**REPUBLIC OF CROATIA**

MINISTRY OF ECONOMY AND SUSTAINABLE DEVELOPMENT

# Croatian greenhouse gas inventory for the period 1990 - 2022 (National Inventory Report 2024)

# CROATIAN GREENHOUSE GAS INVENTORY REPORT FOR THE PERIOD 1990-2022 (NATIONAL INVENTORY REPORT 2024)

SUBMISSION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE


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Zagreb, March 2024.

# NATIONAL INVENTORY REPORT 2024

# SUBMISSION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

March, 2024

**EKONERG – Energy Research and Environmental Protection Institute**

Koranska 5, Zagreb, Croatia

Ordered by: Ministry of Economy and Sustainable Development

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# NATIONAL INVENTORY REPORT 2024

## Croatian greenhouse gas inventory

## for the period 1990-2022

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Zagreb, March 2024

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# Executive summary

# ES.1. Background information on greenhouse gas (GHG) inventories and climate change

## ES.1.1. Background information on climate change in Croatia

Climate change in Croatia was determined by estimating the trends in annual and seasonal mean air temperature and precipitation amounts; and the associated indices of extremes from the data spanning the period 1961 - 2020. The analyses was based on data from 37 series of mean, minimum and maximum daily temperature and 195 series of daily precipitation amount from Croatian Meteorological and Hydrological Service meteorological station network.

Trends in air temperature (mean, mean minimum and mean maximum temperature) in the last 60-year period show significant warming all over Croatia. They are positive and statistically significant, with the highest changes (up to 0.5 ° C / 10 yrs) detected in the central mainland. The overall positive trend in air temperature is mainly due to the summer trends (ranging from 0.35 ° C to 0.67 ° C / 10 yrs), and due to an increase of winter mean air temperature in the central mainland (0.43 ° C to 0.59 ° C / 10 yrs). The observed warming is also evident in all indices of temperature extremes, revealing positive trends in the warm indices (i.e., increased number of warm days and warm nights and longer warm spell duration), and negative trends in the cold indices (i.e., less number of cold days and cold nights and shorter cold spell duration).

The warmest year in Croatia during the 1961 - 2020 period was 2019 with the mean daily temperature of 13.5 ° C, which is 1.6 ° C above the 1981 - 2010 climate normal. The coldest year was 1980 with the average temperature of 10.6 °C and with anomaly of -1.4 °C. In the last 60 years, each decade was gradually warmer, and the last decade (2011 - 2020) was 1.7 ° C warmer than the first one (1961 - 1970). Moreover, among the 10 hottest years, seven of them belong to the last decade.

A significant decrease in summer precipitation amounts along the Adriatic coast and the mountainous region (5% - 15% / 10 yrs) was detected, in the letter one a significant decrease was observed also in the spring season (5% - 10% / 10 yrs). On the other hand, the autumn precipitation amount trend has a positive sign over Croatia, and it is statistically significant in the central parts of the mainland (5% -10% / 10 yrs). No statistically significant changes were detected in the winter months, though a weak negative trend prevails in eastern Croatia and Dalmatia, and a positive one elsewhere. There is a statistically significant decrease of annual precipitation amount in the mountainous region, while the direction and magnitude of trends are not spatially consistent in other regions.

The annual and seasonal precipitation trend pattern is the result of detected changes in the the indices of precipitaiton extremes. The most prominent feature is the significant increase in annual dry spell duration index (defined as a consecutive sequence of days with precipitation below 10 mm, CDD10) in the western mainland (up to 4 days / 10 yrs) and along Adriatic region (up to 8 days / 10 yrs) while a decrease in CDD10 was detected in the eastern mainland (up to 5 days / 10 yrs). Letter one is a consequence of the significant decrease during the winter season. In addition, in the western mainland, in the highlands and at the northern Adriatic region statistically significant increase is observed in the fraction of precipitation due to very wet days and in the simple daily intensity index (5% - 10% / 10 yrs).

Summer drying is revealed in a significant decrease (up to 20% / 10 yrs) in the frequency of moderate wet days along the northern Adriatic coast and the highlands. In the mountainous littoral and central hinterland, there is an increasing trend in the number of dry days accompanied by a decreasing trend in the simple daily precipitation intensity (5% - 10% / 10 yrs) as well as in the maximum daily and five-day precipitation amounts (5% - 15% / 10 yrs). In the northern Adriatic, a significant increase in dry spell duration (CDD10) was also detected (up to 15% / 10 yrs).

Autumn wet conditions are associated with a significant increase in precipitation fraction due to very wet days (15% - 25% / 10 yrs) in central Croatia, and a decrease in the duration of dry spells (CDD1) in the northern Adriatic and western mainland (10% -15% / 10 yrs). In the mainland, a significant increase (5% - 10% / 10 yrs) in the daily intensity index and maximum 1- and 5- day precipitation amounts are found.

In spring, a significant increase (5% - 10% / 10 yrs) in the dry spell duration (CDD1) was found in the northern Adriatic according to the increase in the number of dry days. In the western mainland and the highlands, a statistically significant decreasing trend in moderately wet days (5% - 10% / 10 yrs) was detected, whereas in eastern Croatia trend toward longer wet spells (CWD10) was found.

## ES.1.2. Background information on greenhouse gas (GHG) inventories

The Republic of Croatia became a party to the United Nations Framework Convention on Climate Change (UNFCCC) on 17 January 1996 when the Croatian Parliament passed the law on its ratification (Official Gazette, International Treaties No. 2/96). For the Republic of Croatia, the Convention came into force on 7 July 1996. As a country undergoing the process of transition to market economy, Croatia has, pursuant to Article 22, paragraph 3 of the Convention, assumed the commitments of countries included in Annex I. By the amendment that came into force on 13 August 1998 Croatia was listed among Parties included in Annex I to the Convention.

The adoption of the Decision 7/CP.12 by the Conference of Parties was acknowledged by the Croatian Parliament which ratified the Kyoto Protocol on 27 April 2007 (Official Gazette, International Treaties No. 5/07). The Kyoto Protocol has entered into force in Croatia on 28 August 2007. Initial Report for the first commitment period of the Republic of Croatia under the Kyoto Protocol was submitted in August 2008.

One of the commitments outlined in Article 4, paragraph 1 of the UNFCCC is that Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties.

Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia (Official Gazette No. 5/17) prescribe obligation and procedure for emissions monitoring, which comprise estimation and/or reporting of all anthropogenic emissions and removals. Monitoring of GHG gases is stipulated by Article 21 of the Act on climate change and ozone layer protection (Official Gazette No, 127/2019). In this NIR, the inventory of the emissions and removals of the greenhouse gases (GHG) is reported for the period from 1990 to 2022. The NIR is prepared in accordance with the UNFCCC reporting guidelines on annual Inventories as adopted by the COP by its Decision 24/CP.19. The methodologies used in the calculation of emissions are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC Good Practice Guidance) prepared by the Intergovernmental Panel on Climate Change (IPCC). As recommended by the IPCC Guidelines country-specific methods have been used where appropriate and where they provide more accurate emission data. The important part of the inventory preparation is the uncertainty assessment of the calculation and verification of the input data and results, all this with the aim to increase the quality and reliability of the calculation.

Furthermore, since the introduction of annual technical reviews of the national inventories by experts review teams (ERT), Croatia has undergone fifteen reviews so far, in-country review in 2004, 2007, 2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016, 2020 and 2022. Issues recommended by the ERT have been included in this report as far as possible.

Except of UN reviews, from 2013 (after Croatia become one of EU countries) European commission conducts reviews of NIR each year.

The calculation includes the emissions which are the result of anthropogenic activities and these include the following greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), halogenated carbons (HFCs, PFCs), sulphur hexafluoride ($SF_6$), nitrogen fluoride ($NF_3$) and indirect greenhouse gases: carbon monoxide (CO), oxides of nitrogen ($NO_x$), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide ($SO_2$). The greenhouse gases covered by the Montreal Protocol on the pollutants related to ozone depletion (freons) are reported in the framework of this protocol and therefore are excluded from this Report.

Greenhouse gas emission sources and sinks are divided into five main sectors: Energy, Industrial Processes and Product Use, Agriculture, Land Use, Land-Use Change and Forestry and Waste. Generally, the methodology for emission calculation could be described as a product of the particular activity data (e.g. fuel consumption, cement production, number of animals, increase of wood stock etc.) with corresponding emission factors. The use of specific national emission factors is recommended wherever possible and justified, whereas, on the contrary, the methodology gives typical values of emission factors for all relevant activities of the particular sectors.

### ES.1.2.1. Institutional and organizational structure of greenhouse gas emissions inventory preparation

The National system for Croatia fulfils the requirements, as set forth by both UNFCCC decisions (Decision 24/CP.19 and Decision 19/CMP.1) and by the European Regulation no. 2018/1999 on the management of the energy union and action in the field of climate and Implementing Regulation no. 2020/1208 on the structure, format, submission procedures and revision of information submitted by member states in accordance with Regulation (EU) no. 2018/1999 of the European.

Functioning of Croatian national inventory system is stipulated by Act on Climate Change and Ozone Layer Protection (OG 127/19). Institutional arrangement for inventory preparation in Croatia is regulated in Chapter II of the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia (OG 5/17) entitled National system for the estimation and reporting of anthropogenic greenhouse gas emissions by sources and removals by sinks. Institutional arrangements for inventory management and preparation in Croatia could be characterized as decentralized and out-sourced with clear tasks breakdown between participating institutions including Ministry of economy and sustainable development (MESD) and competent governmental bodies responsible for providing of activity data. The preparation of inventory itself is entrusted to Authorised Institution, which is elected for three-year period by public tendering. Committee for inter-sectorial coordination for national system for monitoring of GHG emission (National System Committee) is included in the approval process; its members provide their opinion on certain parts of the Inventory within the frame of their speciality. Members of the National System Committee are nominated by the authorized Ministries upon the request of the MESD.

MESD is a national focal point for the UNFCCC, with overall responsibility for functioning of the National system in a sustainable manner, including:

- mediation and exchange of data on GHG emissions and removals with international organisations and Parties to the Convention;
- mediation and exchange of data with competent bodies and organisations of the European Union in a manner and within the time limits laid down by legal acts of the European Union;
- control of methodology for emission calculation and GHG removal in line with good practices and national circumstances;

- consideration and approval of the Greenhouse Gas Inventory Report prior to its formal submission to the Convention Secretariat.
- organisation of GHG inventory preparation with the aim of meeting the deadlines;
- collection of activity data;
- development of quality assurance and quality control plan (QA/QC plan) related to the GHG inventory in line with the guidelines on good practices of the Intergovernmental Panel on Climate Change;
- implementation of the quality assurance procedure with regard to the GHG inventory in line with the quality assurance and quality control plan;
- archiving of activity data on calculation of emissions, emission factors, and of documents used for inventory planning, preparation, quality control and quality assurance;
- maintaining of records and reporting on authorised legal persons participating in the Kyoto Protocol flexible mechanisms;
- selection of Authorised Institution (in Croatian: Ovlaštenik) for preparation of the GHG inventory;
- provide insight into data and documents for the purpose of technical reviews.

Authorised Institution is responsible for preparation of inventory, which include:

- emission calculation of all anthropogenic emissions from sources and removals by GHG sinks, and calculation of indirect GHG emissions, in line with the methodology stipulated by the effective guidelines of the Convention, guidelines of the Intergovernmental Panel on Climate Change, Instructions for reporting on GHG emissions as published on the Ministry's website, and on the basis of the activities data;
- quantitative estimate of the calculation uncertainty for each category of source and removal of GHG emissions, as well as for the inventory as a whole, in line with the guidelines of the Intergovernmental Panel on Climate Change;
- identification of key categories of GHG emission sources and removals;
- recalculation of GHG emissions and removals in cases of improvement of methodology, emission factors or activity data, inclusion of new categories of sources and sinks, or application of coordination/adjustment methods;
- calculation of GHG emissions or removal from mandatory and selected activities in the sector of land use, land-use change and forestry;
- reporting on issuance, holding, transfer, acquisition, cancellation and retirement of emission reduction units, certified emission reduction units, assigned amount units and removal units, and carry-over, into the next commitment period, of emission reduction units, certified emission reduction units and assigned amount units, from the Registry in line with the effective decisions and guidelines of the Convention and supporting international treaties;
- implementation of and reporting on quality control procedures in line with the quality control and quality assessment plan;
- preparation of the GHG inventory report, including also all additional requirements in line with the Convention and supporting international treaties and decisions;
- cooperation with the Secretariat’s ERTs for the purpose of technical review and assessment/evaluation of the inventory submissions.

EKONERG – Energy and Environmental Protection Institute was selected as Authorised Institution for preparation of 2024 inventory submission.

### ES.1.2.2. Information on minimization of activities

According to paragraph 24 of the Annex to Decision 15/CMP.1 Parties included in Annex II, and other Parties included in Annex I that are in a position to do so, shall incorporate information on how they give priority, in implementing their commitments based on relevant methodologies referred to in paragraph 8 of decision 31/CMP.1. Considerations of possible impact of the implementation of response measures form part of the fully transparent process of impact assessments or sustainability impact assessments for EU legislative proposals or trade agreements respectively, such as specific proposals on climate action or cross-border sectoral measures including energy, transport, industry and agriculture.

According to Article 4, paragraphs 8 and 9 of the Convention Croatia strives to implement Kyoto commitments in a way which minimize adverse impact on developing countries. In continuation information on implementation of policies and measures that minimise adverse social, environmental and economic impacts on non-Annex I Parties is provided.

a) Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

The ongoing liberalization of the energy market is in line with EU policies and directives. No significant market distortions have been identified. Consumption taxes for electricity and fossil fuels were harmonized recently. The main instrument addressing externalities is the emission trading under the EU ETS.

b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies

In Republic of Croatia, no subsidies for environmentally unsound and unsafe technologies have been identified.

c) Technological development of non-energy uses of fossil fuels

Republic of Croatia has not participated actively in activities of this nature.

d) Carbon capture and storage technology development

Republic of Croatia does not take part in any such activity.

e) Improvements in fossil fuel efficiencies

In 2017 The Fourth National Energy Efficiency Action Plan for the 2017- 2019 period has been drawn up in accordance with the template laid down by the European Commission, with which all EU Member States must comply. Measures for the period from 2017 to 2019 regarding energy efficiency are:

- supporting the use of renewable energy sources and energy efficiency by the Environmental Protection and Energy Efficiency Fund (the Fund),
- encouraging the use of renewable energy and energy efficiency through the Croatian Bank for Reconstruction and Development (HBOR),

- energy efficiency projects with repayment through savings (ESCOs),
- increasing energy efficiency in buildings
- energy audits in the industry,
- promoting energy efficiency in households and the services sector through project activities,
- labelling the energy efficiency of household appliances,
- metering and informative billing of energy consumption,
- eco-design of energy-using products.

In 2019 Integrated National Energy and Climate Plan for the Republic of Croatia for the period 2021-2030 has been drawn up in accordance with the template laid down by the European Commission. Measures for the period from 2021 to 2030 regarding fuel efficiency are:

- Energy efficiency obligation scheme for suppliers
- Promoting nearly-zero energy standard in buildings construction and refurbishment
- Energy renovation programme for multi-apartment buildings, single family houses, public sector buildings, heritage buildings
- Energy management system in the public sector
- Energy renovation programme for public lighting
- Green public procurement
- Energy management system in business (service & production) sector
- Informative bills
- Providing information on energy efficiency
- Energy efficiency education
- Integrated information system for monitoring energy efficiency
- Energy efficiency of the electricity transmission system
- Reduction of losses in the distribution network and introduction of smart grids
- Increasing efficiency of district heating system
- Increasing efficiency of the gas transport network

f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

As regards to the above mentioned activity, Republic of Croatia does not take part in any such activity.

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

In this chapter, national emissions and removals for the Republic of Croatia are presented for the period from 1990 to 2022. The results are presented as total emissions of all greenhouse gases in $CO_2$ equivalents over sectors and then as emissions for the individual greenhouse gas by sectors. Since the certain greenhouse gases have different irradiation properties and consequently different contribution to the greenhouse effect, it is necessary to multiply the emission of every gas with proper Global Warming Potential (GWP). The Global Warming Potential is a measure of the impact on the greenhouse effect of the certain gas compared to $CO_2$ impact which is accordingly defined as a referent value. In that case, the emission of greenhouse gases is presented as the equivalent emission of carbon dioxide ($CO_2$-eq). If the removal of greenhouse gases occurs (e.g. the absorption of $CO_2$ at increase of wood stock in forests) than it refers to sinks of greenhouse gases and the amount is presented as a negative value. Global warming potentials used to calculate $CO_2$ equivalent emissions are defined in IPCC Fifth Assessment Report, 2014 (AR5).

| Gas | Global Warming Potential |
|---|---|
| Carbon dioxide ($CO_2$) | 1 |
| Methane ($CH_4$) | 28 |
| Nitrous oxide ($N_20$) | 265 |
| HFC-23 | 12400 |
| HFC-32 | 677 |
| HFC-125 | 3170 |
| HFC-134a | 1300 |
| HFC-143a | 4800 |
| HFC-227ea | 3350 |
| HFC-236fa | 8060 |
| HFC-365mfc | 804 |
| CF4 | 6630 |
| C2F6 | 11100 |
| C3F8 | 8900 |
| SF6 | 23500 |

Source: Fifth Assessment Report

The results of the greenhouse gas (GHG) emission calculation are presented for the period from 1990 to 2022. Total emissions/removals of GHG and their trend in sectors are given in Tables ES.2-1, ES.2-2 and in Figure ES.2-1 while the contribution of the individual gases is given in Tables ES.2-3, ES.2-4 and Figure ES.2-2.

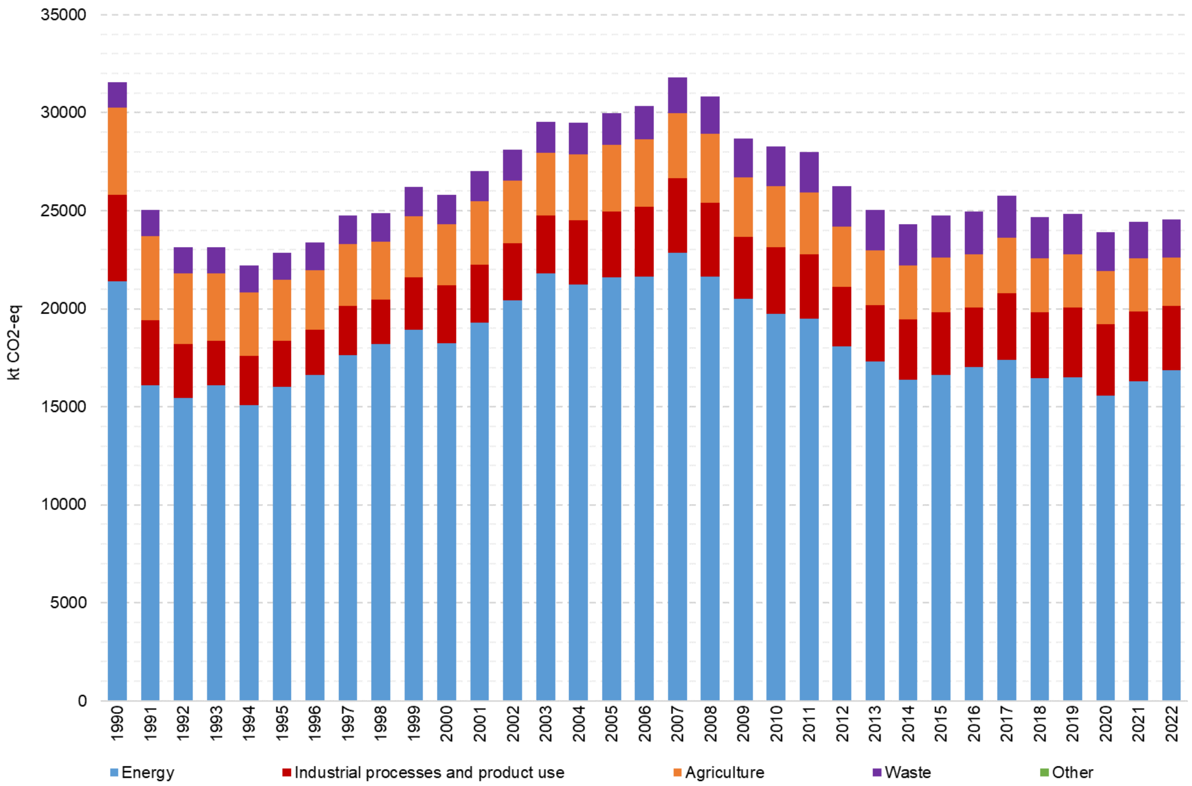
Table ES.2-1: Emissions/removals of GHG by sectors for the every five years from 1990 to 2015 (kt $CO_2$-eq)

| Greenhouse gas source and sink categories | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| 1. Energy | 21,411.7 | 16,031.9 | 18,254.8 | 21,581.4 | 19,733.5 | 16,620.9 |
| 2. Industrial processes and product use | 4,408.8 | 2,325.0 | 2,953.1 | 3,398.5 | 3,404.8 | 3,200.7 |
| 3. Agriculture | 4,424.3 | 3,132.0 | 3,093.2 | 3,361.8 | 3,135.0 | 2,787.2 |
| 4. Land use, land-use change and forestry | -6,348.0 | -8,551.2 | -6,738.1 | -8,003.2 | -6,906.8 | -5,691.9 |
| 5. Waste | 1,301.5 | 1,386.4 | 1,525.7 | 1,621.0 | 2,016.3 | 2,161.7 |
| 6. Other | NO | NO | NO | NO | NO | NO |
| Total (with LULUCF) | 25,198.3 | 14,324.1 | 19,088.7 | 21,959.6 | 21,382.7 | 19,078.5 |
| Total (without LULUCF) | 31,546.3 | 22,875.2 | 25,826.8 | 29,962.8 | 28,289.6 | 24,770.4 |

Table ES.2-2: Emissions/removals of GHG by sectors for the every year from 2016 to 2022 (kt $CO_2$-eq)

| Greenhouse gas source and sink categories | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| 1. Energy | 17,026.4 | 17,399.9 | 16,460.0 | 16,510.4 | 15,561.7 | 16,282.6 | 16,871.7 |
| 2. Industrial processes and product use | 3,024.4 | 3,401.8 | 3,379.0 | 3,551.6 | 3,642.4 | 3,591.8 | 3,277.1 |
| 3. Agriculture | 2,731.1 | 2,829.8 | 2,716.7 | 2,706.8 | 2,700.7 | 2,687.4 | 2,467.9 |
| 4. Land use, land-use change and forestry | -5,698.2 | -4,883.7 | -5,492.8 | -5,725.8 | -5,658.6 | -5,763.7 | -4,867.2 |
| 5. Waste | 2,160.4 | 2,153.9 | 2,103.9 | 2,061.9 | 2,009.7 | 1,875.4 | 1,935.3 |
| 6. Other | NO | NO | NO | NO | NO | NO | NO |
| Total (with LULUCF) | 19,244.1 | 20,901.6 | 19,166.8 | 19,104.9 | 18,255.9 | 18,673.4 | 19,684.8 |
| Total (without LULUCF) | 24,942.3 | 25,785.3 | 24,659.6 | 24,830.7 | 23,914.5 | 24,437.2 | 24,552.0 |

Figure ES2-1: Trend of GHG emissions, by sectors



Tables ES.2-1, ES.2-2 and Figure ES.2-1 represents the contribution of the individual sectors to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2022 excluding LULUCF has the Energy sector with 68.7 %, followed by Industrial Processes and product use with 13.3 %, Waste with 7.9 % and Agriculture with 10.1 %. This structure is with minor changes consistent through all the observed period from 1990 to 2022. In the year 2022, the total GHG emissions in Croatia was 24,552.0 kt $CO_2$-eq excluding LULUCF sector while the total emission was 19,684.8 kt $CO_2$-eq including the LULUCF sector which represents removals by sink from 19.8 % in that year.

