                                   |
| $N_{\text{EFFLUENT}}$      | - nitrogen in the effluent discharged to aquatic environments (kg N/year)                                   |
| $EF_{\text{EFFLUENT}}$     | - emission factor for N <sub>2</sub> O emissions from discharged to wastewater (kg N <sub>2</sub> O-N/kg N) |
| 44/28                      | - the conversion of kg N <sub>2</sub> O-N into kg N <sub>2</sub> O.   |

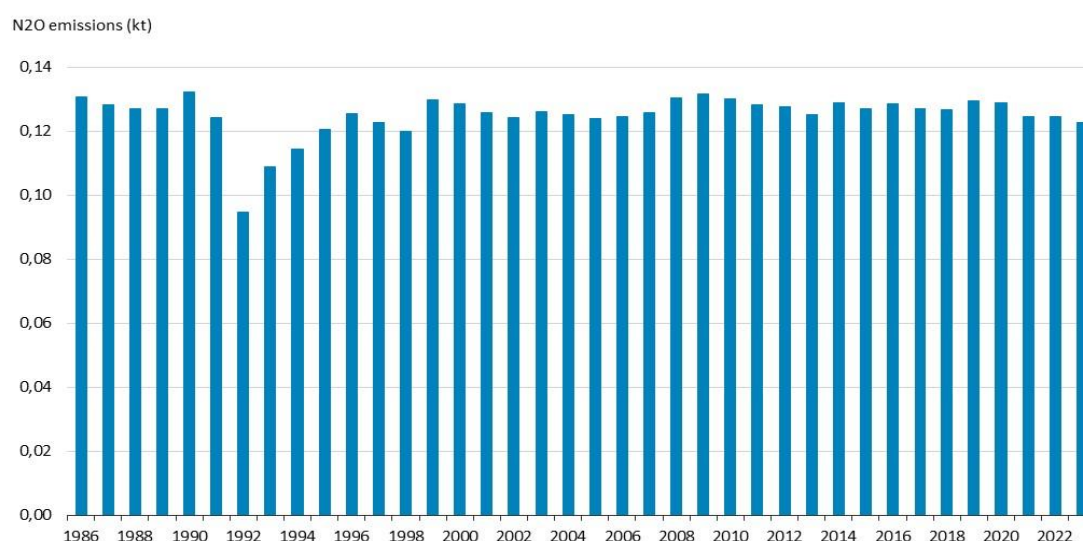


Figure 7.5.3: N<sub>2</sub>O emissions from wastewater effluent.

N<sub>2</sub>O emissions from wastewater effluent for the period 1986 - 2023 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<sub>2</sub>O, relatively low amounts of N<sub>2</sub>O formation can substantially contribute to GHGs emissions.

Emission factor for N<sub>2</sub>O emissions from discharged to wastewater (EF<sub>EFFLUENT</sub>)

The IPCC default value of 0.005 kg N<sub>2</sub>O-N/kg N was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, Table 6.11, pg. 6.27).

Human population (P)

The annual number of country population has been obtained from SORS.

Protein consumption (Protein)

The average consumption of protein per inhabitant in every individual year has been obtained from United Nations Food and Agriculture Organization (FAO). The publication of protein consumption data on the FAO's statistical database (FAOSTAT) has a time lag of four years. The last available consumption rate has been applied to the years with missing data as well. Since the consumption protein data has not been available for the years 2022 value for the year 2021 has been applied. We have also checked other potential sources of required data, but no other institution collects up-to-date data on protein consumption. Data on population and annual protein intake are presented in Table 7.5.4.

**Table 7.5.4: Population and protein consumption in the period 1986-2022.**

| Year | Population | Protein consumption (kg/person/year) | Year | Population | Protein consumption (kg/person/year) |
|------|------------|--------------------------------------|------|------------|--------------------------------------|
| 1986 | 1985486    | 38.0                                 | 2005 | 2003358    | 35.8                                 |
| 1987 | 1994066    | 37.2                                 | 2006 | 2010377    | 35.8                                 |
| 1988 | 1996325    | 36.8                                 | 2007 | 2025866    | 35.9                                 |
| 1989 | 1996377    | 36.8                                 | 2008 | 2032362    | 37.1                                 |
| 1990 | 1999945    | 38.2                                 | 2009 | 2046976    | 37.2                                 |
| 1991 | 1998912    | 35.9                                 | 2010 | 2050189    | 36.7                                 |
| 1992 | 1994084    | 27.4                                 | 2011 | 2055496    | 36.1                                 |
| 1993 | 1989408    | 31.6                                 | 2012 | 2058821    | 35.9                                 |
| 1994 | 1989477    | 33.2                                 | 2013 | 2061085    | 35.1                                 |
| 1995 | 1990266    | 35.0                                 | 2014 | 2062874    | 36.1                                 |
| 1996 | 1986989    | 36.5                                 | 2015 | 2064188    | 35.5                                 |
| 1997 | 1984923    | 35.8                                 | 2016 | 2065895    | 36.0                                 |
| 1998 | 1978334    | 35.0                                 | 2017 | 2066880    | 35.6                                 |
| 1999 | 1987755    | 37.8                                 | 2018 | 2080908    | 35.2                                 |
| 2000 | 1990094    | 37.4                                 | 2019 | 2095861    | 35.7                                 |
| 2001 | 1994026    | 36.5                                 | 2020 | 2108977    | 35.3                                 |
| 2002 | 1995033    | 36.0                                 | 2021 | 2107180    | 34.5                                 |
| 2003 | 1996433    | 36.5                                 | 2022 | 2108739    | 33.6                                 |
| 2004 | 1997590    | 36.2                                 | 2023 | 2120937    | 33.5                                 |

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).

Non-consumed protein added to the wastewater ( $F_{NON-CON}$ )

Additional 'non-consumed' protein discharged to wastewater pathways has to be taken into account for  $N_2O$  emission calculation. Food (waste) that is not consumed may be washed down the drain and also, bath and laundry water can be expected to contribute to nitrogen loadings. Since in Slovenia there is no garbage disposals the IPCC default factor of 1.1 was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, Table 6.11, pg. 6.27).

Industrial and commercial co-discharged protein into the sewer system ( $F_{IND-COM}$ )

Wastewater from industrial or commercial sources that is discharged into the sewer may contain protein. The IPCC default for this fraction is 1.25 and it was used for  $N_2O$  emission calculation (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

Nitrogen removed with sludge ( $N_{SLUDGE}$ )

For sludge removal default IPCC value of zero was used for emission calculations (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 6, pg. 6.25).

**Industrial Wastewater****CH<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.

$$EF_j = B_0 * MCF_j$$

$EF_j$  - emission factor (kg CH<sub>4</sub>/kg COD)  
 $j$  - each treatment and discharge pathway or system  
 $B_0$  - maximum CH<sub>4</sub> producing capacity (kg CH<sub>4</sub>/kg COD)  
 $MCF_j$  - methane correction factor (fraction)

In the end, the total emission of methane from industrial wastewater is estimated. The equation for the calculation of annual CH<sub>4</sub> emissions is as follows:

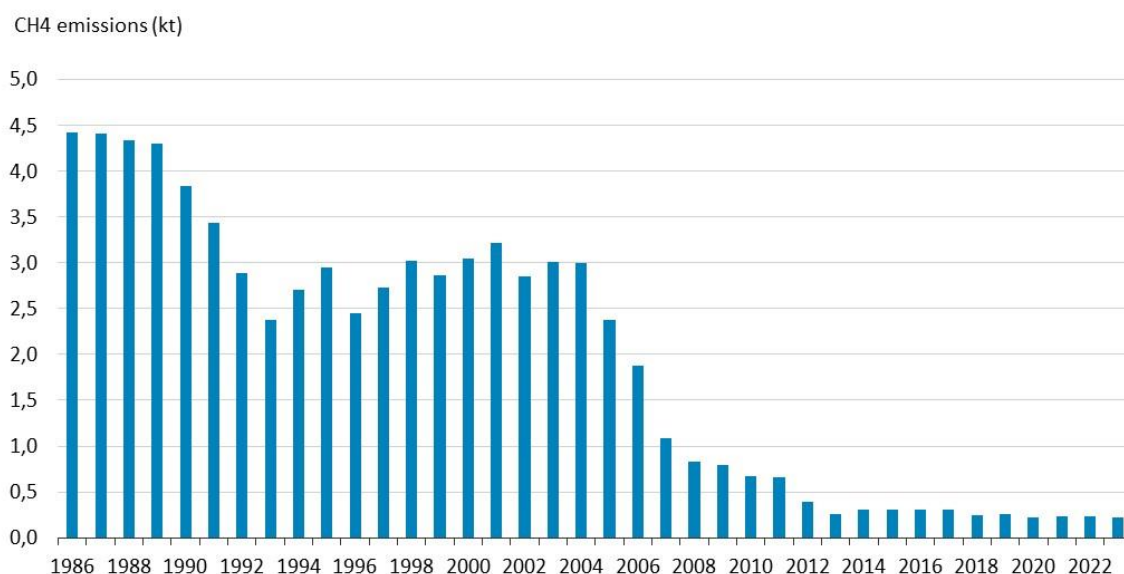
$$CH_4 \text{ emissions} = \sum ( (TOW_i - S_i) * EF_i ) - R_i$$

$CH_4$  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)  
 $S_i$  - organic component removed as sludge for industry i (kg COD/year)  
 $EF_i$  - emission factor for industry i  
 $R_i$  - 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 - 2022 are shown in Figure 7.5.4. The drop in emissions in 1992 could be observed due to the poor economic situation and weaker industrial production as a consequence of the Slovenian war for independence. The decrease in emissions from 2005 onwards has been mainly due to the pre-treatment of wastewater in some large industrial facilities before releasing it into the centralized treatment plant to avoid high discharge fees and to meet regulatory standards. In that period a share of wastewater from the production of beverages and pulp and paper industry have been treated in industrial wastewater treatment plants.

Emissions of methane from industrial wastewater are calculated for the chosen industrial sectors with a large output of wastewater and high content of degradable organic components. In Slovenia, these are:

- production of pulp and paper,
- production of soft drinks and alcohol beverage,
- production of leather,
- production of food,
- production of milk,
- production of meat,
- production of organic chemicals and
- production of the pharmaceutical industry.



**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 1986-2023 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 and 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             | 573968                                  | 850107                                |
| 1987 | 18560824                            | 948137                | 1993276  | 479440             | 1008278            | 908295             | 566773                                  | 860975                                |
| 1988 | 18199349                            | 935331                | 1993223  | 445821             | 1023777            | 962289             | 593392                                  | 925132                                |
| 1989 | 17992579                            | 922503                | 1993164  | 412196             | 1039279            | 1016283            | 655337                                  | 1049322                               |
| 1990 | 17785835                            | 909674                | 1993106  | 378570             | 1054778            | 1070278            | 471021                                  | 775146                                |
| 1991 | 15813639                            | 778661                | 1897174  | 369069             | 1034204            | 1059647            | 285682                                  | 483572                                |
| 1992 | 13167759                            | 736567                | 1773698  | 245566             | 921828             | 764296             | 431824                                  | 752443                                |
| 1993 | 12056736                            | 686178                | 1812219  | 272168             | 767155             | 650592             | 386055                                  | 693076                                |
| 1994 | 13879156                            | 678212                | 1906083  | 296905             | 835621             | 634050             | 483433                                  | 895019                                |
| 1995 | 15431625                            | 459865                | 1879191  | 304715             | 911369             | 574572             | 656937                                  | 1255475                               |
| 1996 | 14369458                            | 529332                | 1881993  | 300437             | 885387             | 662932             | 588977                                  | 1163117                               |
| 1997 | 16266638                            | 496348                | 1941510  | 282961             | 926754             | 663706             | 572488                                  | 1169539                               |
| 1998 | 18163843                            | 463364                | 2001042  | 265483             | 968119             | 664480             | 680999                                  | 1440901                               |
| 1999 | 20061023                            | 430379                | 2060559  | 248007             | 1009486            | 665255             | 714695                                  | 1568206                               |
| 2000 | 21397736                            | 397395                | 2120086  | 230529             | 1050850            | 666029             | 774051                                  | 1763770                               |
| 2001 | 22734450                            | 364411                | 2179603  | 213054             | 1092218            | 666803             | 641688                                  | 1520652                               |
| 2002 | 24071163                            | 331427                | 2239130  | 195578             | 1133582            | 667578             | 630656                                  | 1556779                               |
| 2003 | 25407851                            | 298442                | 2298652  | 178100             | 1174950            | 668352             | 683503                                  | 1760591                               |

| Year | Production of pulp and paper        | Production of leather | Production of soft drinks and alcohol and 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> ) |                       |  |                    |                    |                    |   |                                       |
| 2004 | 27675000                            | 274700                | 1970685  | 136140             | 1133980            | 662367             | 585981                                  | 1578000                               |
| 2005 | 26950000                            | 233185                | 1362038  | 178400             | 1230000            | 1420996            | 527540                                  | 1368600                               |
| 2006 | 21120000                            | 238400                | 2074000  | 164100             | 986700             | 1143262            | 553084                                  | 1545000                               |
| 2007 | 12233000                            | 281863                | 1771724  | 185000             | 985000             | 1393753            | 520545                                  | 1488000                               |
| 2008 | 16500000                            | 228651                | 1572889  | 191900             | 982000             | 1334951            | 540417                                  | 1523000                               |
| 2009 | 15881919                            | 11617                 | 1533764  | 223853             | 901292             | 1162973            | 540513                                  | 1765726                               |
| 2010 | 13596494                            | 9224                  | 1431036  | 167710             | 865144             | 1268351            | 557275                                  | 1633612                               |
| 2011 | 12514742                            | 22597                 | 1507163  | 213732             | 871805             | 1161579            | 643003                                  | 1560375                               |
| 2012 | 12773572                            | 39893                 | 1319973  | 297757             | 820968             | 1119638            | 653731                                  | 1465488                               |
| 2013 | 10408933                            | 44994                 | 1238251  | 343151             | 835151             | 1074228            | 564340                                  | 1528190                               |
| 2014 | 11206175                            | 47428                 | 1267076  | 320628             | 838646             | 1144594            | 605627                                  | 1578317                               |
| 2015 | 11456759                            | 40083                 | 1166442  | 301864             | 750391             | 1307631            | 622207                                  | 1684019                               |
| 2016 | 11491537                            | 35961                 | 1048714  | 232644             | 805551             | 1346137            | 526150                                  | 1747853                               |
| 2017 | 11387032                            | 45468                 | 1031081  | 246433             | 854688             | 1457879            | 761554                                  | 1783843                               |
| 2018 | 11464901                            | 49773                 | 1162256  | 235111             | 909694             | 1405198            | 662125                                  | 1793415                               |
| 2019 | 11675106                            | 46431                 | 1352696  | 201818             | 1008039            | 1359105            | 664053                                  | 1752544                               |
| 2020 | 10795758                            | 40085                 | 1146404  | 207140             | 1057467            | 1325690            | 644570                                  | 1580681                               |
| 2021 | 9382489                             | 56996                 | 1315717  | 223076             | 1077120            | 1347185            | 510377                                  | 1616169                               |
| 2022 | 10628879                            | 59083                 | 1354347  | 312730             | 1058711            | 1343597            | 577104                                  | 1592811                               |
| 2023 | 9132022                             | 44085                 | 1249457  | 246533             | 1039998            | 1327403            | 531836                                  | 1488612                               |

The annual amount of wastewater output for an individual industry for the period 2004-2022 were obtained from a database of annual reports on operational monitoring of industrial effluents collected by the SEA. Since actual monitored volumes of wastewater are not available before the year 2004, estimation of volumes of wastewater for the years 1986-2003 was performed. We estimated volumes of wastewater for the period 1986-2003 in such a way that we multiplied the ratio between data of actual volumes and data of production units for the individual industries for the year 2004 with data on annual production of the individual industry for the period 1986-2003. We decided to choose ratios for the year 2004 since this year most closely represents a situation in previous years.