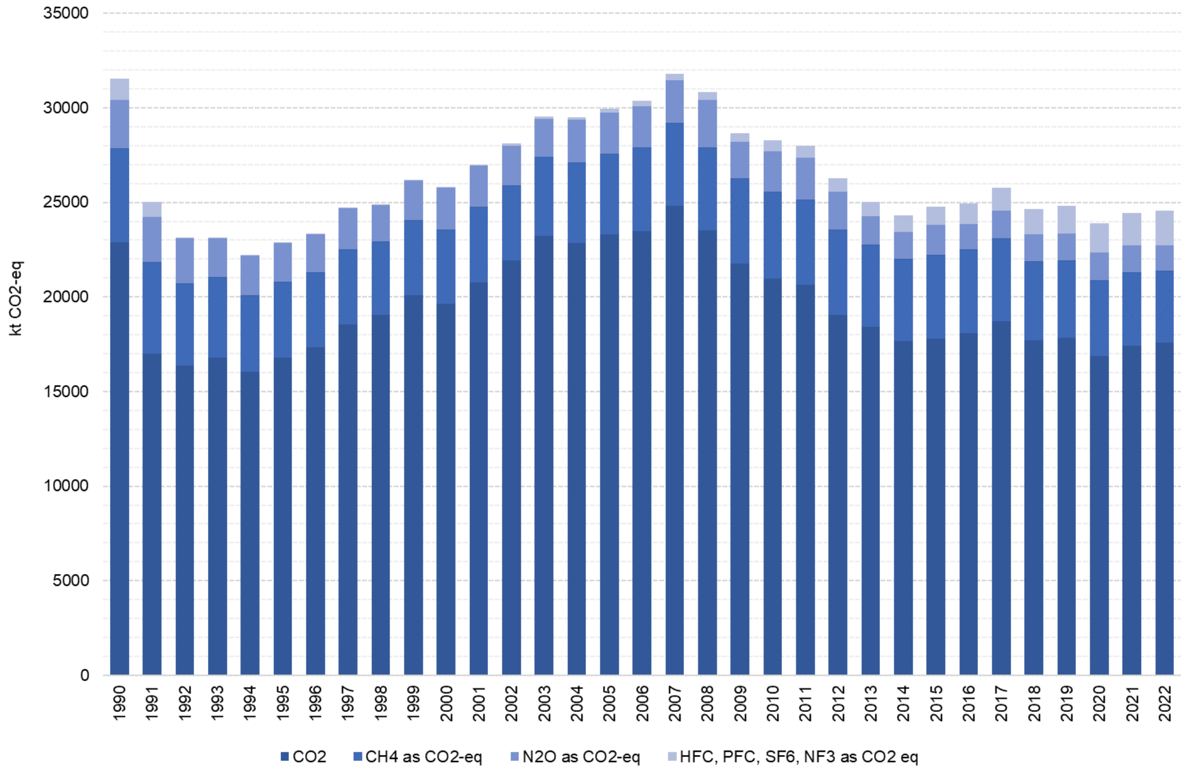
Table ES.2-3: Emissions/removals of GHG by gases for the every five years from 1990 to 2015 (kt $CO_2$-eq)

| Greenhouse gas emissions | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| $CO_2$ emissions without net $CO_2$ from LULUCF | 22,874.5 | 16,811.3 | 19,652.3 | 23,298.0 | 20,986.2 | 17,803.0 |
| $CO_2$ emissions with net $CO_2$ from LULUCF | 16,480.4 | 8,205.2 | 12,705.0 | 15,213.5 | 13,950.6 | 11,925.3 |
| $CH_4$ emissions without $CH_4$ from LULUCF | 5,008.6 | 4,003.0 | 3,909.9 | 4,281.2 | 4,570.7 | 4,442.4 |
| $CH_4$ emissions with $CH_4$ from LULUCF | 5,010.0 | 4,011.4 | 4,018.4 | 4,284.2 | 4,572.6 | 4,458.0 |
| $N_2O$ emissions without $N_2O$ from LULUCF | 2,534.9 | 2,027.0 | 2,202.6 | 2,182.5 | 2,158.6 | 1,575.0 |
| $N_2O$ emissions with $N_2O$ from LULUCF | 2,579.6 | 2,073.6 | 2,303.1 | 2,260.6 | 2,285.4 | 1,745.1 |
| HFCs | NO | 21.4 | 49.4 | 186.5 | 563.9 | 944.3 |
| PFCs | 1,117.3 | NO | NO | NO | NO | NO |
| Unspecified mix of HFCs and PFCs | NO | NO | NO | NO | NO | NO |
| $SF_6$ | 11.1 | 12.4 | 12.7 | 14.7 | 10.1 | 5.7 |
| $NF_3$ | NO | NO | NO | NO | NO | NO |
| Total (without LULUCF) | 31,546.3 | 22,875.2 | 25,826.8 | 29,962.8 | 28,289.6 | 24,770.4 |
| Total (with LULUCF) | 25,198.3 | 14,324.1 | 19,088.7 | 21,959.6 | 21,382.7 | 19,078.5 |
| Total (without LULUCF, with indirect) | NA | NA | NA | NA | NA | NA |
| Total (with LULUCF, with indirect) | NA | NA | NA | NA | NA | NA |

Table ES.2-4: Emissions/removals of GHG by sectors for the every year from 2016 to 2022 (kt $CO_2$-eq)

| Greenhouse gas emissions | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** |
|---|---|---|---|---|---|---|---|
| $CO_2$ emissions without net $CO_2$ from LULUCF | 18,090.0 | 18,719.1 | 17,702.6 | 17,830.3 | 16,881.6 | 17,410.7 | 17,608.2 |
| $CO_2$ emissions with net $CO_2$ from LULUCF | 12,214.6 | 13,551.1 | 12,043.8 | 11,936.0 | 11,002.7 | 11,480.2 | 12,534.2 |
| $CH_4$ emissions without $CH_4$ from LULUCF | 4,417.3 | 4,379.4 | 4,184.3 | 4,108.2 | 3,998.3 | 3,875.9 | 3,796.9 |
| $CH_4$ emissions with $CH_4$ from LULUCF | 4,427.3 | 4,456.9 | 4,185.8 | 4,111.3 | 4,034.8 | 3,882.4 | 3,834.1 |
| $N_2O$ emissions without $N_2O$ from LULUCF | 1,348.4 | 1,454.3 | 1,413.8 | 1,417.4 | 1,453.0 | 1,444.0 | 1,324.8 |
| $N_2O$ emissions with $N_2O$ from LULUCF | 1,515.5 | 1,661.1 | 1,578.4 | 1,582.7 | 1,636.8 | 1,604.2 | 1,494.5 |
| HFCs | 1,079.8 | 1,225.3 | 1,352.4 | 1,466.8 | 1,572.2 | 1,697.0 | 1,812.1 |
| PFCs | NO | NO | NO | NO | NO | NO | NO |
| Unspecified mix of HFCs and PFCs | NO | NO | NO | NO | NO | NO | NO |
| $SF_6$ | 6.8 | 7.2 | 6.5 | 8.1 | 9.4 | 9.6 | 10.0 |
| $NF_3$ | NO | NO | NO | NO | NO | NO | NO |
| Total (without LULUCF) | 24,942.3 | 25,785.3 | 24,659.6 | 24,830.7 | 23,914.5 | 24,437.2 | 24,552.0 |
| Total (with LULUCF) | 19,244.1 | 20,901.6 | 19,166.8 | 19,104.9 | 18,255.9 | 18,673.4 | 19,684.8 |
| Total (without LULUCF, with indirect) | NA | NA | NA | NA | NA | NA | NA |
| Total (with LULUCF, with indirect) | NA | NA | NA | NA | NA | NA | NA |

Figure ES2-2: Trend of GHG emissions, by gases




Tables ES.2-3, ES.2-4 and Figure ES.2-2 represents the contribution of the individual gasses to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2022 excluding LULUCF has $CO_2$ emission with 71.7 %, followed by $CH_4$ with 15.5 %, $N_2O$ with 5.4 % and HFCs, PFCs and $SF_6$ with 7.4 %.

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

## ES.3.1. Greenhouse gas emissions by sectors

**ENERGY SECTOR**

The Energy sector is the largest contributor to GHG emissions. In the year 2022, the GHG emission from the Energy sector was 3.6 % higher in relation to 2021 and 21.2 % lower in relation to 1990. The Energy sector covers all activities that involve fuel combustion from stationary and mobile sources, and fugitive emission from fuels. The Energy sector is the main cause for anthropogenic emission of greenhouse gases. It accounts for approximately 69 % of the total emission of all greenhouse gases presented as equivalent emission of $CO_2$. Looking at its contribution to the total emission of carbon dioxide ($CO_2$), the energy sector accounts for about 65.7 % (in 2022). The contribution of energy in methane ($CH_4$) in total $CO_2$-eq emission is substantially smaller (2.2 % in 2022) while the contribution of energy in nitrous oxide ($N_2O$) in total $CO_2$-eq emission is quite small (0.8 % in 2022). Emissions from fossil fuel combustion comprise the majority (more than 95 %) of energy-related emissions. Emission of individual subsectors is presented in the Table ES.3-1.

Table ES.3.1-1: Energy subsectors total emissions by gases for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 1. Energy | 21,411.7 | 18,254.8 | 21,581.4 | 19,733.5 | 16,620.9 | 15,561.7 | 16,282.6 | 16,871.7 |
| A. Fuel combustion (sectoral approach) | 20,359.2 | 17,285.2 | 20,545.8 | 18,903.3 | 16,154.1 | 15,100.9 | 15,833.2 | 16,360.2 |
| 1. Energy industries | 7,087.3 | 5,831.8 | 6,835.5 | 5,901.5 | 4,740.9 | 3,696.1 | 3,769.4 | 4,106.2 |
| 2. Manufacturing industries and construction | 5,127.9 | 3,065.0 | 3,695.8 | 2,997.6 | 2,210.8 | 2,404.5 | 2,430.4 | 2,324.6 |
| 3. Transport | 3,898.6 | 4,501.4 | 5,563.1 | 5,948.7 | 5,952.1 | 5,791.9 | 6,259.1 | 6,730.9 |
| 4. Other sectors | 4,245.2 | 3,887.0 | 4,451.4 | 4,055.4 | 3,250.3 | 3,208.4 | 3,374.4 | 3,198.4 |
| 5. Other | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE |
| B. Fugitive emissions from fuels | 1,052.5 | 969.6 | 1,035.6 | 830.2 | 466.8 | 460.8 | 449.4 | 511.5 |
| 1. Solid fuels | 66.8 | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA |
| 2. Oil and natural gas and other emissions from energy production | 985.7 | 969.6 | 1,035.6 | 830.2 | 466.8 | 460.8 | 449.4 | 511.5 |
| C. $CO_2$ transport and storage | NO | NO | NO | NO | NO | NO | NO | NO |

The largest part (39.9 % in 2022) of the emissions from Energy sector are a consequence of fuel combustion in Transport, next is the combustion in Energy industries (24.3 % in 2022) and third is combustion in small stationary energy sources, such as Commercial/ Institutional, Residential and Agriculture/ Forestry/ Fishing (19.0 % in 2022). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 13.8 %, while Fugitive Emissions from Fuels contribute with about 3.0 %.

**INDUSTRIAL PROCESSES AND PRODUCT USE**

In Industrial Processes sector, the key emission sources are part of Mineral industry, Chemical industry and Product uses as ODS substitutes, which all together contribute with 96.5 % in total sectoral emission in 2022. The iron production in blast furnaces and aluminium production ended in 1992, and ferroalloys production ended in 2003. Generally, GHG emissions from industrial processes declined from 1990 to 1995, due to the decline in industrial activities caused by the war in Croatia, while in the period 1996 -

2008 emissions slightly increased due to revitalization of the economy. The effects of the economic crisis influenced the emissions trend from 2008 onwards, followed by a moderate recovery since 2013. The decrease in emissions from the chemical industry in 2013 and onwards is due to a strong reduction of $N_2O$ emissions from the nitric acid production after applying abatement technology. In 2022 emissions from industrial processes were decreased by 8.8 % regarding 2021 and decreased by 25.7 % regarding 1990. Industrial processes and product use contributed to total GHG emissions with 13.3 % in 2022. Emission of individual subsectors is presented in the Table ES.3-2.

Table ES.3.1-2: Industrial processes subsectors total emissions by gases for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 2. Industrial processes and product use | 4,408.8 | 2,953.1 | 3,398.5 | 3,404.8 | 3,200.7 | 3,642.4 | 3,591.8 | 3,277.1 |
| A. Mineral industry | 1,297.6 | 1,426.4 | 1,809.9 | 1,403.7 | 1,306.4 | 1,359.3 | 1,372.3 | 1,255.5 |
| B. Chemical industry | 1,427.9 | 1,324.8 | 1,234.1 | 1,298.7 | 849.1 | 593.2 | 401.8 | 96.1 |
| C. Metal industry | 1,458.1 | 30.2 | 12.7 | 14.7 | 9.3 | 4.9 | 14.3 | 13.4 |
| D. Non-energy products from fuels and solvent use | 181.5 | 76.9 | 112.4 | 89.8 | 68.0 | 85.6 | 80.0 | 73.1 |
| E. Electronic Industry | NO | NO | NO | NO | NO | NO | NO | NO |
| F. Product uses as ODS substitutes | NO | 49.4 | 186.5 | 563.9 | 944.3 | 1,572.2 | 1,697.0 | 1,812.1 |
| G. Other prod. manuf. and use | 43.7 | 45.4 | 43.0 | 34.0 | 23.6 | 27.1 | 26.5 | 26.9 |
| H. Other | NA | NA | NA | NA | NA | NA | NA | NA |

## AGRICULTURE

Emission of $CH_4$ and $N_2O$ in the Agricultural sector is conditioned by different agricultural activities. For the emission of $CH_4$, the most important source is livestock farming (Enteric Fermentation) which makes 41.4 % of sectoral $CO_2$-eq emission. The number of cattle showed a continuous decrease in the period from 1990 to 2002. As a consequence, this led to $CH_4$ emission reduction. In the year 2000, the number of cattle has started increasing and this trend was mostly retained until 2006. From 2007 to 2010, cattle number decreased and remained at approximately the same level in 2013 and 2014. Compared to 2021, in 2022 $CO_2$-eq emission from Enteric fermentation decreased by 5.4 %. As for Manure management emissions, $CO_2$-eq emission decreased by 6.3 % in 2022 compared to 2021. Emissions from Agricultural soils decreased after 1990 and during the war due to specific national circumstances and limited agricultural practice at that time. Afterwards, the emission trend is mostly influenced by the changes in the direct soil emissions; thus, emission increase can be noticed in 1997, 2001 and 2002 due to increase in mineral fertilizer consumption and crop production, later on also due to the increase of livestock population. $CO_2$-eq emission from Agricultural soils decreased in 2022 compared to 2021 by 9.8 %. Overall, in the year 2022, the GHG emission from the Agriculture sector decreased by 8.2 % in comparison with 2021. Emission of individual subsectors is presented in the Table ES.3-3.

Table ES.3.1-3: Agriculture subsectors total emissions by gases for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 3. Agriculture | 4,424.3 | 3,093.2 | 3,361.8 | 3,135.0 | 2,787.2 | 2,700.7 | 2,687.4 | 2,467.9 |
| A. Enteric fermentation | 2,336.0 | 1,349.7 | 1,458.8 | 1,303.8 | 1,193.8 | 1,091.1 | 1,079.3 | 1,020.9 |
| B. Manure management | 776.3 | 618.0 | 681.6 | 721.8 | 641.7 | 534.8 | 527.8 | 494.6 |
| C. Rice cultivation | NO | NO | NO | NO | NO | NO | NO | NO |
| D. Agricultural soils | 1,262.0 | 1,064.6 | 1,135.9 | 1,021.4 | 882.3 | 979.6 | 988.0 | 891.7 |

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| E. Presc. burning of sav. | NO | NO | NO | NO | NO | NO | NO | NO |
| F. Field burning | NO | NO | NO | NO | NO | NO | NO | NO |
| G. Liming | NO | NO | 14.5 | 21.5 | 12.1 | 6.9 | 18.7 | 18.7 |
| H. Urea application | 50.0 | 60.9 | 71.0 | 66.6 | 57.2 | 88.3 | 73.6 | 42.0 |
| I. Other carbon-cont. fertilizers | NA | NA | NA | NA | NA | NA | NA | NA |
| J. Other | NO | NO | NO | NO | NO | NO | NO | NO |

## LULUCF

The Act on Forest (Official Gazette No. NN 68/18, 115/18, 98/19, 32/20, 145/20, 101/23, 36/24) regulates the growing, protection, usage and management of forests and forest land as a natural resource aimed to maintain biodiversity and ensure management based on principles of economic sustainability, social responsibility and ecological acceptability. Moreover, one of its the most important provisions, in the context of climate protection, is that forests should be managed in conformity with the sustainable management criteria, implying the maintenance and enhancement of forest ecosystems and their contribution to the global carbon cycle. Planning activities in the forestry sector in Croatia are also regulated by the Low on Forest. Forest management plans determine conditions for harmonious usage of forest and forest land and procedures in that area, necessary scope regarding cultivation and forest protection, possible utilization degree and conditions for wildlife management. The Forest Management Area Plan (FMAP) for the Republic of Croatia determines the ecological, economic and social background for forest improvement in terms of biology and for the increase of forest productivity.

According to National forestry accounting plan for the Republic of Croatia (december 2019), the forests and the forest land cover 47.5 % of the total surface area. By its origin, approximately 95 % of the forests in Croatia were formed by natural regeneration (according to the national definitions applied in the sector) and the 5 % of the forests are grown artificially. The Plan determines, the growing stock of about 398 millions of $m^3$ while its yearly increment amounts around 10.5 million m3. The most frequent species are Common Beech (Fagus sylvatica), Pedunculate Oak (Quercus robur), Sessile Oak (Quercus petrea), Common Hornbeam (Carpinus betulus), Silver Fir (Abies alba), Narrow-leafed Ash (Fraxinus angustifolia), Spruce (Picea abies), Black Alder (Alnus glutinosa), Black Locust (Robinia pseudoacacia), Turkey Oak (Quercus cerris) and other.

The methodology used for $CO_2$ removal calculation is taken from the IPCC and it is based on data on increment and fellings. The problem of deforestation in Croatia does not exist. According to present data, the total forest area has not been reduced in the last 100 years.

Table ES.3-4 shows the $CO_2$ removal trend in the forestry sector. Removals arisen in the LULUCF sector contribute with 24.7 % to the total emissions of $CO_2$ eq in Croatia including LULUCF in the year 2022.