#### Industrial degradable organic component indicator (COD<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 NID, Table 7.5.6.

**Table 7.5.6: Data on COD for the various type of industries.**

| Production of pulp and paper | Production of leather | Production of soft drinks and alcohol beverage | Production of food | Production of milk | Production of meat | Production of organic chemical | Production of pharmaceutical industry |
|------------------------------|-----------------------|--|--------------------|--------------------|--------------------|--------------------------------|---------------------------------------|
| COD (kg/m <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.

**Table 7.5.7: Total organically degradable material (TOW) in industrial wastewater treated on the centralized wastewater treatment plant.**

| Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) |
|------|--|------|--|------|--|------|--|
| 1986 | 191.3                                  | 1996 | 149.2                                  | 2006 | 192.8                                  | 2016 | 55.8                                   |
| 1987 | 190.9                                  | 1997 | 166.5                                  | 2007 | 111.7                                  | 2017 | 55.4                                   |
| 1988 | 187.8                                  | 1998 | 184.2                                  | 2008 | 107.3                                  | 2018 | 45.9                                   |
| 1989 | 186.2                                  | 1999 | 201.6                                  | 2009 | 102.1                                  | 2019 | 46.7                                   |
| 1990 | 183.7                                  | 2000 | 214.1                                  | 2010 | 86.7                                   | 2020 | 40.9                                   |
| 1991 | 164.2                                  | 2001 | 225.8                                  | 2011 | 83.9                                   | 2021 | 43.7                                   |
| 1992 | 138.1                                  | 2002 | 238.1                                  | 2012 | 72.6                                   | 2022 | 43.0                                   |
| 1993 | 127.2                                  | 2003 | 250.5                                  | 2013 | 46.5                                   | 2023 | 40.7                                   |
| 1994 | 144.7                                  | 2004 | 249.8                                  | 2014 | 56.3                                   |      |  |
| 1995 | 158.6                                  | 2005 | 244.1                                  | 2015 | 55.3                                   |      |  |

For the comparison Table 7.5.8. shows the entire amount of TOW considered to have been treated in centralized wastewater treatment plants.

Until 2003 all industrial wastewater was treated in the centralized wastewater treatment plants, therefore the TOW was the same as the total wastewater output. Since 2004 a share of wastewater from the production of beverages and paper industry have been treated in industrial wastewater treatment plants. Comparison of TOWs in Tables 7.5.7 and 7.5.8 shows a decrease in the TOW values. The TOW has been decreasing from 8% in 2004 to 64% in recent years. A share of industrial wastewater from the production of alcoholic beverage treated in industrial wastewater treatment plants was estimated to about 20% for the whole

2004-2023 period. A share of industrial wastewater from the production of pulp and paper treated in industrial wastewater treatment plant grown markedly, from 8% in 2004 to 78% in 2023.

**Table 7.5.8: Entire total organically degradable material (TOW) in industrial wastewater treated on the centralized and industrial wastewater treatment plants.**

| Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) | Year | Total organics in waste water (kt COD) |
|------|--|------|--|------|--|------|--|
| 1986 | 191.3                                  | 1996 | 149.2                                  | 2006 | 215.6                                  | 2016 | 124.5                                  |
| 1987 | 190.9                                  | 1997 | 166.5                                  | 2007 | 135.1                                  | 2017 | 124.9                                  |
| 1988 | 187.8                                  | 1998 | 184.2                                  | 2008 | 172.3                                  | 2018 | 125.9                                  |
| 1989 | 186.2                                  | 1999 | 201.6                                  | 2009 | 165.9                                  | 2019 | 128.5                                  |
| 1990 | 183.7                                  | 2000 | 214.1                                  | 2010 | 144.5                                  | 2020 | 119.0                                  |
| 1991 | 164.2                                  | 2001 | 225.8                                  | 2011 | 135.0                                  | 2021 | 107.1                                  |
| 1992 | 138.1                                  | 2002 | 238.1                                  | 2012 | 136.3                                  | 2022 | 119.0                                  |
| 1993 | 127.2                                  | 2003 | 250.5                                  | 2013 | 114.7                                  | 2023 | 104.1                                  |
| 1994 | 144.7                                  | 2004 | 272.7                                  | 2014 | 122.4                                  |      |  |
| 1995 | 158.6                                  | 2005 | 265.8                                  | 2015 | 124.9                                  |      |  |

#### Methane conversion factor (MCF):

Emissions of methane from industrial wastewater are calculated for the chosen industrial sectors with a large output of wastewater and high content of degradable organic components. In Slovenia, these are in particular production of alcohol beverage and pulp and paper industry. Industrial wastewater in these two productions is mainly treated in well managed aerobic industrial treatment plants with methane recovery. We have assumed that since 2004 around 20% of industrial wastewater from the production of soft drinks and alcohol beverages have been treated in the industrial wastewater treatment plant. In the pulp and paper industry, the first treatment plant with methane recovery started to work in 2004. In 2004 about 8% of industrial wastewater from this industry was treated in that industrial wastewater treatment plant. In 2023 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 2023 70% of industrial wastewater from the production of soft drinks and alcohol beverages and 25% from the pulp and paper industry have been treated in centralized aerobic treatment plants together with the domestic wastewater. For all other industrial wastewater, we have assumed that 100% of industrial wastewater is treated in centralized aerobic treatment plants.

For all these facilities the MCF value of 0.022 was used for emission calculation in 2022. MCF was estimated in the same way as for domestic wastewater treatment plant. In 2022 about 93% of wastewater treated in centralized aerobic treatment plants is treated at aerobic treatment plants that are well managed, the remaining 7% is treated at not well managed plants. The share of well managed aerobic treatment plants was estimated from information on the implementation of the Urban Waste Water Treatment Directive. The default MCF value



of 0 for well managed and 0.3 for not well managed aerobic treatment plant were used for emission calculation (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, pg. 6.13, Table 6.3).

MCF decreased from 0.048 in 1986 to 0.22 in 2012 and stay the same until present. A decrease is due to improvement in WW treatment.

#### Maximum methane producing capacity ( $B_0$ )

The default IPCC value of 0.25 kg CH<sub>4</sub>/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.

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 2022 is 70% and it is a coincidence that the same value is valid also for the 1986 base year. IPCC default emission factor for N<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%.

**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                        |                                 |                            |

### 7.5.5 Source-specific recalculations

#### 5.D.1 Domestic Wastewater, CH<sub>4</sub>, N<sub>2</sub>O

Emissions of N<sub>2</sub>O in 2022 were recalculated due to updated value on protein consumption in the FAO database.