Table ES.3.1-4: Removal trends in LULUCF sector from 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| LULUCF removals | -6,348.0 | -6,738.1 | -8,003.2 | -6,906.8 | -5,691.9 | -5,658.6 | -5,763.7 | -4,867.2 |

## WASTE

Waste sector includes the following categories: solid waste disposal, biological treatment of solid waste, incineration and open burning of waste and wastewater treatment and discharge. Solid waste disposal represents dominant $CH_4$ emission source from sector Waste.

Emissions from solid waste disposal account 71.9 % of sectoral emissions in 2022, compared to 42.9 % in 1990. An increase in generated and deposited of solid waste exists during the reporting period. In recent years, the increasing trend is slower in waste generation, while decreasing trend occurs in waste disposal, compared to the previous period, influenced by the implementation of the measures undertaken to avoid/reduce and recycle waste, which are still not sufficiently applied.

Emissions from wastewater treatment and discharge account 26.3 % of sectoral emissions in 2022, compared to 55.2 % in 1990. Decrease in emissions during the reporting period mainly is a result of population decrease as well reduction of economic activity after 2008 and a declining fluctuating trend in the industrial production.

Biological treatment of solid waste and incineration and open burning of waste have considerably lower contribution to the sectoral emissions during the reporting period.

Waste sector contributes to total GHG emissions with 7.9 % in 2022. Emission of individual subsectors is presented in the Table ES.3-5.

Table ES.3.1-5: Waste subsectors total emissions by gases for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 5. Waste | 1,301.5 | 1,525.7 | 1,621.0 | 2,016.3 | 2,161.7 | 2,009.7 | 1,875.4 | 1,935.3 |
| A. Solid waste disposal | 558.6 | 807.4 | 930.9 | 1,324.4 | 1,506.1 | 1,440.9 | 1,313.8 | 1,391.7 |
| B. Biological treatment of solid waste | NO,IE | 1.4 | 2.3 | 3.7 | 18.2 | 20.1 | 23.0 | 28.2 |
| C. Incineration and open burning of waste | 23.9 | 17.8 | 10.8 | 11.8 | 10.1 | 8.0 | 7.4 | 7.2 |
| D. Waste water treatment and discharge | 719.0 | 699.2 | 677.0 | 676.5 | 627.3 | 540.7 | 531.2 | 508.1 |
| E. Other | NO | NO | NO | NO | NO | NO | NO | NO |

## ES.3.2. Greenhouse gas emissions by gases

### ES.3.2.1. Carbon dioxide emission ($CO_2$)

Carbon dioxide is the most significant anthropogenic GHG. The most significant anthropogenic sources of $CO_2$ emissions in Croatia are the processes of fossil fuel combustion for electricity or/and heat production, transport and industrial processes (cement and ammonia production). The results of the $CO_2$ emission calculation in Croatia are presented in Table ES.3.2-1.

Table ES.3.2-1: $CO_2$ emission/removal by sectors from 1990-2022 (kt $CO_2$)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Energy | 20,257.4 | 17,347.9 | 20,613.7 | 18,774.7 | 15,777.7 | 14,801.2 | 15,486.4 | 16,121.6 |
| Industrial processes | 2,566.6 | 2,237.4 | 2,598.6 | 2,123.5 | 1,955.9 | 1,985.2 | 1,832.0 | 1,425.9 |
| Agriculture | 50.0 | 60.9 | 85.5 | 88.0 | 69.3 | 95.2 | 92.3 | 60.7 |
| LULUCF | -6,394.1 | -6,947.3 | -8,084.4 | -7,035.6 | -5,877.7 | -5,878.9 | -5,930.4 | -5,074.1 |
| Waste | 0.54 | 6.15 | 0.16 | 0.05 | 0.05 | NO,NA | NO,NA | NO,NA |
| Other | NO | NO | NO | NO | NO | NO | NO | NO |
| Total $CO_2$ emission without LULUCF | 22,874.5 | 19,652.3 | 23,298.0 | 20,986.2 | 17,803.0 | 16,881.6 | 17,410.7 | 17,608.2 |
| Total $CO_2$ emission with LULUCF | 16,480.4 | 12,705.0 | 15,213.5 | 13,950.6 | 11,925.3 | 11,002.7 | 11,480.2 | 12,534.2 |

**ENERGY SECTOR**

This sector covers all activities that involve fuel consumption from stationary and mobile sources, and fugitive emission from fuels. Fugitive emission arises from production, transport, processing, storage and distribution of fossil fuels. The Energy sector is the main source of the anthropogenic GHG emission with a share of 91.6 % in total $CO_2$ emission (presented as $CO_2$ emission without LULUCF). $CO_2$ emission from fuel combustion and fugitive emissions makes the largest part of $CO_2$ emission. Emission by sub-sectors is presented in Table ES.3.2-2.

Table ES.3.2-2: $CO_2$ emission by sub-sectors from 1990-2022 (kt $CO_2$)

| GHG source categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Energy industries | 7,065.8 | 5,810.9 | 6,810.0 | 5,877.3 | 4,718.8 | 3,661.1 | 3,731.0 | 4,062.7 |
| Manufacturing industries and construction | 5,103.0 | 3,052.8 | 3,681.1 | 2,983.8 | 2,201.8 | 2,392.6 | 2,418.1 | 2,313.1 |
| Transport | 3,787.1 | 4,354.4 | 5,467.7 | 5,865.8 | 5,887.8 | 5,732.1 | 6,194.9 | 6,667.3 |
| Other sectors | 3,719.0 | 3,418.4 | 3,898.2 | 3,506.2 | 2,719.8 | 2,727.2 | 2,858.6 | 2,722.5 |
| Fugitive emissions from fuels | 582.5 | 711.4 | 756.7 | 541.5 | 249.5 | 288.2 | 283.9 | 356.1 |
| Total $CO_2$ emission | 20,257.4 | 17,347.9 | 20,613.7 | 18,774.7 | 15,777.7 | 14,801.2 | 15,486.4 | 16,121.6 |

Emission calculation is based on fuel consumption data recorded in annual national energy balance, where the fuel consumption and supply is presented at the sufficient level of detail which enables more detailed calculation by sub-sectors in the framework of the formal IPCC methodology (i.e. Sectoral approach).

The energy most intensive stationary sub-sector is Energy Industries (electricity and heat production, refineries and oil and gas field combustion). In the framework of the sub-sector Manufacturing Industries and Construction, the largest $CO_2$ emissions are the result of fuel combustion in industry of construction material and petrochemical production, followed by food processing industry, chemical industry, industry of pulp, paper and print, iron and steel industry and non-ferrous metal industry. Furthermore, this sub-sector includes electricity and heat production in the manufacturing industry for manufacturing processes.

Transport sector is also one of the more important $CO_2$ emission sources. This sector includes emission from road transport, civil aviation, railways and navigation. In the year 2022, the $CO_2$ emission from the Transport sector contributed with 37.9 % to the national total $CO_2$ emission. The largest part of the $CO_2$ emission from the Transport sector arises from road transport (97.5 % of $CO_2$ emission from the transport sector in 2022) followed by national navigation, domestic civil aviation and railways.

Biomass combustion (fuelwood and waste wood, biodiesel, biogas) also results in greenhouse gas emissions. $CO_2$ emission from biomass is not included in balance according to the Guidelines, due to assumption that life-cycle $CO_2$ emitted is formerly absorbed for the growth of biomass. Sinks or $CO_2$ emissions resulted in change of forest biomass is calculated in the LULUCF sector.

Fugitive GHG emission from coal, liquid fuels and natural gas, resulted from exploration of minerals, production, processing, transport, distribution and activities during mineral use is also included in this sector.

## INDUSTRIAL PROCESSES AND PRODUCT USE

The GHG emission is a by-product in various industrial processes, where the raw material is chemically transformed into final product. Industrial processes where the contribution to $CO_2$ emission is identified as relevant are the production of cement, lime, ammonia, as well as the use of limestone and soda ash in various industrial activities.

General methodology used for emission calculation from industrial processes, recommended by the IPCC, includes multiplying the annual produced or consumed amount of a product or material with the appropriate emission factor per unit of this production or consumption. Annual production or consumption data for particular industrial processes are in most cases collected by a direct survey of manufacturers. The results of the $CO_2$ emission calculation for industrial processes are shown in Table ES.3.2-3.

Table ES.3.2-3: $CO_2$ emission from Industrial Processes and product use for the period from 1990-2022 (kt $CO_2$)

| GHG source categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Mineral industry | 1,297.6 | 1,426.4 | 1,809.9 | 1,403.7 | 1,306.4 | 1,359.3 | 1,372.3 | 1,255.5 |
| Chemical industry | 751.1 | 704.4 | 663.6 | 615.4 | 572.3 | 535.3 | 365.5 | 83.9 |
| Metal industry | 336.4 | 29.7 | 12.7 | 14.7 | 9.3 | 4.9 | 14.3 | 13.4 |
| Non-energy products from fuels and solvent use | 181.5 | 76.9 | 112.4 | 89.8 | 68.0 | 85.6 | 80.0 | 73.1 |
| Total $CO_2$ emission | 2,566.6 | 2,237.4 | 2,598.6 | 2,123.5 | 1,955.9 | 1,985.2 | 1,832.0 | 1,425.9 |

The most significant $CO_2$ industrial processes emission sources are the production of cement, ammonia and lime. In 2022, the mineral industry contributes to total sectoral $CO_2$ emission with 88.1 % and chemical industry with 5.9 %. Generally, $CO_2$ emissions from industrial processes declined from 1990 to 1995, due to the decline in industrial activities caused by the war in Croatia, while in the period 1996-2008 emissions slightly increased. Production of iron and aluminium was stopped in 1992. A decrease of economic activities after 2008 influenced a reduction in cement, lime, ammonia and steel productions. In 2022, $CO_2$ emissions from industrial processes decreased by 22.2 %, regarding the year 2021.

### ES.3.2.2. Methane emission ($CH_4$)

The major sources of methane ($CH_4$) emission are fugitive emission from production, processing, transportation and activities related to fuel use in Energy sector, Agriculture and Waste Disposal on Land. In Table ES.3.2-4, sectoral and total $CH_4$ emissions are reported.

Table ES.3.2-4: $CH_4$ emission in Croatia in the period from 1990-2022 (kt $CH_4$)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Energy | 33.32 | 23.35 | 26.80 | 26.73 | 23.48 | 20.36 | 21.30 | 19.59 |
| Industrial processes | 0.37 | 0.14 | 0.15 | 0.11 | NO,NE,IE, NA | NO,NE,IE, NA | NO,NE,IE, NA | NO,NE,IE, NA |
| Agriculture | 101.00 | 64.22 | 70.72 | 67.29 | 61.23 | 54.09 | 53.61 | 50.43 |
| LULUCF | 0.05 | 3.88 | 0.11 | 0.07 | 0.56 | 1.30 | 0.23 | 1.33 |
| Waste | 44.19 | 51.93 | 55.23 | 69.10 | 73.95 | 68.34 | 63.52 | 65.58 |
| Other | NO | NO | NO | NO | NO | NO | NO | NO |
| Total $CH_4$ emission | 178.93 | 143.51 | 153.01 | 163.31 | 159.22 | 144.10 | 138.66 | 136.93 |

In the Agricultural sector, there are two significant methane emission sources present: enteric fermentation in the process of digestion of ruminants (dairy cows represent the major source) and different activities related with storage and use of organic fertilizers (manure management). The total methane emission for domestic animals is being calculated as a sum of emission from enteric fermentation and emission-related to manure management. The emission trend depends on the livestock population trend.

Methane emission from solid waste disposal sites (SWDSs) is a result of anaerobic decomposition of organic waste by methanogenic bacteria. The amount of methane emitted during the process of decomposition is directly proportional to the fraction of degradable organic carbon (DOC) which is defined as carbon content in different types of organic biodegradable wastes. As for the Wastewater treatment and discharge in Croatia, aerobic biological process is used mostly in wastewater treatment. Anaerobic process is applied in some industrial wastewater treatment, which results in $CH_4$ emissions. Disposal of domestic and commercial wastewater, particularly in rural areas where systems such as septic tanks are used, are partly anaerobic without flaring, which results with $CH_4$ emissions. In addition, direct discharge of untreated wastewater results in indirect $CH_4$ emissions. Low methane emissions originate from the categories Biological treatment of solid waste - composting and anaerobic digestion at biogas facilities, and Open burning of waste.

### ES.3.2.3. Nitrous oxide emission ($N_2O$)

The most important sources of $N_2O$ emissions in Croatia are agricultural activities, nitric acid production, but as well, the $N_2O$ emissions occur in the energy sector and waste management. In Table ES.3.2-5 the $N_2O$ emission is reported according to sectors.

Table ES.3.2-5: $N_2O$ emission in Croatia for the period from 1990-2022 (kt $N_2O$)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Energy | 0.84 | 0.96 | 0.82 | 0.79 | 0.70 | 0.72 | 0.75 | 0.76 |
| Industrial processes | 2.65 | 2.45 | 2.24 | 2.66 | 1.11 | 0.29 | 0.20 | 0.11 |
| Agriculture | 5.84 | 4.66 | 4.89 | 4.39 | 3.79 | 4.12 | 4.13 | 3.76 |
| LULUCF | 0.17 | 0.38 | 0.29 | 0.48 | 0.64 | 0.69 | 0.60 | 0.64 |
| Waste | 0.24 | 0.25 | 0.28 | 0.31 | 0.34 | 0.36 | 0.37 | 0.37 |
| Other | NO | NO | NO | NO | NO | NO | NO | NO |
| Total $N_2O$ emission | 9.73 | 8.69 | 8.53 | 8.62 | 6.59 | 6.18 | 6.05 | 5.64 |

In the Agricultural sector, three $N_2O$ emission sources are determined: direct $N_2O$ emission from agricultural soils, direct $N_2O$ emission from livestock farming and indirect $N_2O$ emission induced by agricultural activities. According to IPCC methodology, the mineral nitrogen, nitrogen from organic fertilizers, amount of nitrogen in fixing crops, amount of nitrogen which is released from crop residue mineralization, soil nitrogen mineralization due to cultivation of histosols and amount of nitrogen from the application of sewage sludge is separately analyzed.

In Industrial Processes sector, the $N_2O$ emission occurs in nitric acid production, which is used as a raw material in nitrogen mineral fertilizers. In the framework of the $N_2O$ reduction measure analysis, the possibility for application of non-selective catalytic reduction device was considered, whereby the nitric acid production influence on $N_2O$ emissions would be practically eliminated.

In the Energy sector, the emission was calculated on the basis of fuel consumption and adequate emission factors (IPCC). The major sources of $N_2O$ emission in the Energy sector is the use of three-way catalytic converters in road transport motor vehicles.

$N_2O$ emission from the Waste sector indirectly occurs from human sewage. It is calculated based on the total number of inhabitants and annual protein consumption per inhabitant. Data on the annual per capita Protein Intake Value were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. Low $N_2O$ emissions originate from the categories Biological treatment of solid waste - composting and Open burning of waste.

### ES.3.2.4. Halogenated carbons (HFC, PFC), $SF_6$ and $NF_3$ emissions

Synthetic GHGs include halogenated carbons (HFCs and PFCs) and sulphur hexafluoride ($SF_6$). Although on an absolute scale their emissions are not great, due to their high global warming potential (GWP) their contribution to global warming is considerable. MESD is responsible for the monitoring of consumption of substitutes and a mixture of substitutes for gases that deplete the ozone layer. There is no production of HFCs PFCs, $SF_6$ and $NF_3$ in Croatia; therefore, all quantities of these gases are imported. Minor quantities of some substances are exported.

Croatia is an Article 5 country, according to the Montreal protocol, and has a longer period for using CFC, HCFC and halons. Because of that, Croatia started using HFCs 10 years later than other Annex I countries. According to survey carried out among major agents, users and consumers of these gases, information related to consumption of HFCs, PFCs, $SF_6$ and $NF_3$ (provided by the MESD) was used for emission calculation which is presented in kt of $CO_2$-eq and showed in Table ES.3.2-6.

Table ES.3.2-6: HFCs, PFCs and $SF_6$ emission in the period from 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Emissions of HFC, PFC | 1,117.28 | 49.40 | 186.49 | 563.88 | 944.27 | 1,572.23 | 1,697.01 | 1,812.05 |
| Emissions of $SF_6$ | 11.06 | 12.72 | 14.70 | 10.13 | 5.75 | 9.35 | 9.63 | 10.00 |
| $NF_3$ emission | NO | NO | NO | NO | NO | NO | NO | NO |
| Total | 1,128.3 | 62.1 | 201.2 | 574.0 | 950.0 | 1,581.6 | 1,706.6 | 1,822.1 |

# ES.4. Other information (e.g. indirect GHGs)

The photochemically active gases, carbon monoxide (CO), oxides of nitrogen ($NO_X$) and non-methane volatile organic compounds (NMVOCs) indirectly contribute to the greenhouse gas effect. These are generally called indirect greenhouse gases or ozone precursors because they are involved in the creation and degradation of ozone which is also one of the greenhouse gases. Sulphur dioxide ($SO_2$), as a precursor of sulphate and aerosols, is believed to contribute negatively to the greenhouse effect. Emissions of indirect GHGs have been taken from the draft of emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution'.The calculations of aggregated results for the emissions of indirect gases in the period 1990-2022 are given in table ES.4.1-1.

Table ES.4.1-1: Emissions of ozone precursors and $SO_2$ by sectors (kt)

| Pollutants | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| NOx Emission | 100.03 | 86.84 | 81.58 | 65.82 | 53.61 | 44.30 | 44.49 | 44.95 |
| Energy | 94.19 | 78.14 | 75.84 | 61.18 | 49.74 | 39.65 | 40.82 | 41.54 |
| Industrial Processes | 2.66 | 2.53 | 2.29 | 1.52 | 1.03 | 0.94 | 0.65 | 0.14 |
| Agriculture | 2.79 | 3.07 | 3.15 | 2.84 | 2.27 | 2.57 | 2.66 | 2.66 |
| LULUCF | 0.04 | 2.89 | 0.09 | 0.05 | 0.36 | 0.98 | 0.22 | 0.46 |
| Waste | 0.35 | 0.22 | 0.21 | 0.23 | 0.20 | 0.16 | 0.15 | 0.15 |
| CO Emission | 558.62 | 550.33 | 415.14 | 328.88 | 279.92 | 244.23 | 232.85 | 216.50 |
| Energy | 512.05 | 426.71 | 392.27 | 323.87 | 266.24 | 211.56 | 224.84 | 203.64 |
| Industrial Processes | 39.91 | 30.12 | 17.37 | 0.18 | 0.21 | 0.08 | 0.31 | 0.29 |
| Agriculture | NO | NO | NO | NO | NO | NO | NO | NO |
| LULUCF | 0.74 | 90.40 | 2.62 | 1.63 | 10.71 | 30.38 | 5.65 | 10.57 |
| Waste | 5.93 | 3.09 | 2.89 | 3.20 | 2.76 | 2.21 | 2.04 | 2.00 |
| NMVOC Emission | 164.28 | 106.37 | 109.40 | 88.00 | 69.35 | 70.08 | 66.08 | 60.29 |
| Energy | 66.52 | 57.69 | 52.42 | 42.93 | 33.76 | 26.41 | 27.87 | 25.76 |
| Industrial Processes | 86.10 | 31.11 | 46.28 | 33.85 | 23.55 | 30.36 | 27.42 | 23.45 |
| Agriculture | 10.83 | 8.71 | 9.42 | 9.56 | 9.34 | 9.02 | 8.85 | 8.85 |
| LULUCF | 0.10 | 7.94 | 0.21 | 0.15 | 0.92 | 2.66 | 0.45 | 0.75 |
| Waste | 0.72 | 0.92 | 1.07 | 1.50 | 1.78 | 1.63 | 1.49 | 1.47 |
| SO2 Emission | 169.68 | 60.00 | 58.36 | 34.98 | 15.52 | 5.88 | 5.10 | 5.47 |
| Energy | 168.95 | 59.55 | 57.94 | 34.97 | 15.51 | 5.87 | 5.08 | 5.46 |
| Industrial Processes | 0.72 | 0.44 | 0.41 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 |
| Agriculture | NA | NA | NA | NA | NA | NA | NA | NA |
| LULUCF | NA | NA | NA | NA | NA | NA | NA | NA |
| Waste | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

Although Parties may now choose to report indirect $CO_2$, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, Croatia does not choose to report indirect $CO_2$ emissions from the atmospheric oxidation of $CH_4$, CO and NMVOCs, or indirect $N_2O$ emissions arising from sources other than those in the agriculture and LULUCF sectors.

# ES.5. Key category analysis

According to the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, key categories are those which represent 95% (Tier 1) or 90% (Tier 2) of the total annual emissions in the last reported year or belonging to the total trend, when ranked from contributing the largest to smallest share in annual total and in the trend.

Summary table with the key categories identified for the latest reporting year (by level and trend) on the basis of table 4.4 of volume 1 of the 2006 IPCC Guidelines is provided in Table 1.5-1.

Table ES.5.1-1: Key categories summary table for 2022

| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, year = 2022) | | | | | | | |
|---|---|---|---|---|---|---|---|
| A<br>IPCC Source Categories | B<br>GHG | C<br>Key | D<br>If Column C is Yes, Criteria for Identification | | | | E<br>Com. |
| **1. Energy** | | | | | | | |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Solid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Biomass | $N_2O$ | Yes | | T2e | | | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.3.b Road Transportation | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.3.b Road Transportation | $N_2O$ | Yes | L2e | | | | |
| 1.A.3.d Domestic Navigation - Liquid Fuels | $CH_4$ | Yes | L1e | | | | |
| 1.A.4 Other Sectors - Biomass | $CH_4$ | Yes | L1e L2e | T2e | L1i L2i | | |
| 1.A.4 Other Sectors - Biomass | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Solid Fuels | $CO_2$ | Yes | | T1e T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CO_2$ | Yes | | T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CH_4$ | Yes | | T1e T2e | | T1i T2i | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CH_4$ | Yes | L2e | T2e | | | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CO_2$ | Yes | L1e L2e | | L1i L2i | | |
| **2. Industrial processes and product use** | | | | | | | |
| 2.A.1 Cement Production | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 2.B.1 Ammonia Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.B.2 Nitric Acid Production | $N_2O$ | Yes | | T1e | | T1i | |
| 2.B.8 Petrochemical and Carbon Black Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.2 Ferroalloys Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.3 Aluminium Production | $CO_2$ | Yes | | | | T1i | |
| 2.C.3 Aluminium Production | PFCs | Yes | | T1e | | T1i | |
| 2.F.1 Refrigeration and Air conditioning | F-gases | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| **3. Agriculture** | | | | | | | |
| 3.A Enteric Fermentation | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 3.B Manure Management | $CH_4$ | Yes | L1e, L2e | | L1i | T1i | |
| 3.B Manure Management | $N_2O$ | Yes | | T1e T2e | L2i | T1i T2i | |
| 3.D.1 Direct $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | L1e L2e | T2e | L1i L2i | T1i T2i | |
| 3.D.2 Indirect $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | L1e L2e | T2e | L1i L2i | T2i | |
| **4. Land use land use change and forestry** | | | | | | | |
| 4(III) Direct $N_2O$ emissions from N mineralization/immobilization | $N_2O$ | Yes | | | L1i | T1i T2i | |
| 4(V) Biomass Burning | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.A.1 Forest Land Remaining Forest Land | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.A.2 Land Converted to Forest Land | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.B.1 Cropland Remaining Cropland | $CO_2$ | Yes | | | L1i L2i | T2i | |
| 4.B.2 Land Converted to Cropland | $CO_2$ | Yes | | | L2i | T2i | |
| 4.C.2 Land Converted to Grassland | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.D.2 Land Converted to Wetlands | $CO_2$ | Yes | | | | T2i | |
| 4.E.2 Land Converted to Settlements | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.G Harvested Wood Products | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| **5. Waste** | | | | | | | |
| 5.A Solid Waste Disposal | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 5.D Wastewater Treatment and Discharge | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 5.D Wastewater Treatment and Discharge | $N_2O$ | Yes | L2e | T2e | | | |

L1e - Level excluding LULUCF Tier 1
L2e - Level excluding LULUCF Tier 2
L1i - Level including LULUCF Tier 1
L2i - Level including LULUCF Tier 2

T1e - Trend excluding LULUCF Tier 1
T2e - Trend excluding LULUCF Tier 2
T1i - Trend including LULUCF Tier 1
T2i - Trend including LULUCF Tier 2

Key category analysis is provided by CRF Application too. Although there are differences between the two analyses, large key sources were identified in both analyses. Some categories in CRF analysis differed from categories which are provided in 2006 IPCC Guidelines for key category analysis so detailed comparison between them was not possible to make.

# ES.6. Improvements introduced

Impovements which were performed in NIR 2024 are given in table ES.6-1.

Table ES.6.1-1: Recalculations performed in 2024 for $CO_2$, $CH_4$ and $N_2O$

| Sector | GHG | Year | Explanation for recalculations |
|---|---|---|---|
| **1. Energy** | | | |
| A. Fuel combustion activities | NO | NO | NO |
| 1. Energy industries | NO | NO | NO |
| 2. Manufacturing industries and construction | $CO_2$, $CH_4$, $N_2O$ | 2019-2021 | In 2024 cycle there were recalculations in 1A2gvii Off road vehicless category. It was noticed that fuel consumptions are wrong calculated in Industry analysis balance. |
| 3. Transport | $CH_4$, $N_2O$ | 1990-2021 | Usage of new Copert version. |
| 4. Other sectors | NO | NO | NO |
| 5. Other | NO | NO | NO |
| B. Fugitive Emissions from Fuels | NO | NO | NO |
| 1. Solid fuels | NO | NO | NO |
| 2. Oil and natural gas | NO | NO | NO |
| C. $CO_2$ transport and storage | NO | NO | NO |
| **2. Industrial processes and product use** | NO | NO | |
| A. Mineral industry | NO | NO | NO |
| B. Chemical industry | NO | NO | NO |
| C. Metal industry | $CO_2$ | 1990-2021 | Data harmonization with the IIR. |
| D. Non-energy products from fuels and solvent use | HFC-134a | 1995-2021 | Errors in previous estimates were found and corrected. |
| G. Other product manufacture and use | NO | NO | NO |
| H. Other | NO | NO | NO |
| **3. Agriculture** | | | |
| A. Enteric fermentation | $CH_4$ | 2016-2019 | Correction of AD |
| B. Manure management | $CH_4$, $N_2O$ | 2016-2019, 2021 | Correction of AD<br>Correction of AD and EF parameters (y2021 only) |
| C. Rice cultivation | NO | NO | NO |
| D. Agricultural soils | $N_2O$ | 2016-2019, 2021 | Correction of AD (animal population) |
| E. Prescribed burning of savannahs | NO | NO | NO |
| F. Field burning of agricultural residues | NO | NO | NO |
| G. Liming | NO | NO | NO |
| H. Urea application | $N_2O$ | 2021 | Correction of AD |
| I. Other carbon-containing fertilizer | NO | NO | NO |

| Sector | GHG | Year | Explanation for recalculations |
|---|---|---|---|
| J. Other | NO | NO | NO |
| **4. Land use, land-use change and forestry (net) (4)** | | | |
| A. Forestland | $CO_2$ | 1990-2021 | New data delivered by Croatian Forest ltd on forest areas afforested before year 1990. |
| B. Cropland | NO | NO | NO |
| C. Grassland | $N_2O$ | 1990-2021 | $N_2O$ emission factor for the mineral soil in CL-GL was corrected from 298 to 265 |
| D. Wetlands | NO | NO | NO |
| E. Settlements | NO | NO | NO |
| F. Other land | NO | NO | NO |
| G. Harvested wood products | $CO_2$ | 2021 | Changes in CSC in HWP pool for 2021 due to the new input data on Roundwood import and export quantities delivered by the Ministry of Agriculture. |
| H. Other | NO | NO | NO |
| **5. Waste** | | | |
| A. Solid waste disposal | $CH_4$ | 1990 - 2021 | New activity data and CS DOC are included. |
| B. Biological treatment of solid waste | $CH_4$, $N_2O$ | 1994 - 2021 | New activity data are included. |
| C. Incineration and open burning of waste | NO | 2021 | New activity data are included. |
| D. Waste water treatment and discharge | NO | 1990 - 2021 | New activity data are included. |
| E. Other | NO | NO | NO |
| **6. Other** | NO | NO | NO |

# Chapter 1: Introduction

## 1.1 Background information on GHG inventories and climate change

### 1.1.1. Background information on climate change in Croatia

Climate change in Croatia was determined by estimating the trends in annual and seasonal mean air temperature and precipitation amounts; and the associated indices of extremes from the data spanning the period 1961 - 2020. The analyses was based on data from 37 series of mean, minimum and maximum daily temperature and 195 series of daily precipitation amount from Croatian Meteorological and Hydrological Service meteorological station network.

Trends in air temperature (mean, mean minimum and mean maximum temperature) in the last 60-year period show significant warming all over Croatia. They are positive and statistically significant, with the highest changes (up to 0.5 ° C / 10 yrs) detected in the central mainland. The overall positive trend in air temperature is mainly due to the summer trends (ranging from 0.35 ° C to 0.67 ° C / 10 yrs), and due to an increase of winter mean air temperature in the central mainland (0.43 ° C to 0.59 ° C / 10 yrs). The observed warming is also evident in all indices of temperature extremes, revealing positive trends in the warm indices (i.e., increased number of warm days and warm nights and longer warm spell duration), and negative trends in the cold indices (i.e., less number of cold days and cold nights and shorter cold spell duration).

The warmest year in Croatia during the 1961 - 2020 period was 2019 with the mean daily temperature of 13.5 ° C, which is 1.6 ° C above the 1981 - 2010 climate normal. The coldest year was 1980 with the average temperature of 10.6 °C and with anomaly of -1.4 °C. In the last 60 years, each decade was gradually warmer, and the last decade (2011 - 2020) was 1.7 ° C warmer than the first one (1961 - 1970). Moreover, among the 10 hottest years, seven of them belong to the last decade.

A significant decrease in summer precipitation amounts along the Adriatic coast and the mountainous region (5% - 15% / 10 yrs) was detected, in the letter one a significant decrease was observed also in the spring season (5% - 10% / 10 yrs). On the other hand, the autumn precipitation amount trend has a positive sign over Croatia, and it is statistically significant in the central parts of the mainland (5% -10% / 10 yrs). No statistically significant changes were detected in the winter months, though a weak negative trend prevails in eastern Croatia and Dalmatia, and a positive one elsewhere. There is a statistically significant decrease of annual precipitation amount in the mountainous region, while the direction and magnitude of trends are not spatially consistent in other regions.

The annual and seasonal precipitation trend pattern is the result of detected changes in the the indices of precipitaiton extremes. The most prominent feature is the significant increase in annual dry spell duration index (defined as a consecutive sequence of days with precipitation below 10 mm, CDD10) in the western mainland ( up to 4 days / 10 yrs) and along Adriatic region (up to 8 days / 10 yrs) while a decrease in CDD10 was detected in the eastern mainland (up to 5 days / 10 yrs). Letter one is a consequence of the significant decrease during the winter season. In addition, in the western mainland, in the highlands and at the northern Adriatic region statistically significant increase is observed in the fraction of precipitation due to very wet days and in the simple daily intensity index (5% - 10% / 10 yrs).

Summer drying is revealed in a significant decrease (up to 20% / 10 yrs) in the frequency of moderate wet days along the northern Adriatic coast and the highlands. In the mountainous littoral and central hinterland, there is an increasing trend in the number of dry days accompanied by a decreasing trend in the simple daily precipitation intensity (5% - 10% / 10 yrs) as well as in the maximum daily and five-day precipitation amounts (5% - 15% / 10 yrs). In the northern Adriatic, a significant increase in dry spell duration (CDD10) was also detected (up to 15% / 10 yrs).

Autumn wet conditions are associated with a significant increase in precipitation fraction due to very wet days (15% - 25% / 10 yrs) in central Croatia, and a decrease in the duration of dry spells (CDD1) in the northern Adriatic and western mainland (10% -15% / 10 yrs). In the mainland, a significant increase (5% - 10% / 10 yrs) in the daily intensity index and maximum 1- and 5- day precipitation amounts are found.

In spring, a significant increase (5% - 10% / 10 yrs) in the dry spell duration (CDD1) was found in the northern Adriatic according to the increase in the number of dry days. In the western mainland and the highlands, a statistically significant decreasing trend in moderately wet days (5% - 10% / 10 yrs) was detected, whereas in eastern Croatia trend toward longer wet spells (CWD10) was found.

### 1.1.2. Background information on greenhouse gas (GHG) inventories

The Republic of Croatia became a party to the United Nations Framework Convention on Climate Change (UNFCCC) on 17 January 1996 when the Croatian Parliament passed the law on its ratification (Official Gazette, International Treaties No. 2/96). For the Republic of Croatia, the Convention came into force on 7 July 1996. As a country undergoing the process of transition to market economy, Croatia has, pursuant to Article 22, paragraph 3 of the Convention, assumed the commitments of countries included in Annex I. By the amendment that came into force on 13 August 1998 Croatia was listed among Parties included in Annex I to the Convention.

The adoption of the Decision 7/CP.12 by the Conference of Parties was acknowledged by the Croatian Parliament which ratified the Kyoto Protocol on 27 April 2007 (Official Gazette, International Treaties No. 5/07). The Kyoto Protocol has entered into force in Croatia on 28 August 2007. Initial Report for the first commitment period of the Republic of Croatia under the Kyoto Protocol was submitted in August 2008.

One of the commitments outlined in Article 4, paragraph 1 of the UNFCCC is that Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties.

Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia (Official Gazette No. 5/17) prescribe obligation and procedure for emissions monitoring, which comprise estimation and/or reporting of all anthropogenic emissions and removals. Monitoring of GHG gases is stipulated by Article 20 of the Act on Climate Change and Ozone Layer Protection (Official Gazette No. 127/19).

In this NIR, the inventory of the emissions and removals of the greenhouse gases (GHG) is reported for the period from 1990 to 2022. The NIR is prepared in accordance with the UNFCCC reporting guidelines on annual Inventories as adopted by the COP by its Decision 24/CP.19. The methodologies used in the calculation of emissions are based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC Good Practice Guidance) prepared by the Intergovernmental Panel on Climate Change (IPCC). As recommended by the IPCC Guidelines country-specific methods have been used where appropriate and where they provide more accurate emission data. The important part of the inventory preparation is the uncertainty assessment of the calculation and verification of the input data and results, all this with the aim to increase the quality and reliability of the calculation.

Furthermore, since the introduction of annual technical reviews of the national inventories by experts review teams (ERT), Croatia has undergone fifteen reviews so far, in-country review in 2004, 2007, 2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016, 2020 and 2022. Issues recommended by the ERT have been included in this report as far as possible.

Except of UN reviews, from 2013 (after Croatia become one of EU countries) European commission conducts reviews of NIR each year.

The calculation includes the emissions which are the result of anthropogenic activities and these include the following greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), halogenated carbons (HFCs, PFCs), sulphur hexafluoride ($SF_6$), nitrogen fluoride ($NF_3$) and indirect greenhouse gases: carbon monoxide (CO), oxides of nitrogen ($NO_x$), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide ($SO_2$). The greenhouse gases covered by the Montreal Protocol on the pollutants related to ozone depletion (freons) are reported in the framework of this protocol and therefore are excluded from this Report.

Greenhouse gas emission sources and sinks are divided into five main sectors: Energy, Industrial Processes and Product Use, Agriculture, Land Use, Land-Use Change and Forestry and Waste. Generally, the methodology for emission calculation could be described as a product of the particular activity data (e.g. fuel consumption, cement production, number of animals, increase of wood stock etc.) with corresponding emission factors. The use of specific national emission factors is recommended wherever possible and justified, whereas, on the contrary, the methodology gives typical values of emission factors for all relevant activities of the particular sectors.

### 1.1.3. Changes in the national system

Changes to institutional, legal and procedural arrangements (24/CP.19, 22. (a))

There have been no changes since the last submission.

Changes in staff and capacity (24/CP.19, 22. (b))

Authorised Institution for preparation of 2024 inventory submission stayed the same securing the long-term experience built up over the past years.

Changes to national entity with overall responsibility for the inventory (24/CP.19, 22. (c))

There have been no changes since the last submission.

Changes to the process of inventory planning (24/CP.19, 22.(d,e)/23./24.):

There have been no changes since the last submission.

Changes to the process of inventory preparation (24/CP.19, 25./26.):

There have been no changes since the last submission.

Changes to the process of inventory management (24/CP.19, 27.):

There have been no changes since the last submission.

## 1.2. A description of the national inventory arrangements

### 1.2.1. National entity or national focal point

The National system for Croatia fulfils the requirements, as set forth by both UNFCCC decisions (Decision 24/CP.19 and Decision 19/CMP.1) and by the European Regulation no. 2018/1999 on the management of the energy union and action in the field of climate and Implementing Regulation no. 2020/1208 on the structure, format, submission procedures and revision of information submitted by member states in accordance with Regulation (EU) no. 2018/1999 of the European.

Functioning of Croatian national inventory system is stipulated by Act on Climate Change and Ozone Layer Protection (OG 127/19). Institutional arrangement for inventory preparation in Croatia is regulated in Chapter II of the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia (OG 5/17) entitled National system for the estimation and reporting of anthropogenic greenhouse gas emissions by sources and removals by sinks. Institutional arrangements for inventory management and preparation in Croatia could be characterized as decentralized and out-sourced with clear tasks breakdown between participating institutions including Ministry of Economy and Sustainable Development (MESD) and competent governmental bodies responsible for providing of activity data. The preparation of inventory itself is entrusted to Authorised Institution, which is elected for a three-year period by public tendering. Committee for inter-sectoral coordination for national system for monitoring of GHG emission (National System Committee) is included in the approval process; its members provide their opinion on certain parts of the Inventory within the frame of their speciality. Members of the National System Committee are nominated by the authorized Ministries upon the request of the MESD.

MESD is a national focal point for the UNFCCC, with overall responsibility for the functioning of the National system in a sustainable manner, including:

- mediation and exchange of data on GHG emissions and removals with international organisations and Parties to the Convention;
- mediation and exchange of data with competent bodies and organisations of the European Union in a manner and within the time limits laid down by legal acts of the European Union;
- control of methodology for emission calculation and GHG removal in line with good practices and national circumstances;
- consideration and approval of the Greenhouse Gas Inventory Report prior to its formal submission to the Convention Secretariat.
- organisation of GHG inventory preparation with the aim of MESDting the deadlines;
- collection of activity data;
- development of quality assurance and quality control plan (QA/QC plan) related to the GHG inventory in line with the guidelines on good practices of the Intergovernmental Panel on Climate Change;
- implementation of the quality assurance procedure with regard to the GHG inventory in line with the quality assurance and quality control plan;
- archiving of activity data on calculation of emissions, emission factors, and of documents used for inventory planning, preparation, quality control and quality assurance;
- maintaining of records and reporting on authorised legal persons participating in the Kyoto Protocol flexible mechanisms;
- selection of Authorised Institution (in Croatian: Ovlaštenik) for preparation of the GHG inventory;
- provide insight into data and documents for the purpose of technical reviews.

Authorised Institution is responsible for preparation of inventory, which include:

- emission calculation of all anthropogenic emissions from sources and removals by GHG sinks, and calculation of indirect GHG emissions, in line with the methodology stipulated by the effective guidelines of the Convention, guidelines of the Intergovernmental Panel on Climate Change, Instructions for reporting on GHG emissions as published on the Ministry's website, and on the basis of the activities data;
- quantitative estimate of the calculation uncertainty for each category of source and removal of GHG emissions, as well as for the inventory as a whole, in line with the guidelines of the Intergovernmental Panel on Climate Change;
- identification of key categories of GHG emission sources and removals;
- recalculation of GHG emissions and removals in cases of improvement of methodology, emission factors or activity data, inclusion of new categories of sources and sinks, or application of coordination/adjustment methods;
- calculation of GHG emissions or removal from mandatory and selected activities in the sector of land use, land-use change and forestry;
- reporting on issuance, holding, transfer, acquisition, cancellation and retirement of emission reduction units, certified emission reduction units, assigned amount units and removal units, and carry-over, into the next commitment period, of emission reduction units, certified emission reduction units and assigned amount units, from the Registry in line with the effective decisions and guidelines of the Convention and supporting international treaties;
- implementation of and reporting on quality control procedures in line with the quality control and quality assessment plan;
- preparation of the GHG inventory report, including also all additional requirements in line with the Convention and supporting international treaties and decisions;
- cooperation with the Secretariat’s ERTs for the purpose of technical review and assessment/evaluation of the inventory submissions.

EKONERG – Energy and Environmental Protection Institute was selected as Authorised Institution for preparation of 2024 inventory submission.

#### 1.2.1.1. Inventory planning, preparation and management

Process of inventory preparation encompasses several steps starting with activity data collection and followed by emissions estimation and recalculations in accordance with the IPCC methodology and recommendations for improvements from the ERT review reports, compilation of inventory including the NIR and the CRF and in parallel implementation of general and source-category specific quality control procedures.

Activity data collection is under the responsibility of MESD which represents a hub between governmental and public institutions responsible for providing the activity data and Authorised Institution responsible for inventory preparation. The scope and due dates for delivering activity data to MESD are prescribed by the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia. In addition, several operators from the energy and industrial sector were directly approached by the MESD for more detailed activity data since higher tier methods have been applied (see table 1.4-1 for details).

After activity data are collected and processed, inventory team performed emission estimations and recalculation in accordance with the IPCC methodology and taking into consideration recommendations for inventory improvements. Results are checked against quality control procedures in order to ensure data integrity, correctness and completeness.

#### 1.2.1.2. Quality assurance, quality control and verification plan

QA/QC PLAN

According to Article 7. of the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia, within the competence of MESD is the preparation of quality assurance and quality control plan regarding greenhouse gas inventory (hereinafter QA/QC plan), implementation of the quality assurance procedures in accordance with the QA/QC plan and archiving activity data for emission calculation, emission factors and documents used for planning, preparing, controlling and assuring Inventory quality. QA/QC plan is a part of quality assurance and quality control system (QA/QC system), stipulated by Decision 19/CMP.1 Guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol. Implementation of QA/QC system is based on the following documents: Annual Data Collection Plan (ADCP), QA/QC Plan, Category-specific QC checklist and Improvement Plan.