### 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 the largest recalculations was in the LULUCF sector, while substantial changes was also in the Agriculture and Fuel combustion sectors. The impact of recalculations on the total GHG emissions relative to the 2024 UNFCCC submission 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 in respect to the December 2024 submission.**

|                        | 1986  | 1990  | 2000  | 2005  | 2010   | 2015   | 2020     | 2022     |
|------------------------|-------|-------|-------|-------|--------|--------|----------|----------|
| 1. Energy              | 3.93  | 2.78  | 5.91  | 6.52  | 6.10   | 12.42  | 19.85    | 32.82    |
| 2. IPPU                |       |       | -0.02 | -0.02 | -0.02  | -0.49  | 0.07     | -43.64   |
| 3. Agriculture         | 15.02 | 23.24 | 1.71  | -6.18 | -21.34 | -28.10 | -46.19   | -46.03   |
| 4. LULUCF              | 24.16 | 24.16 | 24.16 | 19.06 | 15.69  | 20.52  | -3,936.6 | -4,045.9 |
| 6. Waste               |       |       |       |       |        |        |          | -0.59    |
| Total w/o LULUCF       | 18.95 | 26.02 | 7.60  | 0.31  | -15.26 | -16.18 | -26.28   | -57.41   |
| Total with LULUCF      | 43.11 | 50.17 | 31.76 | 19.37 | 0.42   | 4.35   | -3,962.8 | -4,103.3 |
| Total in % w/o LULUCF  | 0.09  | 0.14  | 0.04  | 0.00  | -0.08  | -0.10  | -0.17    | -0.37    |
| Total in % with LULUCF | 0.27  | 0.35  | 0.25  | 0.14  | 0.00   | 0.02   | -34.26   | -36.19   |

#### 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 December 2024 submission in Energy sector in kt CO<sub>2</sub> eq.**

| Energy                                   | 1986 | 1990 | 2000 | 2005 | 2010 | 2015  | 2020  | 2022  |
|--|------|------|------|------|------|-------|-------|-------|
| A. Fuel Combustion                       | 3.93 | 2.78 | 5.91 | 6.52 | 6.10 | 12.42 | 19.85 | 32.82 |
| 1. Energy Industries                     | 0.09 | 0.05 | 0.01 | 0.02 | 0.01 | 1.09  | 2.45  | 3.93  |
| 2. Manufacturing Ind.                    | 2.02 | 1.18 | 0.95 | 1.71 | 1.48 | 6.68  | 9.88  | 15.02 |
| 3. Transport                             | 0.00 | 0.00 | 0.00 | 0.18 | 0.30 | 0.18  | -0.60 | -1.03 |
| 4. Other Sectors                         | 1.81 | 1.55 | 4.94 | 4.62 | 4.32 | 4.46  | 8.12  | 14.90 |
| 5. Other                                 |      |      |      |      |      |       |       |       |
| B. Fugitive Emissions                    |      |      |      |      |      |       |       |       |
| 1. Solid Fuels                           |      |      |      |      |      |       |       |       |
| 2. Oil and Natural Gas                   |      |      |      |      |      |       |       |       |
| Total of Energy in kt CO <sub>2</sub> eq | 3.93 | 2.78 | 5.91 | 6.52 | 6.10 | 12.42 | 19.85 | 32.82 |
| Total of Energy in %                     | 0.02 | 0.02 | 0.04 | 0.04 | 0.04 | 0.09  | 0.16  | 0.26  |

1.A. Fuel combustion, all sectors, Gaseous fuels, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O have been recalculated for the period 2005-2022 due to the use of NCV values for natural gas from natural gas provider instead of SORS data. In addition CO<sub>2</sub> EF have been also slightly improved. Until 2021 recalculations was very minor.

1.A. Fuel combustion, all sectors, Liquid fuels, CO<sub>2</sub>

In present submission we have started to use country specific CO<sub>2</sub> EF for LPG instead of default value. Recalculation of emissions affected all years in the period 1986-2022 and all sectors, if the LPG has been used.

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> and N<sub>2</sub>O emissions for the period 2000-2022 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.8.1) was used for emissions calculation.

1.A.4.b Residential, Biomass, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O

GHG emissions from wood biomass combustion in residential sector for the period 2016-2022 were recalculated due to the improved data on wood (TJ) used in this sector obtained from SORS. The improvement of SORS data was taking into account estimates from the model for determining the heating demand.

## 10.1.2 Industrial processes and product use

The impact of recalculations on emissions in this sector is presented in the Table 10.1.3 below.

**Table 10.1.3: Changes due to recalculation in relation to the December 2024 submission in the sector Industrial processes and product use, in kt CO<sub>2</sub> eq.**

| IPPU                                 | 1986 | 1990 | 2000  | 2005  | 2010  | 2015  | 2020  | 2022   |
|--------------------------------------|------|------|-------|-------|-------|-------|-------|--------|
| A. Mineral Products                  |      |      |       |       |       |       |       |        |
| B. Chemical Industry                 |      |      |       |       |       |       |       |        |
| C. Metal Production                  |      |      |       |       |       |       |       |        |
| D. Non-energy Prod.                  |      |      |       |       |       |       |       | -0.42  |
| F. ODS Substitutes                   |      |      |       |       |       |       | 0.56  | 4.29   |
| G. Other Products                    |      |      | -0.02 | -0.02 | -0.02 | -0.49 | -0.49 | -47.51 |
| Total IPPU in kt CO <sub>2</sub> eq. |      |      | -0.02 | -0.02 | -0.02 | -0.49 | 0.07  | -43.64 |
| Total of IPPU in %                   |      |      | -0.00 | -0.00 | -0.00 | -0.04 | 0.01  | -3.98  |

2.D.1 Lubricant Use

Recalculation of CO<sub>2</sub> emissions for the period 2012-2022 was performed due to the application of a new version of the COPERT 5 model. The newest version of COPERT 5 (version 5.8.1) 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.2. Paraffin wax use

The CO<sub>2</sub> emissions for the year 2022 were recalculated due to new activity data applied. The Statistical Office of the Republic of Slovenia provided updated data on the use of paraffin wax.

2.D.3 Other

Recalculation of CO<sub>2</sub> emissions for 2022 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 5.8.1) 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.2. ODS Substitutes

Emissions of HFC from Refrigeration and AC were recalculated for the period 2019-2022 due to the improved data from service companies.

2.G.2. Other Product use, SF<sub>6</sub>

In the present submissions the errors in CRT tables generated with the new ETF tools were corrected.

2.G.3. N<sub>2</sub>O from product uses

The N<sub>2</sub>O emissions for the year 2022 were recalculated due to new activity data applied. The Statistical Office of the Republic of Slovenia provided updated data on the N<sub>2</sub>O use in medical applications.

## 10.1.1 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  | 2000   | 2005   | 2010   | 2015   | 2020   | 2022   |
|--|-------|-------|--------|--------|--------|--------|--------|--------|
| A. Enteric Fermentation                        | 3.79  | 3.31  | 11.16  | 14.86  | 14.47  | 13.37  | 13.90  | 13.28  |
| B. Manure Management                           | 1.28  | 9.82  | -21.19 | -31.75 | -46.33 | -52.57 | -71.24 | -68.61 |
| D. Agricultural Soils                          | 9.96  | 10.11 | 11.74  | 10.70  | 10.52  | 11.10  | 11.15  | 9.29   |
| G. Liming                                      |       |       |        |        |        |        |        |        |
| H. Urea application                            |       |       |        |        |        |        |        |        |
| I. Other C-containing fertilizers              |       |       |        |        |        |        |        |        |
| Total in Agriculture in kt CO <sub>2</sub> eq. | 15.02 | 23.24 | 1.71   | -6.18  | -21.34 | -28.10 | -46.19 | -46.03 |
| Total of Agriculture in %                      | 0.73  | 1.17  | 0.09   | -0.35  | -1.25  | -1.62  | -2.67  | -2.77  |

3.A.1 Enteric fermentation, CH<sub>4</sub>

The default factors for methane emissions from enteric fermentation in sheep and goats have been updated. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines.

3.B.1 Manure management, CH<sub>4</sub>

The estimates of VS excretion in pigs were updated for the entire reporting period. The default values have been replaced by values based on average body weight taking into account the 2019 Refinement to the 2006 IPCC Guidelines

Based on the results of the farm census, it was found that the share of cattle slurry systems was overestimated in the past. We have created new estimates for the entire time series.

New estimates were made for manure management for laying hens. The gradual abandonment of cage system after 2016 was taken into account.

The number of broilers and geese for 2022 has been corrected. The statistical office has corrected the values following the submission of the previous report.

3.B.1 Manure management, N<sub>2</sub>O

Based on the results of the farm census, it was found that the share of cattle slurry systems was overestimated in the past. We have created new estimates for the entire time series.