Annual data Collection Plan (ADCP) is the main document for data collection which is the responsibility of MESD. It contains source categories, activity, activity data, data source and competent authority and is made for each sector. This document is prepared annually in collaboration between MESD and National System Committee.

QA/QC plan describes overall responsibilities and roles of institutions involved in inventory planning, preparation and management, general timetable of activities for data collection, inventory preparation, inventory submission, internal audits, annual review and reporting on GHG registry and general and specific QA/QC procedures.

Improvement Plan is document which defines objectives related to the improvement of National Inventory. This document takes into account the key category analysis and recommendations outlined in the Annual review report. This document is prepared annually.

QA/QC plan follows the proposed cycle of activities and responsibilities:

| Activity | Responsibility |
|---|---|
| Preparation of the QA/QC plan<br>- Documentation revision and supplement | QA/QC coordinator (MESD) |
| Approval of the QA/QC plan | MESD |
| Implementation of QC procedures<br>- Internal audit<br>- Corrective and preventive activities<br>- Reporting on performed internal audit | QA/QC coordinator (MESD)<br>Sectoral experts (MESD),<br>Project leader in NIR preparation (MESD)<br>Project Coordinator (Authorized Institution)<br>Sectoral experts (Authorized Institution)<br>QA/QC coordinator (Authorized Institution) |
| Reporting on QC procedures | Authorized Institution |
| Implementation of QA procedures | MESD, National System Committee |

Quality control activities are focused on following elements of inventory preparation and submission process:

- Activity data collection and archiving;
- Preparation of inventory report;
- Submission of inventory report;
- Review activities;

- Reporting on GHG registry.

For the purposes of transparency of the emission calculation and archiving of data, inventory team has continued with the good practice in preparation of Inventory Data Record Sheets which were introduced in 2001 submission and which contain details of the person and/or organization responsible for an emission estimate, the primary or secondary sources of activity data and emission factors used, the methodology applied, data gaps, ways to cross-check, suggestion for future improvement in the estimates and relevant bibliographic references. The information provided in Inventory Data Record Sheets is available for each source category and for the entire time-series. An example of Inventory Data Record Sheet for 2022 in the Energy sector is presented in Annex 5, Table A5-1. All data in the form of Inventory Data Record Sheets are also archived at MESD.

During the preparation of the NIR, a number of checks were carried out by sector experts related to completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates. The details on these issues are elaborated in the NIR by each sector, subsector and corresponding CRF tables.

Before the Authorized Institution submits the NIR to MESD, QA/QC manager carried out an audit which covers selected IPCC source categories, as outlined in the QA/QC plan, with purpose to check which quality control elements, both general (Tier 1) and specific (Tier 2), as defined in the IPCC Good Practice Guidance, are already implemented by sector experts and which improvements and corrective actions should be carried out in the future submissions. CRF tables for each sector are reviewed in accordance with the Quality Management Standard (ISO 9001) and Environmental Management Standard (ISO 14001) implemented within the Authorized institution. Audit results are registered in control lists as well as performed correction activities.

National System Committee is included in the approval process; its members provide their opinion on certain parts of the Inventory within the frame of their speciality. QA/QC coordinator documents all National System Committee results/findings.

Finally, MESD approves and submits Inventory to the UNFCCC.

## VERIFICATION AND CONFIDENTIALITY ISSUES

The verification process of calculation is aimed at the improvement of the input quality and identification of the calculation reliability. The IPCC Guidelines recommend that inventories should be verified through the use of a set of simple checks for completeness and accuracy, such as checks for arithmetic errors, checks of country estimates against independently published estimates, checks of national activity data against international statistics and checks of $CO_2$ emissions from fuel combustion calculated using sectoral methods with the IPCC Reference Approach. Further verification checks may be done through comparison with other national inventory calculation data.

In the development of the Croatian inventory, certain steps and some of these checks were performed:

- Comparison with the national inventory data of other countries was conducted by comparing CRF tables or through a direct communication;
- Activity data were compared using different sources such as the Croatian Bureau of Statistics and individual emission sources;
- The $CO_2$ emissions from fossil fuel combustion, within the framework of IPCC methodology, are estimated using two approaches: (1) Reference Approach and (2) Sectoral Approach (Tier 1).

**TREATMENT OF CONFIDENTIALITY ISSUES**

In Croatian GHG Inventory, only data that refers to a single enterprise is in general confidential. In the National Inventory Report, for those activities, the activity data and emissions are aggregated on the subsector level.

### 1.2.1.3. Information on minimization of activities

According to paragraph 24 of the Annex to Decision 15/CMP.1 Parties included in Annex II, and other Parties included in Annex I that are in a position to do so, shall incorporate information on how they give priority, in implementing their commitments based on relevant methodologies referred to in paragraph 8 of decision 31/CMP.1. Considerations of possible impact of the implementation of response measures form part of the fully transparent process of impact assessments or sustainability impact assessments for EU legislative proposals or trade agreements respectively, such as specific proposals on climate action or cross-border sectoral measures including energy, transport, industry and agriculture.

According to Article 4, paragraphs 8 and 9 of the Convention Croatia strives to implement Kyoto commitments in a way which minimize adverse impact on developing countries. In continuation information on implementation of policies and measures that minimise adverse social, environmental and economic impacts on non-Annex I Parties is provided.

a) Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

The ongoing liberalization of the energy market is in line with EU policies and directives. No significant market distortions have been identified. Consumption taxes for electricity and fossil fuels were harmonized recently. The main instrument addressing externalities is the emission trading under the EU ETS.

b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies

In the Republic of Croatia, no subsidies for environmentally unsound and unsafe technologies have been identified.

c) Technological development of non-energy uses of fossil fuels

Republic of Croatia has not participated actively in activities of this nature.

d) Carbon capture and storage technology development

Republic of Croatia does not take part in any such activity.

e) Improvements in fossil fuel efficiencies

In 2017 The Fourth National Energy Efficiency Action Plan for the 2017- 2019 period has been drawn up in accordance with the template laid down by the European Commission, with which all EU Member States must comply. Measures for the period from 2017 to 2019 regarding energy efficiency are:

- supporting the use of renewable energy sources and energy efficiency by the Environmental Protection and Energy Efficiency Fund (the Fund),

- encouraging the use of renewable energy and energy efficiency through the Croatian Bank for Reconstruction and Development (HBOR),
- energy efficiency projects with repayment through savings (ESCOs),
- increasing energy efficiency in buildings
- energy audits in the industry,
- promoting energy efficiency in households and the services sector through project activities,
- labelling the energy efficiency of household appliances,
- metering and informative billing of energy consumption,
- eco-design of energy-using products.

In 2019 Integrated National Energy and Climate Plan for the Republic of Croatia for the period 2021-2030 has been drawn up in accordance with the template laid down by the European Commission. Measures for the period from 2021 to 2030 regarding fuel efficiency are:

- Energy efficiency obligation scheme for suppliers
- Promoting nearly-zero energy standard in buildings construction and refurbishment
- Energy renovation programme for multi-apartment buildings, single family houses, public sector buildings, heritage buildings
- Energy management system in the public sector
- Energy renovation programme for public lighting
- Green public procurement
- Energy management system in business (service & production) sector
- Informative bills
- Providing information on energy efficiency
- Energy efficiency education
- Integrated information system for monitoring energy efficiency
- Energy efficiency of the electricity transmission system
- Reduction of losses in the distribution network and introduction of smart grids
- Increasing efficiency of district heating system
- Increasing efficiency of the gas transport network

f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

As regards to the above-motioned activity, Republic of Croatia does not take part in any such activity.

### 1.2.2. Inventory preparation process

Process of inventory preparation encompasses several steps starting with activity data collection and followed by emissions estimation and recalculations in accordance with the IPCC methodology and recommendations for improvements from the ERT review reports, compilation of inventory including the NIR and the CRF and in parallel implementation of general and source-category specific quality control procedures.

Activity data collection is under the responsibility of MESD which represents a hub between governmental and public institutions responsible for providing the activity data and Authorised Institution responsible for inventory preparation. The scope and due dates for delivering activity data to MESD are prescribed by the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia. In addition, several operators from the energy and industrial sector were directly approached by the MESD for more detailed activity data since higher tier methods have been applied (see table 1.4-1 for details).

After activity data are collected and processed, inventory team performed emission estimations and recalculation in accordance with the IPCC methodology and taking into consideration recommendations for inventory improvements. Results are checked against quality control procedures in order to ensure data integrity, correctness and completeness.

Process of inventory preparation has been improved in recent submissions mainly as a result of activities carried out under the framework of two capacity-building projects, i.e.:

UNDP/GEF regional project "Capacity building for improving the quality of GHG inventories" in which following inventory related documents were prepared:

- National GHG Inventory Improvement Strategy
- National QA/QC plan
- National QA/QC guidance
- Manuals of procedures for compiling, archiving, updating and managing GHG Inventory
- Description of inventory archives
- Description of awareness-raising campaign
- Improvement of GHG emission calculation from road transport
- Improvement of methane emission calculations from waste disposal

EC LIFE Third Countries project "Capacity building for implementation of the UNFCCC and the Kyoto Protocol in the Republic of Croatia"

Furthermore, since the introduction of annual technical reviews of the national inventories by experts review teams (ERT), Croatia has undergone fifteen reviews so far, in-country review in 2004, 2007, 2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016, 2020 and 2022. Issues recommended by the ERT have been included in this report as far as possible.

Except of UN reviews, from 2013 (after Croatia become one of EU countries) European commission conducts reviews of NIR each year.

### 1.2.3. Archiving of information

For the purposes of transparency of the emission calculation and archiving of data, inventory team annually prepare Inventory Data Record Sheets which were introduced in 2001 submission and which contain details of the person and/or organization responsible for an emission estimate, the primary or secondary sources of activity data and emission factors used, the methodology applied, data gaps, ways to cross-check, suggestion for future improvement in the estimates and relevant bibliographic references. The information provided in Inventory Data Record Sheets is available for each source category and for the entire time-series. An example of Inventory Data Record Sheet for 2022 in the Energy sector is presented in Annex 5, Table A5-1. All data in the form of Inventory Data Record Sheets are also archived at MESD.

### 1.2.4. Processes for official consideration and approval of inventory

During the preparation of the NIR, a number of checks were carried out by sector experts related to completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates. The details on these issues are elaborated in the NIR by each sector, subsector and corresponding CRF tables.

Before the Authorized Institution submits the NIR to MESD, QA/QC manager carried out an audit which covers selected IPCC source categories, as outlined in the QA/QC plan, with purpose to check which quality control elements, both general (Tier 1) and specific (Tier 2), as defined in the IPCC Good Practice Guidance, are already implemented by sector experts and which improvements and corrective actions should be carried out in the future submissions. CRF tables for each sector are reviewed in accordance with the Quality Management Standard (ISO 9001) and Environmental Management Standard (ISO 14001) implemented within the Authorized institution. Audit results are registered in control lists as well as performed correction activities.

National System Committee is included in the approval process; its members provide their opinion on certain parts of the Inventory within the frame of their speciality. QA/QC coordinator documents all National System Committee results/findings.

Finally, MESD approves and submits Inventory to the UNFCCC.

## 1.3. Brief general description of methodologies (including tiers used) and data sources used

The methodologies from 2006 IPCC Guidelines for National GHG Inventories and Good Practice Guidance and Uncertainty Management in National GHG Inventories, recommended by the UNFCCC were used for emission estimations of greenhouse gases which are result of anthropogenic activities, i.e. $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$ and $NF_3$. Emissions of indirect GHGs have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution'.

Carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) are principal greenhouse gases and though they occur naturally in the atmosphere, their recent atmospheric build-up appears to be largely the result of human activities. Synthetic gases such as halogenated hydrocarbons (PFCs, HFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride ($NF_3$) are also considered as greenhouse gases and they are solely the result of human activities. The methodology does not include the CFCs which are the subject of the Montreal Protocol. In addition, there are other photochemically active gases such as carbon monoxide (CO), oxides of nitrogen (NOx) and non-methane volatile organic compounds (NMVOCs) that, although not considered as greenhouse gases, contribute indirectly to the greenhouse effect in the atmosphere. These are generally referred to as ozone precursors because they participate in the creation and destruction of tropospheric and stratospheric ozone (which is also GHG). Sulphur dioxide ($SO_2$), as a precursor of sulphate and aerosols, is believed to exacerbate the greenhouse effect because the creation of aerosols removes heat from the environment.

Generally, methodology applied to estimate emissions includes the product of activity data (e.g. fuel consumption, cement production, wood stock increment and so forth) and associated emission factor. The use of country-specific emission factors, if available, is recommended but these cases should be based on well-documented research. Otherwise, the 2006 IPCC Guidelines provides a methodology with default emission factors for different tiers. The emission estimates are divided into the following sectors: Energy, Industrial Processes and Product Use, Agriculture, Land Use, Land-Use Change and Forestry and Waste. A detailed description of the applied methodologies is described in sector-specific chapters of the NIR from 3 to 9 and an overview is given in the CRF tables Summary 3s1 - Summary 3s2.

The 2008 reporting cycle represents a transition from voluntary to in principal mandatory activity data collection system stipulated by the Regulation on the Monitoring of Greenhouse Gas Emissions in the Republic of Croatia (Official Gazette No. 01/07). Activity data sources for inventory preparation are presented in the Table 1.3-1, but more detailed information is given in sectoral chapters.

Table 1.3-1: Data sources for GHG inventory preparation

| CRF Sector/Sub-sector | Type of data | Source of data |
|---|---|---|
| Energy | Energy balance | - Ministry of Economy and Sustainable Development with assistance of Energy Institute Hrvoje Požar |
| | Registered motor vehicles database | - Ministry of the Interior |
| | Fuel consumption and fuel characteristic data for thermal power plants | - Pollution Emission Register MESD<br>- Verified reports of $CO_2$ emission<br>- Voluntary survey of Power Utility Company |
| | Fuel characteristic data | - Voluntary survey of Oil and Gas Company |
| | Natural gas processed (scrubbed), $CO_2$ content before scrubbing and $CO_2$ emission | - Voluntary survey of Central Gas Station |
| Industrial Processes | Activity data on production/consumption of material for a particular industrial process | - CBS, Industry, Energy and Information Society Department<br>- MESD<br>- 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution' |
| | Activity data on production/consumption of halogenated hydrocarbons (PFCs, HFCs) and sulphur hexafluoride ($SF_6$) | - MESD |
| | Data on consumption and composition of natural gas in ammonia production<br>Data on cement and lime production | - Survey of ammonia manufacturer<br>- Survey of cement and lime manufacturers<br>- MESD |
| Solvent and Other Product Use | Activity data on production for a particular source category and number of inhabitants | - 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution' |
| Agriculture | Livestock number | - CBS<br>- Ministry of Agriculture |
| | Production of N-fixing crops and non N-fixing crops | - CBS |
| | Area of histosols | - MESD |
| | Activity data on mineral fertilisers applied in Croatia | - Voluntary survey of Fertilizer Companies |
| | Activity data on sewage sludge applied | - MESD |
| LULUCF | Activity data on areas of different land use categories, annual increment and annual harvest and wildfires<br>Activity data on crop production | - Ministry of Agriculture with the assistance of public company "Hrvatske šume"<br>- MESD<br>- CBS |
| Waste | Activity data on solid waste disposal | - MESD |
| | Activity data on biological treatment of solid waste - composting | - MESD<br>- Composting facilities |
| | Activity data on biological treatment of solid waste - anaerobic digestion at biogas facilities | - MESD<br>- Biogas facilities |
| | Activity data on waste incineration | - MESD |
| | Activity data on open-burned waste | - Ministry of Agriculture<br>- CBS |
| | Activity data on wastewater treatment and discharge | - State company Croatian Water (Hrvatske vode)<br>- CBS<br>- FAOSTAT |

### 1.3.1. Usage of data from European Union greenhouse gas emission trading system (EU ETS)

Two main instruments of the European policy to reach greenhouse gas emission reduction goals are emissions trading system - EU ETS and national emission reduction targets in the sectors not covered by the EU ETS. European greenhouse gas emission reduction goals were formulated in two sets of binding legislation. 2020 climate and energy package sets the target for the year 2020 and that is a 20% reduction of greenhouse gas emissions from the 1990 level. 2030 climate and energy framework sets the target of 40% reduction of greenhouse gas emissions compared to 1990 level. Compared to 2005 emissions level EU ETS sectors would have to cut emissions by 43% and non-ETS sectors would have to cut emissions by 30% until 2030. While EU ETS target is to be reached collectively on the EU level, the non-ETS target is translated into individual binding targets for each Member State.

Croatia has been participating in the EU ETS since 2013 - the year of its accession to the European Union. This is also the year of the beginning of the Phase III (2013-2020) of the EU ETS. Therefore results of consistency examination between reported emissions and EU ETS data in Annex 5-6 can be presented only from 2013 onwards. Consistency checks are performed to draw conclusions regarding the completeness and consistency of the inventory.

From 2013 the representatives of the energy and manufacturing industry and aviation in Croatia that are covered by the EU ETS have an obligation to monitor greenhouse gas emissions from their installations and aircraft and to submit to the competent authority an annual emission report. Annual emission reports are verified by accredited independent verifiers. Prior to monitoring emissions, operators of stationary installations have to apply for the greenhouse gas emission permit which guarantees that the monitoring methodology applied is in line with monitoring and reporting rules.

The following EU ETS activities are represented in Croatia: combustion of fuels, refining of mineral oil, production of pig iron or steel, production of cement clinker, production of lime, manufacture of glass, manufacture of ceramic products, manufacture of mineral wool insulation materials, production of paper and cardboard, production of carbon black, production of nitric acid, production of ammonia and aviation. Majority of installations were included based on the combustion activity. Other installations were included in the trading system primarily based on their production activity, nevertheless, they also use fuels for the combustion. Greenhouse gases covered by the EU ETS that are represented in Croatia are $CO_2$ and $N_2O$, later resulting only from the production of nitric acid. There were around 50 EU ETS installations and two aircraft operators in Croatia in operation in 2022 responsible for approximately 35 % of total Croatian greenhouse gas emissions.

Monitoring methodologies laid down in the EU ETS monitoring and reporting rules are based on tiers implying a definition of different levels of required data accuracy. Low tiers are related to standard (default) values that can be selected from a predefined list of values mainly for emission factors and net calorific values. In contrast to low tier approach, application of high tiers requires determination of unique values for the specific fuel, material or product. If a high tier is required, the operator has to collect physical samples and apply analytical methods for determination of calculation factors – emission factors, net calorific values, oxidation factor, conversion factor, biomass fraction and carbon content. Generally, higher tiers are always required for installations with large emissions while low-emission installations are allowed to apply low tiers.

Annex 5-3 to this report contains parameters for fuels used in Croatia prepared exclusively for operators of the installations under the EU ETS. According to monitoring and reporting rules, for net calorific value, emission factor and oxidation factor operators have to apply under certain conditions standard factors used by the Member State for its national inventory submission. In fact, this is a tier higher than the tier for standard factors but lower than the tier which implies performing laboratory analyses. In order to provide operators with a complete list of factors, the table presented in Annex 5-3 was introduced. For calculating emissions in their annual emission reports operators use factor values from the table published in the latest national inventory.

## 1.4. Brief description of key categories

According to the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, key categories are those which represent 95% (Tier 1) or 90% (Tier 2) of the total annual emissions in the last reported year or belonging to the total trend, when ranked from contributing the largest to smallest share in annual total and in the trend.

Summary table with the key categories identified for the latest reporting year (by level and trend) on the basis of table 4.4 of volume 1 of the 2006 IPCC Guidelines is provided in Table 1.4-1.

Table 1.4-1: Key categories summary table for 2022

| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, year = 2022) | | | | | | | |
|---|---|---|---|---|---|---|---|
| A<br>IPCC Source Categories | B<br>GHG | C<br>Key | D<br>If Column C is Yes, Criteria for Identification | | | | E<br>Com. |
| **1. Energy** | | | | | | | |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Solid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Biomass | $N_2O$ | Yes | | T2e | | | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.3.b Road Transportation | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.3.b Road Transportation | $N_2O$ | Yes | L2e | | | | |
| 1.A.3.d Domestic Navigation - Liquid Fuels | $CH_4$ | Yes | L1e | | | | |
| 1.A.4 Other Sectors - Biomass | $CH_4$ | Yes | L1e L2e | T2e | L1i L2i | | |
| 1.A.4 Other Sectors - Biomass | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Solid Fuels | $CO_2$ | Yes | | T1e T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CO_2$ | Yes | | T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CH_4$ | Yes | | T1e T2e | | T1i T2i | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CH_4$ | Yes | L2e | T2e | | | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CO_2$ | Yes | L1e L2e | | L1i L2i | | |
| **2. Industrial processes and product use** | | | | | | | |
| 2.A.1 Cement Production | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 2.B.1 Ammonia Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.B.2 Nitric Acid Production | $N_2O$ | Yes | | T1e | | T1i | |
| 2.B.8 Petrochemical and Carbon Black Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.2 Ferroalloys Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.3 Aluminium Production | $CO_2$ | Yes | | | | T1i | |
| 2.C.3 Aluminium Production | PFCs | Yes | | T1e | | T1i | |
| 2.F.1 Refrigeration and Air conditioning | F-gases | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| **3. Agriculture** | | | | | | | |
| 3.A Enteric Fermentation | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 3.B Manure Management | $CH_4$ | Yes | L1e, L2e | | L1i | T1i | |
| 3.B Manure Management | $N_2O$ | Yes | | T1e T2e | L2i | T1i T2i | |
| 3.D.1 Direct $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | L1e L2e | T2e | L1i L2i | T1i T2i | |
| 3.D.2 Indirect $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | L1e L2e | T2e | L1i L2i | T2i | |
| **4. Land use land use change and forestry** | | | | | | | |
| 4(III) Direct $N_2O$ emissions from N mineralization/immobilization | $N_2O$ | Yes | | | L1i | T1i T2i | |
| 4(V) Biomass Burning | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.A.1 Forest Land Remaining Forest Land | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.A.2 Land Converted to Forest Land | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.B.1 Cropland Remaining Cropland | $CO_2$ | Yes | | | L1i L2i | T2i | |
| 4.B.2 Land Converted to Cropland | $CO_2$ | Yes | | | L2i | T2i | |
| 4.C.2 Land Converted to Grassland | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.D.2 Land Converted to Wetlands | $CO_2$ | Yes | | | | T2i | |
| 4.E.2 Land Converted to Settlements | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| 4.G Harvested Wood Products | $CO_2$ | Yes | | | L1i L2i | T1i T2i | |
| **5. Waste** | | | | | | | |
| 5.A Solid Waste Disposal | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 5.D Wastewater Treatment and Discharge | $CH_4$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 5.D Wastewater Treatment and Discharge | $N_2O$ | Yes | L2e | T2e | | | |

L1e - Level excluding LULUCF Tier 1 T1e - Trend excluding LULUCF Tier 1
L2e - Level excluding LULUCF Tier 2 T2e - Trend excluding LULUCF Tier 2

| | |
|---|---|
| L1i - Level including LULUCF Tier 1 | T1i - Trend including LULUCF Tier 1 |
| L2i - Level including LULUCF Tier 2 | T2i - Trend including LULUCF Tier 2 |

Key category analysis is provided by CRF Application too. Although there are differences between the two analyses, large key sources were identified in both analyses. Some categories in CRF analysis differed from categories which are provided in 2006 IPCC Guidelines for key category analysis so detailed comparison between them was not possible to make.

## 1.5. Brief general description of QA/QC plan and implementation

QA/QC PLAN

According to Article 7. of the Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia, within the competence of MESD is the preparation of quality assurance and quality control plan regarding greenhouse gas inventory (hereinafter QA/QC plan), implementation of the quality assurance procedures in accordance with the QA/QC plan and archiving activity data for emission calculation, emission factors and documents used for planning, preparing, controlling and assuring Inventory quality. QA/QC plan is a part of quality assurance and quality control system (QA/QC system), stipulated by Decision 19/CMP.1 Guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol. Implementation of QA/QC system is based on the following documents: Annual Data Collection Plan (ADCP), QA/QC Plan, Category-specific QC checklist and Improvement Plan.

Annual data Collection Plan (ADCP) is the main document for data collection which is the responsibility of MESD. It contains source categories, activity, activity data, data source and competent authority and is made for each sector. This document is prepared annually in collaboration between MESD and National System Committee.

QA/QC plan describes overall responsibilities and roles of institutions involved in inventory planning, preparation and management, general timetable of activities for data collection, inventory preparation, inventory submission, internal audits, annual review and reporting on GHG registry and general and specific QA/QC procedures.

Improvement Plan is document which defines objectives related to the improvement of National Inventory. This document takes into account the key category analysis and recommendations outlined in the Annual review report. This document is prepared annually.

QA/QC plan follows the proposed cycle of activities and responsibilities:

| Activity | Responsibility |
|---|---|
| Preparation of the QA/QC plan<br>- Documentation revision and supplement | QA/QC coordinator (MESD) |
| Approval of the QA/QC plan | MESD |
| Implementation of QC procedures<br>- Internal audit<br>- Corrective and preventive activities<br>- Reporting on performed internal audit | QA/QC coordinator (MESD)<br>Sectoral experts (MESD),<br>Project leader in NIR preparation (MESD)<br>Project Coordinator (Authorized Institution)<br>Sectoral experts (Authorized Institution)<br>QA/QC coordinator (Authorized Institution) |

| Activity | Responsibility |
|---|---|
| Reporting on QC procedures | Authorized Institution |
| Implementation of QA procedures | MESD, National  System Committee |

Quality control activities are focused on following elements of inventory preparation and submission process:

- Activity data collection and archiving;
- Preparation of inventory report;
- Submission of inventory report;
- Review activities;
- Reporting on GHG registry.

For the purposes of transparency of the emission calculation and archiving of data, inventory team has continued with the good practice in preparation of Inventory Data Record Sheets which were introduced in 2001 submission and which contain details of the person and/or organization responsible for an emission estimate, the primary or secondary sources of activity data and emission factors used, the methodology applied, data gaps, ways to cross-check, suggestion for future improvement in the estimates and relevant bibliographic references. The information provided in Inventory Data Record Sheets is available for each source category and for the entire time-series. An example of Inventory Data Record Sheet for 2022 in the Energy sector is presented in Annex 5, Table A5-1. All data in the form of Inventory Data Record Sheets are also archived at MESD.

During the preparation of the NIR, a number of checks were carried out by sector experts related to completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates. The details on these issues are elaborated in the NIR by each sector, subsector and corresponding CRF tables.

Before the Authorized Institution submits the NIR to MESD, QA/QC manager carried out an audit which covers selected IPCC source categories, as outlined in the QA/QC plan, with purpose to check which quality control elements, both general (Tier 1) and specific (Tier 2), as defined in the IPCC Good Practice Guidance, are already implemented by sector experts and which improvements and corrective actions should be carried out in the future submissions. CRF tables for each sector are reviewed in accordance with the Quality Management Standard (ISO 9001) and Environmental Management Standard (ISO 14001) implemented within the Authorized institution. Audit results are registered in control lists as well as performed correction activities.

National System Committee is included in the approval process; its members provide their opinion on certain parts of the Inventory within the frame of their speciality. QA/QC coordinator documents all National System Committee results/findings.

Finally, MESD approves and submits Inventory to the UNFCCC.

## VERIFICATION AND CONFIDENTIALITY ISSUES

The verification process of calculation is aimed at the improvement of the input quality and identification of the calculation reliability. The IPCC Guidelines recommend that inventories should be verified through the use of a set of simple checks for completeness and accuracy, such as checks for arithmetic errors, checks of country estimates against independently published estimates, checks of national activity data against international statistics and checks of $CO_2$ emissions from fuel combustion calculated using sectoral methods with the IPCC Reference Approach. Further verification checks may be done through comparison with other national inventory calculation data.

In the development of the Croatian inventory, certain steps and some of these checks were performed:

- Comparison with the national inventory data of other countries was conducted by comparing CRF tables or through a direct communication;
- Activity data were compared using different sources such as the Croatian Bureau of Statistics and individual emission sources;
- The $CO_2$ emissions from fossil fuel combustion, within the framework of IPCC methodology, are estimated using two approaches: (1) Reference Approach and (2) Sectoral Approach (Tier 1).

**TREATMENT OF CONFIDENTIALITY ISSUES**

In Croatian GHG Inventory, only data that refers to a single enterprise is in general confidential. In the National Inventory Report, for those activities, the activity data and emissions are aggregated on the subsector level.

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

The uncertainties associated with both annual estimates of emissions and emission trends over time are reported according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The uncertainties are estimated using Tier 1 and Tier 2 (Monte Carlo analysis) methods described by the IPCC, which provide estimates of uncertainties by pollutant. The uncertainties are estimated for both excluding LULUCF and including LULUCF due to the Good Practice Guidance for Land Use, Land-Use Change and Forestry.

Uncertainty in the emissions excluding LULUCF

The estimations of $CO_2$-eq emissions were 24,551.89 kt $CO_2$-eq for the year 2022 and 31,546.32 kt $CO_2$-eq for the year 1990 without removals from LULUCF.

Monte Carlo analysis shows that with a certainty of 95% total emissions of all categories for the year 2022 (25,139.45 kt $CO_2$-eq) according to simulation varies between 23,970 kt $CO_2$-eq (2.5 percentile) and 26,429 kt $CO_2$-eq (97.5 percentile).

Monte Carlo analysis shows that with a certainty of 95% total simulated emissions of all categories excluding LULUCF for the year 1990 (32,571.76 kt $CO_2$-eq) varies between 30,832 kt $CO_2$-eq (2.5 percentile) and 34,516 kt $CO_2$-eq (97.5 percentile).

Uncertainty in the trend excluding LULUCF

The Inventory trend excluding LULUCF is -22.17%, simulated trend is -22.76% and the 95% probability range of the trend is -28.28% (2.5 percentile) to -16.76% (97.5 percentile).

Uncertainty in the emissions including LULUCF

The estimations of $CO_2$-eq emissions were 19,684.82 kt $CO_2$-eq for the year 2022, and 25,198.28 kt $CO_2$-eq for the year 1990.

Monte Carlo analysis shows that with a certainty of 95% total emissions of categories for the year 2022 (22,603.89 kt $CO_2$-eq) according to simulation varies between 17,280 kt $CO_2$-eq (2.5 percentile) and 28,544 kt $CO_2$-eq (97.5 percentile).

Monte Carlo analysis shows that with a certainty of 95% total simulated emissions of all categories including LULUCF for the year 1990 (28,846.15 kt $CO_2$-eq) varies between 24,001 kt $CO_2$-eq (2.5 percentile) and 34,050 kt $CO_2$-eq (97.5 percentile).

Uncertainty in the trend including LULUCF

The Inventory trend including LULUCF is -21.88%, simulated trend is -20.99% and the 95% probability range of the trend is -42.9% (2.5 percentile) to 4.9% (97.5 percentile).

The results of the Tier 1 approach and the results of the Tier 2 approach are shown in Table A2.2-1 (Annex 2).

The results of the uncertainty analysis are used to drive improvements in the inventory. Most efforts were made to collect detailed information on AD and EFs (especially country-specific EFs) in order to improve the accuracy of the emission calculation.

## 1.7. General assessment of completeness

### 1.7.1. Information on completeness

Croatian inventory consists of the emission estimates for the period from 1990-2022.

The completeness is evaluated following the IPCC methodology and appropriate use of the following notation keys: NO (not occurred); NE (not estimated); NA (not applicable); IE (included elsewhere); C (confidential). Detailed description by activities and gases of the status of the emission calculation is given in corresponding CRF tables.

Generally, the objective of the completeness is achieved in compliance with the capabilities of the Republic of Croatia in collecting adequate and acceptable activity data. The issues related with lack of activity data are described in sectoral chapters where necessary. The aim of the Croatian inventory is to include all anthropogenic sources of GHGs in the future.

### 1.7.2. Description of insignificant categories

Croatia do not have insignificant categories. Emission from all mandatory categories are calculated.

### 1.7.3. Total aggregate emissions considered insignificant

Croatia do not have insignificant emissions.

## 1.8. Metrics

The results are presented as total emissions of all greenhouse gases in $CO_2$ equivalents over sectors and then as emissions for the individual greenhouse gas by sectors. Since the certain greenhouse gases have different irradiation properties and consequently different contribution to the greenhouse effect, it is necessary to multiply the emission of every gas with proper Global Warming Potential (GWP). The Global Warming Potential is a measure of the impact on the greenhouse effect of the certain gas compared to $CO_2$ impact which is accordingly defined as a referent value. In that case, the emission of greenhouse gases is presented as the equivalent emission of carbon dioxide ($CO_2$ -eq). If the removal of greenhouse gases occurs (e.g. the absorption of $CO_2$ at increase of wood stock in forests) than it refers to sinks of greenhouse gases and the amount is presented as a negative value. Global warming potentials used to calculate $CO_2$ equivalent emissions are defined in IPCC Fifth Assessment Report, 2014 (AR5).

# Chapter 2: Trends in greenhouse gas emissions

## 2.1 Description and interpretation of emission trends for aggregated GHG emissions

The total GHG emissions in 2022, excluding removals by sinks, amounted 24,552.0 mil. t $CO_2$-eq (equivalent $CO_2$ emissions), which represents a 22.2 % emission reduction compared to GHG emission in the year 1990.

Overall decline of economic activities and energy consumption in the period 1991-1994, which was mainly the consequence of the war in Croatia, had directly caused the decline in total emissions of greenhouse gases in that period. With the entire national economy in transition process, some energy-intensive industries reduced their activities or phased out certain productions (e.g. blast furnaces in Sisak, primary aluminium production in Šibenik, coke plant in Bakar), which was considerably reflected in GHG emissions reduction. Emissions have started to increase in 1995 at an average rate of 3 % per year, till 2008. Due to the decreasing of economic activity within the period 2008-2018, emission has been reducing constantly till 2014 when emissions started to grow slowly.

The main reasons of GHG emission increase in the period 1995-2008 was Energy (Public electricity and Heat production and Transport), Industrial processes (Cement production, Lime production, Ammonia production, Nitric acid production and Consumption of HFCs) and Waste. Increase in Public electricity and Heat production sector is mostly due to higher consumption of liquid fuels. Lately, cement, lime, ammonia and nitric acid producers reached their highest producing capacity which has reflected on emission levels. Waste disposal on land, as well as Wastewater treatment and discharge, have the greatest impact on emission increase in Waste sector.

The main reasons of GHG emission decrease in the period from 2008 to 2014 was economic crisis as well as the implementation of measures for $CO_2$ emission reduction according to National Action plans for energy efficiency for the period from 2014 to 2016, for the period from 2017 to 2019, for the period from 2020 to 2021 and from 2021 to 2030. Namely, because of the economic crisis, there was a decrease in industrial production and consequently, decrease in fuel consumption (greatest reduction in fuel consumption was in Manufacturing industries and construction sector and also in the transport sector), and it was contributed to the GHG emission decrease.

A decrease in economic activities after 2008 influenced a reduction in cement, lime, and steel productions.

The results of the greenhouse gas (GHG) emission calculation are presented for the period from 1990 to 2022. Total emissions/removals of GHG and their trend in sectors are given in Tables 2.1-1, 2.1-2 and in Figure 2.1-1 while the contribution of the individual gases is given in Tables 2.1-3, 2.1-4 and Figure 2.1-2.

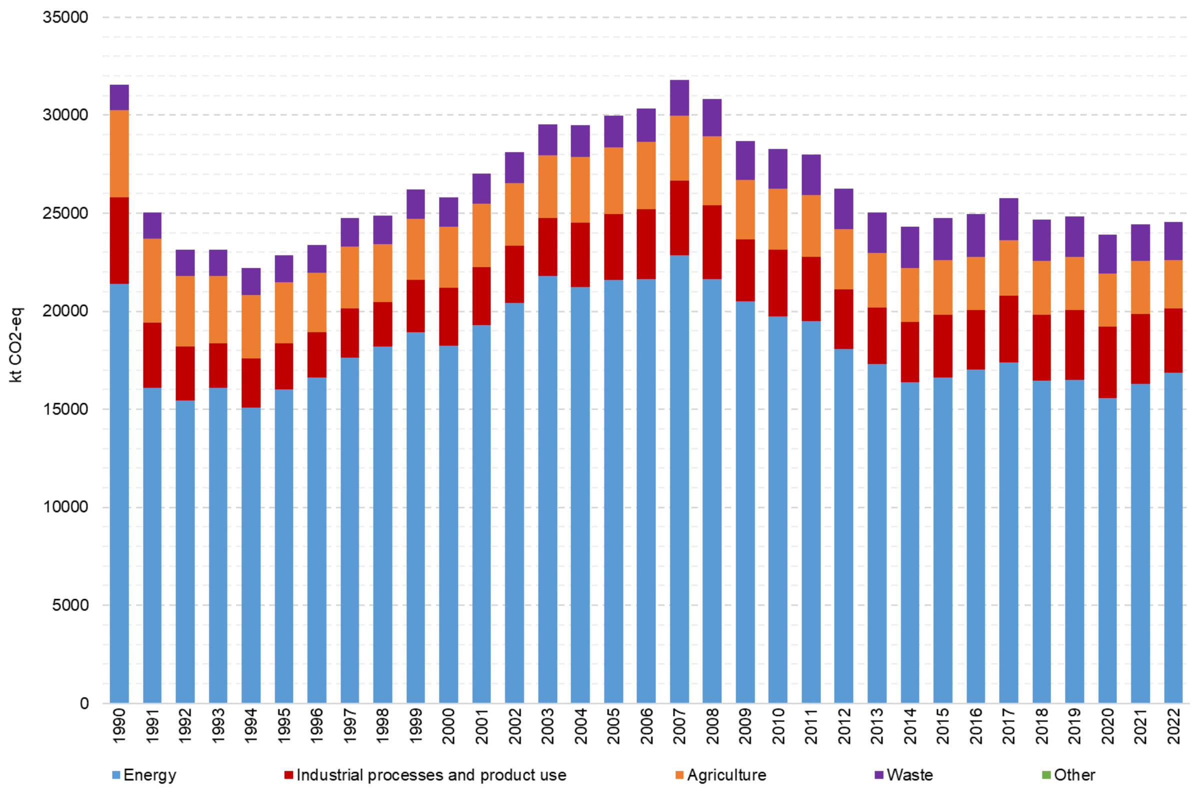
Table 2.1-1: Emissions/removals of GHG by sectors for the every five years from 1990 to 2015 (kt $CO_2$-eq)

| Greenhouse gas source and sink categories | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| 1. Energy | 21,411.7 | 16,031.9 | 18,254.8 | 21,581.4 | 19,733.5 | 16,620.9 |
| 2. Industrial processes and product use | 4,408.8 | 2,325.0 | 2,953.1 | 3,398.5 | 3,404.8 | 3,200.7 |
| 3. Agriculture | 4,424.3 | 3,132.0 | 3,093.2 | 3,361.8 | 3,135.0 | 2,787.2 |
| 4. Land use, land-use change and forestry | -6,348.0 | -8,551.2 | -6,738.1 | -8,003.2 | -6,906.8 | -5,691.9 |
| 5. Waste | 1,301.5 | 1,386.4 | 1,525.7 | 1,621.0 | 2,016.3 | 2,161.7 |
| 6. Other | NO | NO | NO | NO | NO | NO |
| Total (with LULUCF) | 25,198.3 | 14,324.1 | 19,088.7 | 21,959.6 | 21,382.7 | 19,078.5 |
| Total (without LULUCF) | 31,546.3 | 22,875.2 | 25,826.8 | 29,962.8 | 28,289.6 | 24,770.4 |

Table 2.1-2: Emissions/removals of GHG by sectors for the every year from 2016 to 2022 (kt $CO_2$-eq)

| Greenhouse gas source and sink categories | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| 1. Energy | 17,026.4 | 17,399.9 | 16,460.0 | 16,510.4 | 15,561.7 | 16,282.6 | 16,871.7 |
| 2. Industrial processes and product use | 3,024.4 | 3,401.8 | 3,379.0 | 3,551.6 | 3,642.4 | 3,591.8 | 3,277.1 |
| 3. Agriculture | 2,731.1 | 2,829.8 | 2,716.7 | 2,706.8 | 2,700.7 | 2,687.4 | 2,467.9 |
| 4. Land use, land-use change and forestry | -5,698.2 | -4,883.7 | -5,492.8 | -5,725.8 | -5,658.6 | -5,763.7 | -4,867.2 |
| 5. Waste | 2,160.4 | 2,153.9 | 2,103.9 | 2,061.9 | 2,009.7 | 1,875.4 | 1,935.3 |
| 6. Other | NO | NO | NO | NO | NO | NO | NO |
| Total (with LULUCF) | 19,244.1 | 20,901.6 | 19,166.8 | 19,104.9 | 18,255.9 | 18,673.4 | 19,684.8 |
| Total (without LULUCF) | 24,942.3 | 25,785.3 | 24,659.6 | 24,830.7 | 23,914.5 | 24,437.2 | 24,552.0 |

Figure 2.1-1: Trend of GHG emissions, by sectors




Tables 2.1-1, 2,1-2 and Figure 2.1-1 represents the contribution of the individual sectors to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2022 excluding LULUCF has the Energy sector with 68.7 %, followed by Industrial Processes and product use with 13.3 %, Waste with 7.9 % and Agriculture with 10.1 %. This structure is with minor changes consistent through all the observed period from 1990 to 2022. In the year 2022, the total GHG emissions in Croatia was 24,552.0 kt $CO_2$-eq excluding LULUCF sector while the total emission was 19,684.8 kt $CO_2$-eq including the LULUCF sector which represents removals by sink from 19.8 % in that year.