New estimates were made for manure management for laying hens. The gradual abandonment of cage system after 2016 was taken into account.

The number of broilers and geese for 2022 has been corrected. The statistical office has corrected the values following the submission of the previous report.

The nitrogen excretion rate for rabbits was set for the period after 2017. The factor for does was incorrectly applied to all breeding rabbits in previous reports.

3.D. Agricultural soils, N<sub>2</sub>O

The consumption of urea in 2022 has been corrected. Previously, the consumption of urea was slightly overestimated, while the consumption of nitrogen from other mineral fertilisers was underestimated by the same amount.

The area of managed organic soils was reassessed using a vector approach. The entire time series was corrected.

The emission factors used for the estimation of indirect nitrous oxide emissions due to nitrogen leaching (EF<sub>5</sub> and FracLEACH-(H)) were updated for all nitrogen sources. The values from the 2006 IPCC Guidelines have been replaced by values from the 2019 Refinement to the 2006 IPCC Guidelines.

In addition, the assessment of direct and indirect nitrous oxide emissions from agricultural soils was influenced by some corrections described under Manure management - nitrous oxide.

## 10.1.2 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   | 2000   | 2005   | 2010   | 2015   | 2020      | 2022      |
|----------------------|--------|--------|--------|--------|--------|--------|-----------|-----------|
| A. Forest Land       |        |        |        |        |        |        | -3,963.33 | -4,069.99 |
| B. Cropland          | -15.98 | -15.98 | -15.98 | -21.08 | -23.79 | -18.28 | -16.47    | -22.83    |
| C. Grassland         | 40.13  | 40.13  | 40.13  | 40.13  | 39.47  | 38.80  | 42.54     | 45.54     |
| D. Wetlands          |        |        |        |        |        |        | 0.35      | 0.71      |
| E. Settlements       |        |        |        |        |        |        | 0.35      | 0.71      |
| F. Other Land        |        |        |        |        |        |        |           |           |
| G. HWP               |        |        |        |        |        |        |           |           |
| Total in LULUCF      | 24.16  | 24.16  | 24.16  | 19.06  | 15.69  | 20.52  | -3,936.55 | -4,045.87 |
| Total of LULUCF in % | -0.51  | -0.55  | -0.39  | -0.26  | -0.22  | 3.54   | 90.77     | 95.91     |

### 4. A Forest land

Recalculations were conducted for the period 2018-2022 for the forest land remaining forest due to updated emission factors for living biomass and dead wood, derived from recent estimates from the NFI 2020-2023. Minor adjustment have been applied to other years as well owing to refinements in the method used for calculating the merchantable volume. Additionally, recalculations were made for land converted to forest land, incorporating updated emission factors specifically for dead wood.

### 4. B Cropland

Recalculations have been undertaken for the period 1986-2022 concerning land converted to cropland, incorporating updated emission factors for living biomass and dead organic matter (conversions from forest land to cropland) and updated emission factors for mineral soil (conversions from settlements to cropland).

### 4. C Grassland

Recalculations for the period 1986-2022 for land converted to grassland were made based on updated emission factors for living biomass and dead organic matter (conversions from forest land to grassland) and updated emission factors for mineral soil (conversions from settlements to grassland and from wetlands to grassland).

### 4. D Wetlands

Recalculations have been made concerning land converted to wetlands based on updated emission factors for living biomass and dead organic matter (conversions from forest land to wetlands) and updated emission factors for mineral soil (conversions from forest land to wetlands and from grassland to wetlands).

### 4. E Settlements

Recalculations have been made for land converted to settlements based on updated emission factors for living biomass, dead organic matter and mineral soil.



#### 4. F Other land

Recalculations have been made for the period 1986-2022 for land converted to other land based on updated emission factors for living biomass and dead organic matter (conversions from forest land to other land) and updated emission factors for mineral soil (conversions from settlements to other land).

#### Direct N<sub>2</sub>O emissions from N mineralization/immobilization and indirect N<sub>2</sub>O emissions from managed soils (nitrogen leaching and run-off)

Recalculations were made on the basis of updated emission factors for all land use changes where the change in soil organic carbon stocks is negative.

### 10.1.1 Waste

The impact of the recalculations on emissions in the Waste sector is presented in the Table 10.1.6.

**Table 10.1.6: Changes due to the recalculation with a respect to the previous submission in Waste sector in kt CO<sub>2</sub> eq.**

| 6. Waste                                | 1986 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2022  |
|---|------|------|------|------|------|------|------|-------|
| A. Solid waste disposal                 |      |      |      |      |      |      |      |       |
| B. Biological treatment                 |      |      |      |      |      |      |      |       |
| C. Incineration                         |      |      |      |      |      |      |      |       |
| D. Waste water treatment                |      |      |      |      |      |      |      | -0.59 |
| Total in Waste in kt CO <sub>2</sub> eq |      |      |      |      |      |      |      | -0.59 |
| Total of Waste in %                     |      |      |      |      |      |      |      | -0.16 |

#### 5.D.2 Domestic Wastewater, N<sub>2</sub>O

Emissions of N<sub>2</sub>O in 2022 were recalculated due to updated value on protein consumption in the FAO database.

## **10.2 Response to the Review Process**

In 2022 Slovenian GHG inventory was included in the ESD review and UNFCCC centralised review. The details of Slovenian response to the recommendations UNFCCC review processes are in the excel file SVN\_2023\_Art10\_AnnexVIII\_Recommendations v2.

There were no recommendations from the ESD review. A majority recommendations from UNFCCC review were implemented in this submission. The number of paragraph from the implemented review recommendation is included in the description of recalculations, if relevant.

Table 10.2.1: A response to the recommendations from the UNFCCC review process.

| CRT category / issue  | Review recommendation   | Review report, paragraph | Status of the implementation | Comment             |
|---|---|--------------------------|------------------------------|---------------------|
| <b>ENERGY</b>   |   |                          |                              |                     |
| Fuel combustion - RA, 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.   | E1                       | implemented                  | NID 2023, Ch. 3.2.1 |
| 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  | E3                       | Not implemented              | No data available   |
| 1A.2.d Pulp, paper and print - biomass, CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O      | Include in the NID for this category the NCVs and EFs applied for all biomass types (black liquor, wood, fibrous sludge and biogas) and a description of the data sources used for the AD, NCVs and EFs.  | E8                       | Implemented                  | NID 2023, Ch. 3.2.5 |
| 1A.3.b Road transportation - liquid fuels, CO <sub>2</sub>  | Include in the NID the verification information provided during the review of the 2020 submission demonstrating the correlation between the CO <sub>2</sub> EFs used by the Party (sourced from the COPERT 5 default values) and the country-specific EFs of Italy and Austria.   | E10                      | Implemented                  | NID 2023, Ch. 3.2.6 |
| 1. General (energy sector) – solid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O | The ERT recommends that the Party correct the NCV used for other bituminous coal for all years of the time series in which the plant for which the incorrect NCV was reported was in operation. The ERT also recommends that the Party recalculate the emission estimates for subcategory 1.A.2.b under the sectoral approach and implement relevant changes to the information reported on | E16                      | Implemented                  | CRT table 1.A(b)    |

SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue  | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                            |
|---|--|--------------------------|------------------------------|------------------------------------|
|   | other bituminous coal in CRT table 1.A(b) under the reference approach.  |                          |                              |                                    |
| 1. General (energy sector) – solid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O | The ERT recommends that the Party correct the double counting of fuel consumption and the emission estimates for the pharmaceutical industry and clearly explain in the NID where the AD and emissions for consumption of other fossil fuels are allocated. The ERT also recommends that the Party correct the identified error in the consumption data for other fossil fuels for 2019 under the reference approach.                                      | E17                      | Implemented                  | NID 2023, Ch. 3.2.5 CRT Tables     |
| 1A.3.b Road transportation - liquid fuels, CO <sub>2</sub>  | The ERT recommends that the Party review the information on NCVs for gasoline used in road transportation reported in the most recent annual submissions of Austria and Italy to determine whether NCVs that are appropriate for use by Slovenia can be derived on the basis of the shares of gasoline imported into Slovenia and recalculate the time series using the updated NCVs, if it is determined that they better reflect national circumstances. | E18                      | Implemented                  | NID 2023, Ch. 3.2.6.1.4 CRT Tables |
| 1.A.3.b.iii Heavy-duty trucks and buses – liquid fuels – CO <sub>2</sub>                          | The ERT recommends that the Party report in CRT table 1.A(a)s3 the quantity of gasoline consumed and associated emissions for heavy-duty trucks and buses for 1986–1991 in its next annual submission.   | E19                      | Implemented                  | CRT table 1.A(a)s3                 |

| CRT category / issue  | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                 |
|---|--|--------------------------|------------------------------|-------------------------|
| 1.A.3.b.iii Heavy-duty trucks and buses – liquid fuels – CO <sub>2</sub>                            | The ERT recommends that the Party review the AD, EFs and NCVs for gasoline use for subcategory 1.A.3.b.iii (heavy-duty trucks and buses) and confirm in the NID whether accurate and time-series consistent data for fossil gasoline are reported. The ERT also recommends that the Party explain in the NID any anomalous trends and variations in the CO <sub>2</sub> IEF for gasoline use in heavy-duty trucks and buses, including any significant differences compared with the trend and values observed for the CO <sub>2</sub> IEF for gasoline use for subcategories 1.A.3.b.i (cars) and 1.A.3.b.ii (light-duty trucks). | E20                      | Implemented                  | NID 2023, Ch. 3.2.6     |
| 1.A.3.d Domestic navigation – liquid fuels – N <sub>2</sub> O                                       | The ERT recommends that the Party describe in its NID the national circumstances for domestic navigation relating to vehicle classes and the extent to which they operate along the national coastline, and provide justification for choosing the default N <sub>2</sub> O EF for gas/diesel oil in table 3.3.1 of the 2006 IPCC Guidelines (vol. 2, chap. 3) instead of the default EF in table 3.5.3.   | E21                      | Implemented                  | NID 2023, Ch. 3.2.6.2.2 |
| 1.A.4.a Commercial/institutional – biomass – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O | The ERT recommends that the Party clearly document the allocation of the emissions from combustion of landfill gas in the chapter of the NID on the energy sector, including justification for the assumptions used for classifying SWDS as autoproducers and ensure that the allocation of emissions from CH <sub>4</sub> recovery for energy use for the entire time series in line with the allocation of   | E22                      | Implemented                  | NID 2023, Ch. 3.2.7.1.2 |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue  | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                        |
|---|--|--------------------------|------------------------------|--------------------------------|
|   | emissions in the 2006 IPCC Guidelines (vol. 2, Chap. 2, table 2.1, p.2.7).   |                          |                              |                                |
| International bunkers and multilateral operations – liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O | The ERT recommends that the Party report the missing quantity of gas/diesel oil consumption in CRT table 1.D for international marine bunkers (corresponding to approximately 28 kt CO <sub>2</sub> eq) in its next annual submission.   | E23                      | Implemented                  | CRT Table 1.D                  |
| Fuel combustion – reference approach – solid fuels – CO <sub>2</sub>  | The ERT recommends that the Party correct the NCV for coke oven/gas coke for 2020 in CRT table 1.A(b) using the revised data from SORS (29.906 TJ/kt).   | E24                      | Implemented                  | CRT Table 1.A(b)               |
| <b>INDUSTRIAL PROCESSES AND PRODUCT USE</b>   |  |                          |                              |                                |
| 2.A.4. Other processes use of carbonates, CO <sub>2</sub>   | Estimate the emission levels for bricks and ceramics production for 1990–1994 using a robust extrapolation method relevant to the country's circumstances, taking into account factors such as the peaking of the country's construction industry in 2006 and the 2008 economic crisis | I1                       | Implemented                  | NID 2023, Ch. 4.2.4 CRT Tables |
| 2.C.1. Iron and steel, CO <sub>2</sub>  | Estimate CO <sub>2</sub> emissions from pig iron production on the basis of a basic carbon balance method considering the inputs (e.g. iron ore, coke) and outputs (e.g. pig iron) in the process and update the methodological description in the NID.                                | I4                       | Implemented                  | NID 2023, Ch. 4.4.1 CRT Tables |
| 2.F.1 Refrigeration and air conditioning – HFCs   | Provide in the NID evidence that all transport equipment is exported before decommissioning.   | I5                       | Implemented                  | NID 2023, Ch. 4.6.2            |

SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue   | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                           |
|--|--|--------------------------|------------------------------|-----------------------------------|
| 2.F.1 Refrigeration and air conditioning – HFCs              | Investigate whether part of the transport refrigeration equipment is disposed of on the national market without recovery (e.g. broken equipment but with a working refrigeration system, equipment containing less than 50 per cent fill-in and not efficiently cooling, leakage during accidents) | 16                       | Implemented                  | NID 2023, Ch. 4.6.2               |
| 2.G.1 Electrical equipment – SF6                             | Reassess the value of the disposal loss factor applied to estimate SF6 emissions from the disposal of electrical equipment and, on the basis of that analysis, provide documentation and references that justify the value of 0.10 per cent, or revise it accordingly.                             | 18                       | Implemented                  | NID 2023, Ch. 4.7.1               |
| 2.A.1 – Cement production – CO <sub>2</sub>                  | The ERT recommends that Slovenia improve the explanation in the NID of the methodological change in the estimation of emissions from CKD, including the changes in the cement production process since 2019.   | 19                       | Implemented                  | NID 2023, Ch. 4.2.1               |
| 2.A.4 – Other processes uses of carbonates – CO <sub>2</sub> | The ERT recommends that Slovenia include in the NID details regarding the timing and frequency of the surveys conducted to determine that all carbonate use in the country is accounted for under category 2.A.4 (other process uses of carbonates).   | 110                      | Implemented                  | NID 2023, Ch. 4.2.4               |
| 2.F.1 Refrigeration and air conditioning – HFCs              | The ERT recommends that the Party check the time-series consistency of the values used for the product life factors and include in the NID an explanation for the inter-annual fluctuations in the product life factors for F-gases (HFC-134a, HFC-125, HFC-143a and HFC-32) for subcategory       | 111                      | Implemented                  | NID 2023, Ch. 4.6.2<br>CRT Tables |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue  | Review recommendation   | Review report, paragraph | Status of the implementation | Comment                           |
|---|---|--------------------------|------------------------------|-----------------------------------|
|   | 2.F.1.c (industrial refrigeration). The ERT encourages the Party to continue improving the accuracy of the product life factors to ensure that they reflect the actual situation in the country as further data become available.   |                          |                              |                                   |
| 2.F.1 Refrigeration and air conditioning –HFC-134a            | The ERT recommends that the Party correct the amount of HFC-134a remaining in products at decommissioning for subcategory 2.F.1.e (mobile air-conditioning) for 2019 in CRT table 2(II).B-Hs2.  | I12                      | Implemented                  | CRT tables                        |
| 2.F.1 Refrigeration and air conditioning –HFC-134a            | The ERT recommends that the Party include in the NID an explanation of the trend in the disposal factors for HFC-134a for subcategory 2.F.1.e (mobile air-conditioning). The ERT also recommends that the Party correct the estimates of disposal emissions for HFC-134a for 2009–2020 in order to take into account the proportion of air-conditioning equipment in disposed vehicles when reporting emissions in CRT table 2(II).B-Hs2. | I13                      | Implemented                  | NID 2023, Ch. 4.6.2<br>CRT Tables |
| 2.F.1 Refrigeration and air conditioning – HFC-32 and HFC-125 | The ERT recommends that the Party correct the disposal loss factors for HFC-32 and HFC-125 reported in CRT table 2(II),B-Hs2 for 2016–2020 for subcategory 2.F.1.f (stationary air-conditioning) and improve the QA/QC checks to avoid similar errors.  | I14                      | Implemented                  | CRT tables                        |
| 2.F.3 Fire protection – HFC-227ea                             | The ERT recommends that the Party improve the information in the NID on the methodology applied for the category, including details of the sources of data used to calculate HFCs in fire extinguishers and the sources of data for the   | I15                      | Implemented                  | NID 2023, Ch. 4.6.2<br>CRT Tables |



## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue          | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                 |
|-------------------------------|--|--------------------------|------------------------------|-------------------------|
|                               | product manufacturing factor for HFC-227ea across the time series, together with justification for the reduction in the value of the EF for first filling across the time series. The ERT further recommends that the correct values of the percentage of the EF are entered in CRT 2(II).B-Hs2 (as a per cent and not as a fraction). |                          |                              |                         |
| <b>AGRICULTURE</b>            |  |                          |                              |                         |
| 3.B - Manure management - N2O | Provide additional information on nitrogen excretion rate and demonstrate that those parameters are appropriate in the specific national circumstances and more accurate than the default data provided in the 2006 IPCC Guidelines.   | A2                       | Implemented                  | NID 2023, Ch. 5.4.2     |
| 3.B Manure management – CH4   | The ERT recommends that Slovenia reassess the MCF value applied (which is currently zero) for anaerobic digestion of cattle and swine manure to ensure that CH4 emissions are not underestimated for this MMS.   | A4                       | Implemented                  | CRT tables              |
| 3.B Manure management, N2O    | Specify the source for each parameter used in estimating N2O emissions from manure management of cattle (in NID table 5.4.4) and swine (in NID table 5.4.5)  | A5                       | Implemented                  | NID 2023, Ch. 5.4.2     |
| 3. General (agriculture)      | The ERT recommends that the Party follow the protocol for expert elicitation when conducting the uncertainty analysis for the agriculture sector, in line with the 2006 IPCC Guidelines (vol. 1, chap. 2, annex 2A.1) and include references to the key  | A7                       | Not implemented              | In the improvement plan |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue                          | Review recommendation  | Review report, paragraph | Status of the implementation | Comment  |
|---|--|--------------------------|------------------------------|--|
|   | assumptions based on expert judgment in the next annual submission.  |                          |                              |  |
| 3.B Manure management, N2O                    | The ERT recommends that the Party correct the EF for manure stores for rabbits in NID table 5.4.7 and provide sufficient justification for the selection of EF values where there is no IPCC default value for a specific animal type.   | A9                       | Implemented                  | NID 2023, Ch. 5.4.2  |
| <b>LULUCF</b>                                 |  |                          |                              |  |
| 4. General (LULUCF) – CO2                     | Improve the transparency of the reporting on the LULUCF sector by completing the table provided during the review (which shows carbon stocks for each carbon pool by land use type, further separated by subcategory) with values for gains and losses for living biomass and including the table in the next NID. | L2                       | Partly implemented           | Average carbon stocks for each carbon pool by land use type are presented in Tables 6.3.10, 6.3.11 and 6.3.12. Values for gains and losses are included in subcategories under subchapters |
| 4.A.1 Forest land remaining forest land – CO2 | Includes in its next NID the information provided during the review concerning prohibition of fertilization of forest land and also a documentation (if possible a reference to a legal document) on the non-occurrence of drainage and rewetting of forests in Slovenia to justify the assumptions made.          | L5                       | Implemented                  | NID 2023, Ch. 6.4.4.2  |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue   | Review recommendation   | Review report, paragraph | Status of the implementation | Comment                           |
|--|---|--------------------------|------------------------------|-----------------------------------|
| 4.B.1 Cropland remaining cropland – CO2<br>4.C.2 Grassland remaining grassland – CO2 | Develop a higher-tier method for estimating emissions/removals from the SOC pool in mineral soils for the subcategories annual grassland remaining annual grassland and annual cropland remaining annual cropland, or include in the NID the reason that national circumstances do not allow a higher-tier method to be applied.  | L8                       | Implemented                  | NID 2023,<br>Ch. 6.5.4.1, 6.6.4.1 |
| 4.B.1 Cropland remaining cropland – CO2<br>4.C.2 Grassland remaining grassland – CO2 | Improve the transparency in the NID by including clarification on (1) how carbon stock change for mineral soil is calculated between annual and perennial grassland; (2) the SOC values applied for annual grassland remaining annual grassland; (3) the rationale justifying why carbon stock change for perennial grassland remaining perennial grassland is considered in equilibrium; (4) how carbon stock change for mineral soil is calculated between annual and perennial cropland (i.e. that there is no differentiation in the method for calculating carbon stock change in mineral soils between annual cropland remaining annual cropland and perennial cropland remaining perennial croplands). | L9                       | Implemented                  | NID 2023,<br>Ch. 6.5.4.1, 6.6.4.1 |
| 4.B.2 Land converted to cropland – CO2<br>4.C.2 Land converted to grassland –CO2     | Include the justification provided during the review concerning using zero as the value of carbon stocks in living biomass after land conversion (“Cafter”).  | L12                      | Implemented                  | NID 2023,<br>Ch. 6.5.4.2, 6.6.4.2 |

| CRT category / issue   | Review recommendation  | Review report, paragraph | Status of the implementation | Comment                           |
|--|--|--------------------------|------------------------------|-----------------------------------|
| 4.B.2 Land converted to cropland – CO <sub>2</sub><br>4.C.2 Land converted to grassland –CO <sub>2</sub> | Apply equations 2.15 and 2.16 from the 2006 IPCC Guidelines (vol. 4) correctly by taking into account losses in biomass carbon stocks to avoid any possible overestimation of removals or an underestimation of emissions from the land-use category land converted to cropland and land converted to grassland. In case it is not possible to estimate losses in living biomass, apply a simple stock change approach (equations 2.4 and 2.5 from the 2006 IPCC Guidelines), thereby taking into account the mean values of the land use types (and not the values immediately after the conversion). | L13                      | Implemented                  | NID 2023,<br>Ch. 6.5.4.2, 6.6.4.2 |
| 4.C.1 Grassland remaining grassland – CO <sub>2</sub>  | Include in the NID explanation concerning the reasons that caused the drop in the values of net carbon stock change in mineral soils between 2006 and 2007 and for the continuing decreasing after 2007.   | L14                      | Implemented                  | NID 2023,<br>Ch. 6.6.4.1          |
| 4.E Settlements – CO <sub>2</sub>  | Provide information on methodology used in living biomass in settlements remaining settlements in the NID, take further consideration whether carbon stock in settlements area is increasing or expected to be maturing in the future and examine application of actual growing period (AGP) if considered necessary.  | L15                      | Implemented                  | NID 2023,<br>Ch. 6.8.4.1          |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue                                      | Review recommendation   | Review report, paragraph | Status of the implementation | Comment                                  |
|---|---|--------------------------|------------------------------|--|
| 4.E.2 Land converted to settlements – CO <sub>2</sub>     | Include in the NID the information underpinning the assumption that the carbon stock of soils for settlements is half of the carbon stock value for annual grassland (e.g references to scientific literature and to the study on visual interpretation of digital orthophotos, as well as to the expert judgement as described above). | L16                      | Implemented                  | NID 2023, Ch. 6.8.4.2                    |
| Land representation – CO <sub>2</sub>                     | The ERT recommends that the Party correct the information reported in the CRT tables on the area of forest land for 2020 and the area of settlements for 2015 and related CO <sub>2</sub> estimates   | L20                      | Implemented                  | CRT 2022 and 2023                        |
| 4.A Forest land – CO <sub>2</sub>                         | The ERT recommends that the Party include in its NID comprehensive information on the methodology for estimating the country-specific BEF, including the parameters used, the results by species and an evaluation of the consistency of the country-specific BEFs with the values in the 2006 IPCC Guidelines (vol. 4, chap. 4).       | L21                      | Implemented                  | NID 2023, Ch. 6.4.4.1                    |
| 4.A.1 Forest land remaining forest land – CO <sub>2</sub> | The ERT recommends that the Party update the information in the NID on the growing stock volume in line with Global Forest Resources Assessment 2020 for Slovenia (section 2a, p.22) to reflect the recalculated estimates of CSC in living biomass for 2019 and 2020 provided in the revised CRT tables 4.A.                           | L22                      | Implemented                  | CRT 2023, table 4.A, NID 2023, Ch. 6.4.7 |
| 4.B Cropland – CO <sub>2</sub>                            | The ERT recommends that the Party include additional information in the NID on the method applied for estimating the country-specific value for carbon stock changes for living biomass in  | L23                      | Not implemented              | In the improvement plan                  |