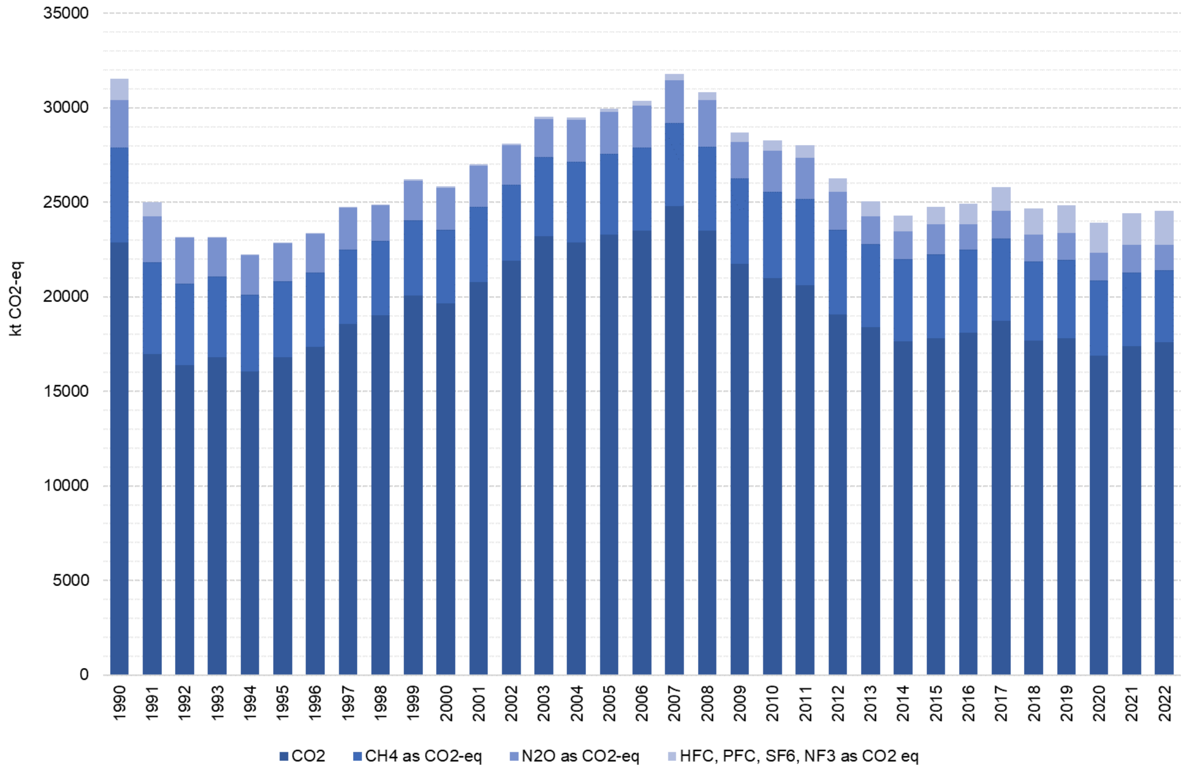
Table 2.1-3: Emissions/removals of GHG by gases for the every five years from 1990 to 2015 (kt $CO_2$-eq)

| Greenhouse gas emissions | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| $CO_2$ emissions without net $CO_2$ from LULUCF | 22,874.5 | 16,811.3 | 19,652.3 | 23,298.0 | 20,986.2 | 17,803.0 |
| $CO_2$ emissions with net $CO_2$ from LULUCF | 16,480.4 | 8,205.2 | 12,705.0 | 15,213.5 | 13,950.6 | 11,925.3 |
| $CH_4$ emissions without $CH_4$ from LULUCF | 5,008.6 | 4,003.0 | 3,909.9 | 4,281.2 | 4,570.7 | 4,442.4 |
| $CH_4$ emissions with $CH_4$ from LULUCF | 5,010.0 | 4,011.4 | 4,018.4 | 4,284.2 | 4,572.6 | 4,458.0 |
| $N_2O$ emissions without $N_2O$ from LULUCF | 2,534.9 | 2,027.0 | 2,202.6 | 2,182.5 | 2,158.6 | 1,575.0 |
| $N_2O$ emissions with $N_2O$ from LULUCF | 2,579.6 | 2,073.6 | 2,303.1 | 2,260.6 | 2,285.4 | 1,745.1 |
| HFCs | NO | 21.4 | 49.4 | 186.5 | 563.9 | 944.3 |
| PFCs | 1,117.3 | NO | NO | NO | NO | NO |
| Unspecified mix of HFCs and PFCs | NO | NO | NO | NO | NO | NO |
| $SF_6$ | 11.1 | 12.4 | 12.7 | 14.7 | 10.1 | 5.7 |
| $NF_3$ | NO | NO | NO | NO | NO | NO |
| Total (without LULUCF) | 31,546.3 | 22,875.2 | 25,826.8 | 29,962.8 | 28,289.6 | 24,770.4 |
| Total (with LULUCF) | 25,198.3 | 14,324.1 | 19,088.7 | 21,959.6 | 21,382.7 | 19,078.5 |
| Total (without LULUCF, with indirect) | NA | NA | NA | NA | NA | NA |
| Total (with LULUCF, with indirect) | NA | NA | NA | NA | NA | NA |

Table 2.1-4: Emissions/removals of GHG by gases for the every year from 2016 to 2022 (kt $CO_2$-eq)

| Greenhouse gas emissions | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| $CO_2$ emissions without net $CO_2$ from LULUCF | 18,090.0 | 18,719.1 | 17,702.6 | 17,830.3 | 16,881.6 | 17,410.7 | 17,608.2 |
| $CO_2$ emissions with net $CO_2$ from LULUCF | 12,214.6 | 13,551.1 | 12,043.8 | 11,936.0 | 11,002.7 | 11,480.2 | 12,534.2 |
| $CH_4$ emissions without $CH_4$ from LULUCF | 4,417.3 | 4,379.4 | 4,184.3 | 4,108.2 | 3,998.3 | 3,875.9 | 3,796.9 |
| $CH_4$ emissions with $CH_4$ from LULUCF | 4,427.3 | 4,456.9 | 4,185.8 | 4,111.3 | 4,034.8 | 3,882.4 | 3,834.1 |
| $N_2O$ emissions without $N_2O$ from LULUCF | 1,348.4 | 1,454.3 | 1,413.8 | 1,417.4 | 1,453.0 | 1,444.0 | 1,324.8 |
| $N_2O$ emissions with $N_2O$ from LULUCF | 1,515.5 | 1,661.1 | 1,578.4 | 1,582.7 | 1,636.8 | 1,604.2 | 1,494.5 |
| HFCs | 1,079.8 | 1,225.3 | 1,352.4 | 1,466.8 | 1,572.2 | 1,697.0 | 1,812.1 |
| PFCs | NO | NO | NO | NO | NO | NO | NO |
| Unspecified mix of HFCs and PFCs | NO | NO | NO | NO | NO | NO | NO |
| $SF_6$ | 6.8 | 7.2 | 6.5 | 8.1 | 9.4 | 9.6 | 10.0 |
| $NF_3$ | NO | NO | NO | NO | NO | NO | NO |
| Total (without LULUCF) | 24,942.3 | 25,785.3 | 24,659.6 | 24,830.7 | 23,914.5 | 24,437.2 | 24,552.0 |
| Total (with LULUCF) | 19,244.1 | 20,901.6 | 19,166.8 | 19,104.9 | 18,255.9 | 18,673.4 | 19,684.8 |
| Total (without LULUCF, with indirect) | NA | NA | NA | NA | NA | NA | NA |
| Total (with LULUCF, with indirect) | NA | NA | NA | NA | NA | NA | NA |

Figure 2.1-2: Trend of GHG emissions, by gases




Tables 2.1-3, 2.1-4 and Figure 2.1-2 represents the contribution of the individual gasses to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2022 excluding LULUCF has $CO_2$ emission with 71.7 %, followed by $CH_4$ with 15.5 %, $N_2O$ with 5.4 % and HFCs, PFCs and $SF_6$ with 7.4 %.

## 2.2 Description and interpretation of emission trends by sector

**ENERGY SECTOR**

The Energy sector is the largest contributor to GHG emissions. In the year 2022, the GHG emission from the Energy sector was 3.6 % higher in relation to 2021 and 21.2 % lower in relation to 1990. The Energy sector covers all activities that involve fuel combustion from stationary and mobile sources, and fugitive emission from fuels. The Energy sector is the main cause for anthropogenic emission of greenhouse gases. It accounts for approximately 69 % of the total emission of all greenhouse gases presented as equivalent emission of $CO_2$. Looking at its contribution to the total emission of carbon dioxide ($CO_2$), the energy sector accounts for about 65.7 % (in 2022). The contribution of energy in methane ($CH_4$) in total $CO_2$-eq emission is substantially smaller (2.2 % in 2022) while the contribution of energy in nitrous oxide ($N_2O$) in total $CO_2$-eq emission is quite small (0.8 % in 2022). Emissions from fossil fuel combustion comprise the majority (more than 95 %) of energy-related emissions. Emission of individual subsectors is presented in the Table 2.2-1.

Table 2.2-1: Energy subsectors total emissions by sectors for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 1. Energy | 21,411.7 | 18,254.8 | 21,581.4 | 19,733.5 | 16,620.9 | 15,561.7 | 16,282.6 | 16,871.7 |
| A. Fuel combustion (sectoral approach) | 20,359.2 | 17,285.2 | 20,545.8 | 18,903.3 | 16,154.1 | 15,100.9 | 15,833.2 | 16,360.2 |
| 1. Energy industries | 7,087.3 | 5,831.8 | 6,835.5 | 5,901.5 | 4,740.9 | 3,696.1 | 3,769.4 | 4,106.2 |
| 2. Manufacturing industries and construction | 5,127.9 | 3,065.0 | 3,695.8 | 2,997.6 | 2,210.8 | 2,404.5 | 2,430.4 | 2,324.6 |
| 3. Transport | 3,898.6 | 4,501.4 | 5,563.1 | 5,948.7 | 5,952.1 | 5,791.9 | 6,259.1 | 6,730.9 |
| 4. Other sectors | 4,245.2 | 3,887.0 | 4,451.4 | 4,055.4 | 3,250.3 | 3,208.4 | 3,374.4 | 3,198.4 |
| 5. Other | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE |
| B. Fugitive emissions from fuels | 1,052.5 | 969.6 | 1,035.6 | 830.2 | 466.8 | 460.8 | 449.4 | 511.5 |
| 1. Solid fuels | 66.8 | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA | NO,NA |
| 2. Oil and natural gas and other emissions from energy production | 985.7 | 969.6 | 1,035.6 | 830.2 | 466.8 | 460.8 | 449.4 | 511.5 |
| C. $CO_2$ transport and storage | NO | NO | NO | NO | NO | NO | NO | NO |

The largest part (39.9 % in 2022) of the emissions from Energy sector are a consequence of fuel combustion in Transport, next is the combustion in Energy industries (24.3 % in 2022) and third is combustion in small stationary energy sources, such as Commercial/ Institutional, Residential and Agriculture/ Forestry/ Fishing (19.0 % in 2022). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 13.8 %, while Fugitive Emissions from Fuels contribute with about 3.0 %.

## INDUSTRIAL PROCESSES AND PRODUCT USE

In Industrial Processes sector, the key emission sources are part of Mineral industry, Chemical industry and Product uses as ODS substitutes, which all together contribute with 96.5 % in total sectoral emission in 2022. The iron production in blast furnaces and aluminium production ended in 1992, and ferroalloys production ended in 2003. Generally, GHG emissions from industrial processes declined from 1990 to 1995, due to the decline in industrial activities caused by the war in Croatia, while in the period 1996 - 2008 emissions slightly increased due to revitalization of the economy. The effects of the economic crisis influenced the emissions trend from 2008 onwards, followed by a moderate recovery since 2013. The decrease in emissions from the chemical industry in 2013 and onwards is due to a strong reduction of $N_2O$ emissions from the nitric acid production after applying abatement technology. In 2022 emissions from industrial processes were decreased by 8.8 % regarding 2021 and decreased by 25.7 % regarding 1990. Industrial processes and product use contributed to total GHG emissions with 13.3 % in 2022. Emission of individual subsectors is presented in the Table 2.2-2.

Table 2.2-2: Industrial processes subsectors total emissions by sectors for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 2. Industrial processes and product use | 4,408.8 | 2,953.1 | 3,398.5 | 3,404.8 | 3,200.7 | 3,642.4 | 3,591.8 | 3,277.1 |
| A. Mineral industry | 1,297.6 | 1,426.4 | 1,809.9 | 1,403.7 | 1,306.4 | 1,359.3 | 1,372.3 | 1,255.5 |
| B. Chemical industry | 1,427.9 | 1,324.8 | 1,234.1 | 1,298.7 | 849.1 | 593.2 | 401.8 | 96.1 |
| C. Metal industry | 1,458.1 | 30.2 | 12.7 | 14.7 | 9.3 | 4.9 | 14.3 | 13.4 |
| D. Non-energy products from fuels and | 181.5 | 76.9 | 112.4 | 89.8 | 68.0 | 85.6 | 80.0 | 73.1 |

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| E. Electronic Industry | NO | NO | NO | NO | NO | NO | NO | NO |
| F. Product uses as ODS substitutes | NO | 49.4 | 186.5 | 563.9 | 944.3 | 1,572.2 | 1,697.0 | 1,812.1 |
| G. Other prod. manuf. and use | 43.7 | 45.4 | 43.0 | 34.0 | 23.6 | 27.1 | 26.5 | 26.9 |
| H. Other | NA | NA | NA | NA | NA | NA | NA | NA |

## AGRICULTURE

Emission of $CH_4$ and $N_2O$ in the Agricultural sector is conditioned by different agricultural activities. For the emission of $CH_4$, the most important source is livestock farming (Enteric Fermentation) which makes 41.4 % of sectoral $CO_2$-eq emission. The number of cattle showed a continuous decrease in the period from 1990 to 2002. As a consequence, this led to $CH_4$ emission reduction. In the year 2000, the number of cattle has started increasing and this trend was mostly retained until 2006. From 2007 to 2010, cattle number decreased and remained at approximately the same level in 2013 and 2014. Compared to 2021, in 2022 $CO_2$-eq emission from Enteric fermentation decreased by 5.4 %. As for Manure management emissions, $CO_2$-eq emission decreased by 6.3 % in 2022 compared to 2021. Emissions from Agricultural soils decreased after 1990 and during the war due to specific national circumstances and limited agricultural practice at that time. Afterwards, the emission trend is mostly influenced by the changes in the direct soil emissions; thus, emission increase can be noticed in 1997, 2001 and 2002 due to increase in mineral fertilizer consumption and crop production, later on also due to the increase of livestock population. $CO_2$-eq emission from Agricultural soils decreased in 2022 compared to 2021 by 9.8 %. Overall, in the year 2022, the GHG emission from the Agriculture sector decreased by 8.2 % in comparison with 2021. Emission of individual subsectors is presented in the Table 2.2-3.

Table 2.2-3: Agriculture subsectors total emissions by sectors for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 3. Agriculture | 4,424.3 | 3,093.2 | 3,361.8 | 3,135.0 | 2,787.2 | 2,700.7 | 2,687.4 | 2,467.9 |
| A. Enteric fermentation | 2,336.0 | 1,349.7 | 1,458.8 | 1,303.8 | 1,193.8 | 1,091.1 | 1,079.3 | 1,020.9 |
| B. Manure management | 776.3 | 618.0 | 681.6 | 721.8 | 641.7 | 534.8 | 527.8 | 494.6 |
| C. Rice cultivation | NO | NO | NO | NO | NO | NO | NO | NO |
| D. Agricultural soils | 1,262.0 | 1,064.6 | 1,135.9 | 1,021.4 | 882.3 | 979.6 | 988.0 | 891.7 |
| E. Presc. burning of sav. | NO | NO | NO | NO | NO | NO | NO | NO |
| F. Field burning | NO | NO | NO | NO | NO | NO | NO | NO |
| G. Liming | NO | NO | 14.5 | 21.5 | 12.1 | 6.9 | 18.7 | 18.7 |
| H. Urea application | 50.0 | 60.9 | 71.0 | 66.6 | 57.2 | 88.3 | 73.6 | 42.0 |
| I. Other carbon-cont. fertilizers | NA | NA | NA | NA | NA | NA | NA | NA |
| J. Other | NO | NO | NO | NO | NO | NO | NO | NO |

## LULUCF

The Act on Forest (Official Gazette No. NN 68/18, 115/18, 98/19, 32/20, 145/20, 101/23, 36/24) regulates the growing, protection, usage and management of forests and forest land as a natural resource aimed to maintain biodiversity and ensure management based on principles of economic sustainability, social responsibility and ecological acceptability. Moreover, one of its the most important provisions, in the context of climate protection, is that forests should be managed in conformity with the sustainable management criteria, implying the maintenance and enhancement of forest ecosystems and their contribution to the global carbon cycle. Planning activities in the forestry sector in Croatia are also regulated by the Low on Forest. Forest management plans determine conditions for harmonious usage of forest and forest land and procedures in that area, necessary scope regarding cultivation and forest protection, possible utilization degree and conditions for wildlife management. The Forest Management Area Plan (FMAP) for the Republic of Croatia determines the ecological, economic and social background for forest improvement in terms of biology and for the increase of forest productivity.

According to National forestry accounting plan for the Republic of Croatia (december 2019), the forests and the forest land cover 47.5 % of the total surface area. By its origin, approximately 95 % of the forests in Croatia were formed by natural regeneration (according to the national definitions applied in the sector) and the 5 % of the forests are grown artificially. The Plan determines, the growing stock of about 398 millions of $m^3$ while its yearly increment amounts around 10.5 million $m^3$. The most frequent species are Common Beech (Fagus sylvatica), Pedunculate Oak (Quercus robur), Sessile Oak (Quercus petrea), Common Hornbeam (Carpinus betulus), Silver Fir (Abies alba), Narrow-leafed Ash (Fraxinus angustifolia), Spruce (Picea abies), Black Alder (Alnus glutinosa), Black Locust (Robinia pseudoacacia), Turkey Oak (Quercus cerris) and other.

The methodology used for $CO_2$ removal calculation is taken from the IPCC and it is based on data on increment and fellings. The problem of deforestation in Croatia does not exist. According to present data, the total forest area has not been reduced in the last 100 years.

Table 2.2-4 shows the $CO_2$ removal trend in the forestry sector. Removals arisen in the LULUCF sector contribute with 24.7 % to the total emissions of $CO_2$ eq in Croatia including LULUCF in the year 2022.

Table 2.2-4: Emission trends in LULUCF sector from 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| LULUCF removals | -6,348.0 | -6,738.1 | -8,003.2 | -6,906.8 | -5,691.9 | -5,658.6 | -5,763.7 | -4,867.2 |

## WASTE

Waste sector includes the following categories: solid waste disposal, biological treatment of solid waste, incineration and open burning of waste and wastewater treatment and discharge. Solid waste disposal represents dominant $CH_4$ emission source from sector Waste.

Emissions from solid waste disposal account 71.9 % of sectoral emissions in 2022, compared to 42.9 % in 1990. An increase in generated and deposited of solid waste exists during the reporting period. In recent years, the increasing trend is slower in waste generation, while decreasing trend occurs in waste disposal, compared to the previous period, influenced by the implementation of the measures undertaken to avoid/reduce and recycle waste, which are still not sufficiently applied.

Emissions from wastewater treatment and discharge account 26.3 % of sectoral emissions in 2022, compared to 55.2 % in 1990. Decrease in emissions during the reporting period mainly is a result of population decrease as well reduction of economic activity after 2008 and a declining fluctuating trend in the industrial production.

Biological treatment of solid waste and incineration and open burning of waste have considerably lower contribution to the sectoral emissions during the reporting period.

Waste sector contributes to total GHG emissions with 7.9 % in 2022. Emission of individual subsectors is presented in the Table 2.2.5.

Table 2.2-5: Waste subsectors total emissions by sectors for the period 1990-2022 (kt $CO_2$-eq)

| GHG source and sink categories | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| 5. Waste | 1,301.5 | 1,525.7 | 1,621.0 | 2,016.3 | 2,161.7 | 2,009.7 | 1,875.4 | 1,935.3 |
| A. Solid waste disposal | 558.6 | 807.4 | 930.9 | 1,324.4 | 1,506.1 | 1,440.9 | 1,313.8 | 1,391.7 |
| B. Biological treatment of solid waste | NO,IE | 1.4 | 2.3 | 3.7 | 18.2 | 20.1 | 23.0 | 28.2 |
| C. Incineration and open burning of waste | 23.9 | 17.8 | 10.8 | 11.8 | 10.1 | 8.0 | 7.4 | 7.2 |
| D. Waste water treatment and discharge | 719.0 | 699.2 | 677.0 | 676.5 | 627.3 | 540.7 | 531.2 | 508.1 |
| E. Other | NO | NO | NO | NO | NO | NO | NO | NO |

# Chapter 3: Energy (CRF sector 1)

## 3.1 Overview of sector

For the emission calculation for the period from 1990 to 2022 National energy balance was used.

Institutional arrangement for creating national energy data balance is defined in the Ordinance on Energy balance (OG 33/2003). This ordinance defines the content and manner of delivery of data that the bodies of state authorities, bodies of local and regional self-government units and energy entities are obliged to submit.

The following entities are obligated to deliver data for energy balance:

- Data of the Central Bureau of Statistics on production, consumption of raw materials and energy consumption in all industrial plants in Croatia,
- Data of the Central Bureau of Statistics on all legal entities in Croatia,
- Data from the Monthly Natural Gas Consumption Survey in individual sectors of consumption for all-natural gas distribution companies in Croatia,
- Data from the annual coal consumption survey in individual sectors of consumption for the quantities of coal sold through all coal trade companies in Croatia,
- Customs Administration Data on Annual Import and Export of All Fuels by Tariff Items for All Importers / Exporters.