## SLOVENIA'S NATIONAL INVENTORY DOCUMENT 2025

| CRT category / issue  | Review recommendation   | Review report, paragraph | Status of the implementation | Comment               |
|---|---|--------------------------|------------------------------|-----------------------|
|   | annual cropland, including crop types, and the size and representativeness of the sample  |                          |                              |                       |
| 4.C.1 Grassland remaining grassland – CO <sub>2</sub>                       | The ERT recommends that the Party estimate and report the losses in living biomass for perennial grassland remaining perennial grassland or include better justification in the NID why such estimates are not included in the inventory  | L24                      | Implemented                  | NID 2023, Ch. 6.6.4.1 |
| <b>WASTE</b>  |   |                          |                              |                       |
| 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 NID information of the annual reports prepared by installations operating under the EU directive on integrated pollution prevention and control on monitoring of gas recovery both for flaring and for energy.   | W3                       | Implemented                  | NID 2023, Ch. 7.2.2   |
| 5.D Wastewater treatment and discharge – CH <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 NID the methods and data used, as well as the recalculation performed, in accordance with paragraphs 43–45 of the UNFCCC Annex I inventory reporting guidelines. | W4                       | Not implemented              | No data available     |
| 5. General (waste) – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O | The ERT recommends that the Party improve the transparency of the NID by including, in the  | W9                       | Implemented                  | NID 2023, Ch. 7.1.    |

| CRT category / issue   | Review recommendation   | Review report, paragraph | Status of the implementation | Comment                           |
|--|---|--------------------------|------------------------------|-----------------------------------|
|  | section on the overview of the waste sector, information (e.g. a flow chart) on the waste flows used in the inventory estimates; the amounts of all types of waste produced in the country (MSW, industrial, hazardous, clinical, sludge), considering both imports and exports; and the treatment applied to the different types of waste in the country, including recycling          |                          |                              |                                   |
| 5.A.1 Managed waste disposal sites – CH <sub>4</sub>             | The ERT recommends that the Party correctly report in the chapter on the waste sector of the NID the category in the energy sector in which energy use of landfill gas occurs and the associated emissions are reported.  | W10                      | Implemented                  | NID 2023, Ch. 7.2.2               |
| 5.B.2 Anaerobic digestion at biogas facilities – CH <sub>4</sub> | The ERT recommends that the Party include in the NID a section on subcategory 5.B.2 (anaerobic digestion), explaining that the activity started in 2009, and provide a detailed explanation and justification for reporting CH <sub>4</sub> recovery and emissions from anaerobic digestion as “NE”, in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. | W11                      | Implemented                  | NID 2023, Ch. 7.3.2               |
| 5.C.1 Waste incineration – CO <sub>2</sub>                       | The ERT recommends that the Party update the CO <sub>2</sub> EF for clinical waste using the correct value for dm content from the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.6, p.2.16) and recalculate CO <sub>2</sub> emissions from clinical waste for the entire time series   | W12                      | Implemented                  | NID 2023, Ch. 7.4.2<br>CRT Tables |

| CRT category / issue                          | Review recommendation  | Review report, paragraph | Status of the implementation | Comment             |
|---|--|--------------------------|------------------------------|---------------------|
| 5.D.2 Industrial wastewater – CH <sub>4</sub> | The ERT recommends that the Party include, in the section of the NID on the MCF, information on the changes in the value of the MCF throughout the time series to clarify the improvement in treatment conditions for industrial wastewater and corresponding decrease in emissions. | W13                      | Implemented                  | NID 2023, Ch. 7.5.2 |



## 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   |
| CRT                 | Common Reporting Format  |
| EEA                 | European Environment Agency  |
| EF                  | Emission factor  |
| EMEP                | European Monitoring and Evaluation Programme   |
| ETC-ACC             | European Topic Centre on Air and Climate Change  |
| ETS                 | Emission Trading Scheme  |
| EU                  | European Union   |
| FAO                 | The Food and Agriculture Organization of the United Nations                                  |
| F-Gases             | Hydrofluorocarbons (HFC), Perfluorocarbons (PFC) and Sulphur hexafluoride (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  |
| NID              | National Inventory Document   |
| 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 gozdnatosti v zasnovi gozdne inventure na Slovenskem. Zbornik gozdarstva in lesarstva, 97: 31-42. (available on-line: <http://www.gozdis.si/zbqgl/2012/zbqgl-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.

- Liebetrau J., Reinelt T., Clemens J., Hafermann C, Friehe J., Weiland, P 2013. Analysis of greenhouse gas emissions from 10 biogas plants within the agricultural sector. *Water Science & Technology*, 67: 1370-1379
- 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., Sayler 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://rkq.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.
- Marinšek A., Žlindra D., Ferlan M., Kozamernik E., Mali B., Hladnik J., Zagorac E., Mesarec N., Bergant J., Vrščaj B., Simončič P. 2023. Poročilo o izvedbi naloge javnega naročila: "Monitoring ogljika v gozdnih tleh, mokriščih in urbanih tleh". Ljubljana, Gozdarski inštitut Slovenije, Junij 2023.
- 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., Pečnik Ž., Perpar T., Podgoršek P., Vodopivec U. Rezultati kontrole prireje mleka in mesa: Slovenija 2022 = Results of dairy and beef recording: Slovenia 2022. Ljubljana, Kmetijski inštitut Slovenije, 2023, 90 p. [https://www.govedo.si/wp-content/uploads/2023/11/POROCILO\\_2022.pdf](https://www.govedo.si/wp-content/uploads/2023/11/POROCILO_2022.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 zaloga ogljika na kmetijskih zemljiščih v letu 2019: Sklop B – Lesni ostanki iz trajnih nasadov. Ljubljana, Kmetijski inštitut Slovenije.
- Šušteršič A. et al. 2004. National CO<sub>2</sub> 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 energetski pomen gozda in lesa. Ljubljana, Gozdarski inštitut Slovenije.
- UNECE, 2014. Draft revised United Nations Economic Commission for Europe Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions. ECE/EB.AIR/2014/8, United Nations Economic Commission for Europe [http://www.nutrientchallenge.org/sites/default/files/documents/files/ECE\\_EB\\_AIR\\_2014\\_8\\_E.PDF](http://www.nutrientchallenge.org/sites/default/files/documents/files/ECE_EB_AIR_2014_8_E.PDF)
- 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., Grecs 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.
- WUR. Nitrogen and phosphorous excretion factors of livestock. Wageningen, Wageningen UR Livestock Research, 2014, 137 p.
- 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 2022. Ljubljana, Kmetijski inštitut Slovenije. 2023, p. 3-39 [https://www.govedo.si/wp-content/uploads/2023/05/Pregled\\_zakola\\_in\\_klavne\\_kakovosti\\_goveda\\_v\\_Sloveniji\\_za\\_leto\\_2022\\_s\\_CI.pdf](https://www.govedo.si/wp-content/uploads/2023/05/Pregled_zakola_in_klavne_kakovosti_goveda_v_Sloveniji_za_leto_2022_s_CI.pdf)