Apart from the data listed in the relational databases, additional data from the Croatian Electric Power Industry, INA and other sources were also used.

The annual energy balance is a special form of statistics that tracks the flow of energy from the appearance in the energy system to their delivery to the immediate users, ie to their transformation into some of the useful forms of energy.

National energy balance was estimated with the same methodology and approach for the whole period from 1988 till 2022.

In 2014 project named ‘’Technical assistance in the business statistics development, preparation of documents on the data quality and improving the data collection system’’ by Energy Institute Hrvoje Požar was lunched. This project was launched in the framework of the IPA 2009 Programme and covered the area of energy statistics and improvement of methodologies of data collection in the final energy consumption sectors: households, services and transport. The aim of the project was to determine the energy consumption indicators based on the survey of energy consumption and according to EUROSTAT’s list of variables and models for calculating energy efficiency. One of result was to determine actual consumption of fuel on domestic and international routes and others to determine real consumption of solid biomass commercial and residential sector. The revised values of fuel consumptions were available for the whole period from 1990 to 2013 and were used to calculate emissions from Transport and Other sectors.

### 3.1.1. Connection of energy balance and industrial processes over fuel consumption

Determining total emissions (fuel emission+row material emission) in categories 2.A.1, 2.A.C. and 2.B.8. is a complex task, since the Energy Balance, emissions reporting, emissions trading and association statistics differ widely in terms of their underlying methods. In Croatia, there is no accurate information by which to disaggregate the emissions between energy and process so $CO_2$ emissions due to the consumption of coke, coal or other reducing agents used in the cement production and in iron and steel industry have been accounted for as fuel consumption and reported in the energy sector (1.A.2).

For example in Iron and steel industry coke in the blast furnace has several roles:

- the combustion of coke produces carbon monoxide which is responsible for the reduction of iron ores;
- the combustion of coke generates the heat needed to melt the iron ore;
- coke mechanically supports the charge allowing the crossing of the reducing gas;
- coke allows the process of carburation of liquid iron by lowering its melting point.

Coke when burning simultaneously produces energy in the form of heat and CO as a reducing agent and these properties of the coke can not be separated one from the another. Disaggregation would not reflect the real situation so leaving the fuel emissions from the use of coke in the iron and steel industry in the energy sector is appropriate. In that way, emissions are not double-counted.

### 3.1.2. Overview of the energy situation

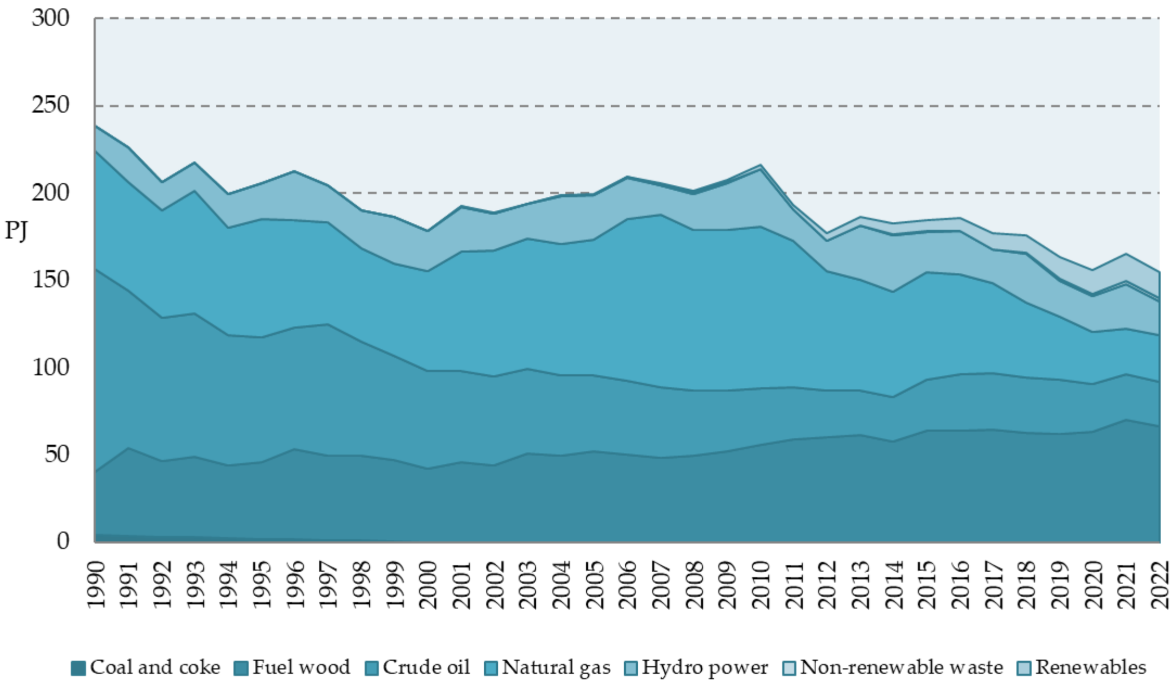
Primary sources of energy that are produced in Croatia are fuelwood, crude oil, natural gas, renewables and hydropower. Coal production stopped in 2000. Primary energy production for the 1990, 2000, 2005, 2010, 2015 and period from 2020 to 2022 is presented in the Table 3.1-1.

Table 3.1-1: Primary energy production

| PJ | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Coal and coke | 4.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fuel wood | 36.17 | 41.92 | 52.08 | 56.06 | 64.15 | 63.26 | 69.88 | 66.68 |
| Crude oil | 116.19 | 56.52 | 43.30 | 32.02 | 29.02 | 27.70 | 26.45 | 25.41 |
| Natural gas | 67.80 | 56.72 | 78.09 | 92.73 | 61.61 | 29.52 | 26.11 | 26.30 |
| Hydro power | 14.10 | 23.23 | 25.33 | 32.85 | 23.01 | 20.38 | 25.66 | 19.65 |
| Non-renewable waste | 0.00 | 0.06 | 0.18 | 0.32 | 0.39 | 1.63 | 1.89 | 1.94 |
| Renewables | 0.00 | 0.06 | 0.49 | 2.44 | 6.66 | 13.77 | 15.60 | 15.05 |
| **Total** | **238.47** | **178.50** | **199.47** | **216.42** | **184.82** | **156.27** | **165.59** | **155.02** |

Figure 3.1-1 presents the trends in the primary energy production from 1990 to 2022.

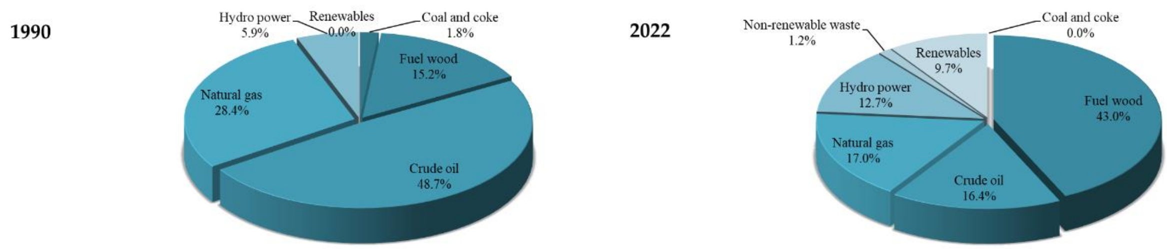
Figure 3.1-1: Trends in primary energy production for the period from 1990 to 2022




In 1990 primary energy production was about 238.5 PJ, which is 35.0 % higher comparing to 2022. In 2022, the total primary energy production decreased by 6.4 % with relation to 2021. Comparing to 2021, the energy production from renewables decreased by 3.6 % in 2022. The production of natural gas increased by 0.7 %. Production of crude oil decreased by 3.9 %, hydropower production by 23.4. % and fuelwood production (4.6 %).

While in 1990 the share of liquid fuels in primary energy production was the highest one with 48.7 %, in 2022 its' share was 16.4 %. In 2022, the share of Fuel wood was highest one with 43.0%. The comparison of shares in primary energy productions for the 1990 and 2022 are presented in Figure 3.1-2.

Figure 3.1-2: Shares of individual energy forms in the total production for the 1990 and 2022




Primary energy supply

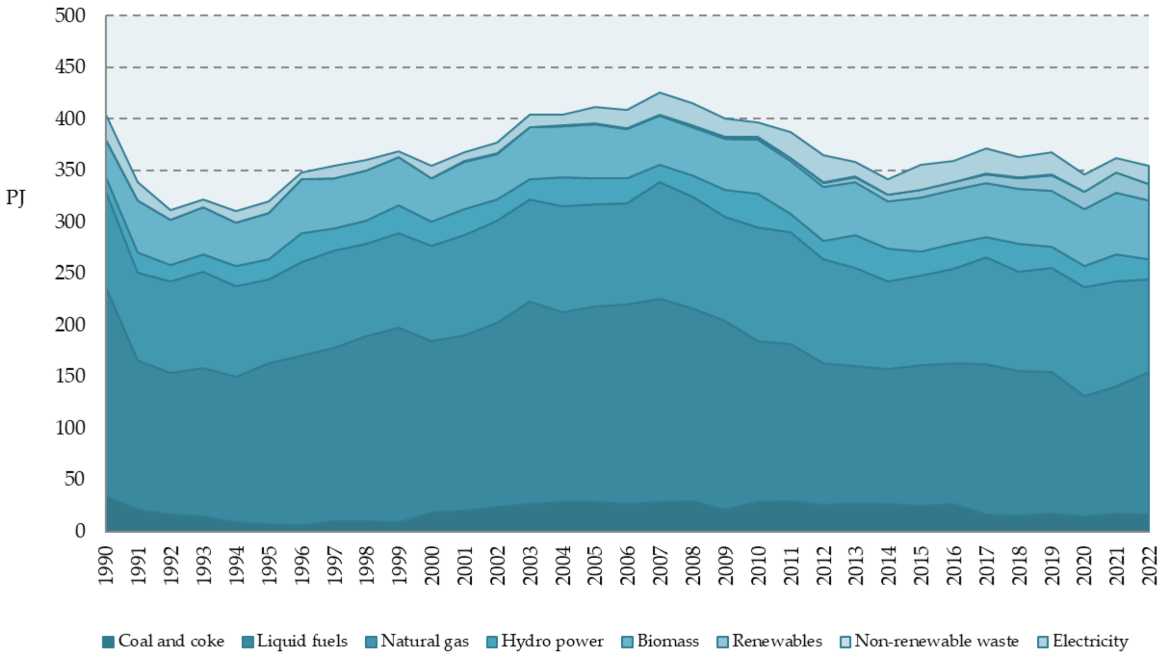
Total primary energy supply is determined by adding the import and subtracting the export of all primary and transformed energy forms to the total primary energy supply. Primary energy supply for the 1990, 2000, 2005, 2010, 2015 and period from 2020 to 2022 is presented in the Table 3.1-2.

Table 3.1-2: Primary energy supply

| PJ | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Coal and coke | 34.10 | 18.07 | 28.62 | 28.57 | 25.34 | 15.12 | 17.39 | 17.03 |
| Liquid fuels | 203.22 | 166.50 | 189.30 | 156.08 | 136.04 | 116.64 | 123.58 | 137.87 |
| Natural gas | 91.88 | 92.50 | 99.52 | 110.21 | 87.17 | 105.73 | 101.71 | 89.30 |
| Hydro power | 14.10 | 23.23 | 25.33 | 32.85 | 23.01 | 20.38 | 25.66 | 19.65 |
| Biomass | 36.17 | 41.92 | 52.08 | 52.10 | 52.68 | 54.94 | 60.17 | 57.65 |
| Renewables | 0.00 | 0.06 | 0.49 | 2.10 | 7.00 | 16.47 | 19.35 | 15.89 |
| Non-renewable waste | 0.00 | 0.06 | 0.18 | 0.32 | 0.39 | 1.63 | 1.89 | 1.94 |
| Electricity | 24.77 | 12.32 | 15.87 | 14.28 | 24.44 | 16.70 | 14.26 | 16.90 |
| **Gross inland consumption** | **404.25** | **354.66** | **411.39** | **396.53** | **356.06** | **347.62** | **364.02** | **356.22** |

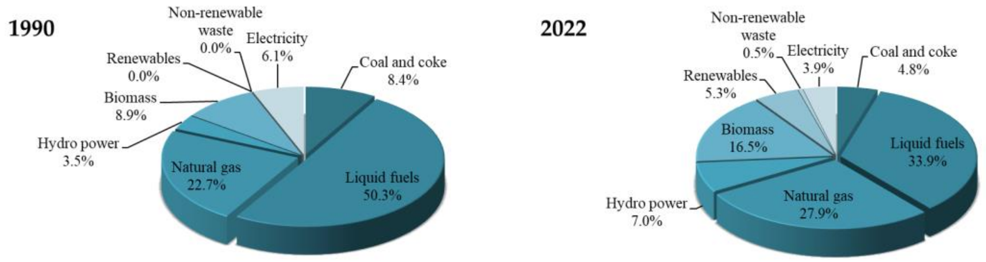
Figure 3.1-3 presents the trends in the primary energy supply from 1990 to 2022.

Figure 3.1-3: Trends in primary energy supply for the period from 1990 to 2022




In 1990 the primary energy supply was about 404.25 PJ, which is 11.9 % higher comparing to 2022. In 2022, the total primary energy supply decreased by 2.1 % in relation to the previous year. There was an increase in renewable energy sources, fuelwood and natural gas while consumption of coal and coke and liquid fuels decreased. Hydropower energy supply increased by 23.4 % with relation to 2021. Figure 3.1-4 presents a comparison of the shares of individual energy forms in the total primary energy supply for the 1990 and 2022.

Figure 3.1-4: Comparison of the shares of individual energy forms for the 1990 and 2022




Liquid fuels had the largest share in total primary energy supply in 1990 as well as in 2022 (50.3 % in 1990 and 33.9 % in 2022). It was followed by the natural gas with a share of approximately 27.9 %.

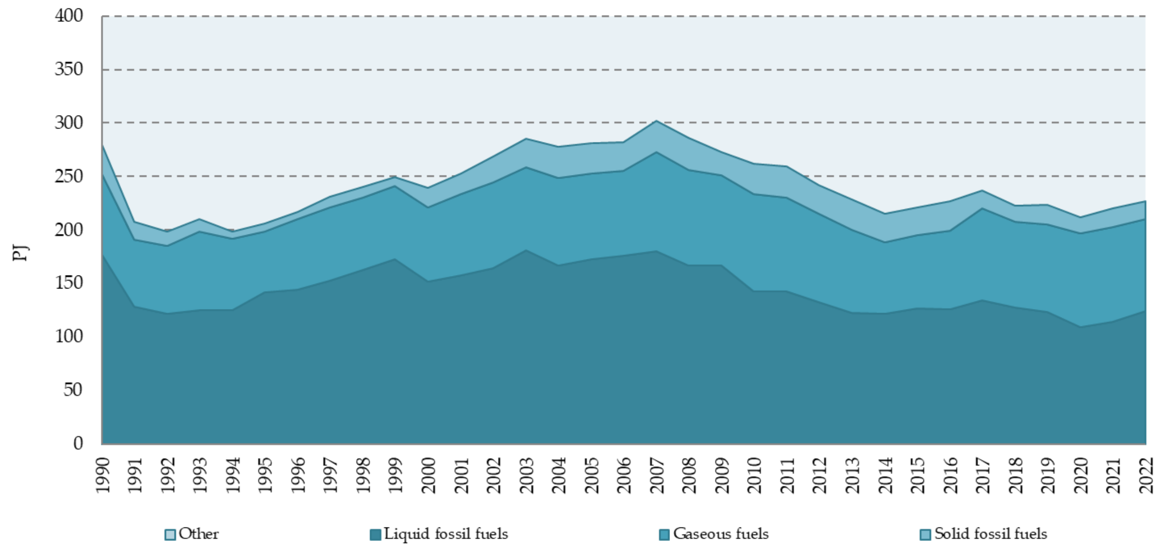
The basis for estimating the GHG emissions from Energy sector is the national energy balance. Data on production, imports, exports, stock change and consumption of fuels are reported both in natural units (kg or $m^3$) and energy units (PJ). National energy balance for 2022 is presented in Annex 4. For easier comparison of data from energy balance, the natural units are transformed to energy units using appropriate national net calorific values (Table 3.1-3).

Table 3.1-3: National net calorific values, $CO_2$ emission factors and oxidation factors for 2022

| Gorivo / Fuel | | DOV (GJ/t($10^3m^3$)) 2022 | | $CO_2$ Emission factor (t $CO_2$/TJ) | Oxidation factor (OF) |
|---|---|---|---|---|---|
| Motorni benzin | Motor Gasoline | GJ/t | 44.5900 | 69.30 | 1 |
| Aviobenzin | Aviation Gasoline | GJ/t | 44.5900 | 70.00 | 1 |
| Kerozin (Mlazno gorivo) | Jet Kerosene | GJ/t | 43.9600 | 71.50 | 1 |
| Dizel i ekstra lako loživo ulje (plinsko ulje) | Gas/Diesel Oil | GJ/t | 42.7100 | 74.10 | 1 |
| Loživo ulje i srednje loživo ulje | Residual Fuel Oil | GJ/t | 40.1900 | 77.40 | 1 |
| Ukapljeni naftni plin | Liquefied Petroleum Gases | GJ/t | 46.8900 | 63.10 | 1 |
| Maziva | Lubricants | GJ/t | 33.5000 | 73.30 | 1 |
| Naftni koks | Petroleum Coke | GJ/t | 31.0000 | 97.50 | 1 |
| Petrolej | Petroleum | GJ/t | 43.9600 | 73.30 | 1 |
| Antracit | Anthracite | GJ/t | 29.3100 | 98.30 | 1 |
| *Kameni ugljen-Industrija* | Other bituminous coal *Industry* | GJ/t | 26.7800 | 94.60 | 1 |
| Kameni ugljen-*Termoelektrane* | Other bituminous coal *Thermal power plant* | GJ/t | 24.7900 | 93.104 | 1 |
| Ugljen za proizvodnju koksa (koksni ugljen) | Coking coal | GJ/t | 28.2000 | 94.60 | 1 |
| Mrki ugljen (smeđi ugljen) *Industrija* | Sub bituminous coal *Industry* | GJ/t | 18.5000 | 96.10 | 1 |
| Lignit | Lignite | GJ/t | 11.5000 | 101.00 | 1 |
| Briketi kamenog ugljena | Brown coal briquettes | GJ/t | 20.7000 | 97.50 | 1 |
| Koks | Coke oven coke | GJ/t | 29.3100 | 107.00 | 1 |
| Prirodni plin | Natural Gas | GJ/$10^3m^3$ | 35.3000 | 56.10 | 1 |
| Gradski plin | Gas Works Gas | GJ/t | 38.7000 | 44.40 | 1 |
| Koksni plin | Coke Oven Gas | GJ/t | 38.7000 | 44.40 | 1 |
| Rafinerijski plin | Refinery Gas | GJ/t | 42.6000 | 57.60 | 1 |

The structure of energy consumption of fossil fuels from 1990 to 2022 is shown in Figure 3.1-5.

Figure 3.1-5: Structure of energy consumption




Liquid fossil fuels are mainly used with a share between 50 to 65 %, and natural gas with approximately 30 %, while the share of solid fossil fuels is between 3 to 11 %. Fuelwoods and biomass-based fuels are neutral regarding $CO_2$ emission, therefore are not shown in the Figure 3.1-5.

### 3.1.3. Overview of emissions

Energy sector covers all activities that involve fuel combustion from stationary and mobile sources, and fugitive emission from fuels.

The Energy sector is the main cause for anthropogenic emission of greenhouse gases. It accounts for approximately 65% of the total emission of all greenhouse gases presented as equivalent emission of $CO_2$. Looking at its contribution to the total emission of carbon dioxide ($CO_2$), the energy sector accounts for about 92 % in 2022. The contribution of energy in methane ($CH_4$) emission is substantially smaller (14 %) while the contribution of energy in nitrous oxide ($N_2O$) emission is 14 % in 2022.

During complete combustion, the carbon contained in fuel oxidizes and transforms into $CO_2$, while through the incomplete combustion the small amounts of $CH_4$, CO and NMVOC emissions also appear. The $CO_2$ is the most important greenhouse gas from fuel combustion. The emission of $CO_2$ depends on the quantity and type of fuel used. The specific emission is the highest during the combustion of coal, then oil and natural gas. A rough ratio of specific emission during combustion of the stated fossil fuels is 1: 0.75: 0.55 (coal: oil: gas).

There are some other gases generated from fuel combustion such as methane ($CH_4$) and nitrous oxide ($N_2O$), and indirect greenhouse gases such as nitrogen oxides (NOx), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC). The indirect greenhouse gases participate in the process of creation and destruction of ozone, which is one of the GHGs. In the framework of the IPCC methodology, the calculation of sulphur dioxide ($SO_2$) emission is also recommended. The sulphur dioxide as a precursor of sulphate and aerosols has a negative impact on the greenhouse effect because the creation of aerosols removes heat from the atmosphere.

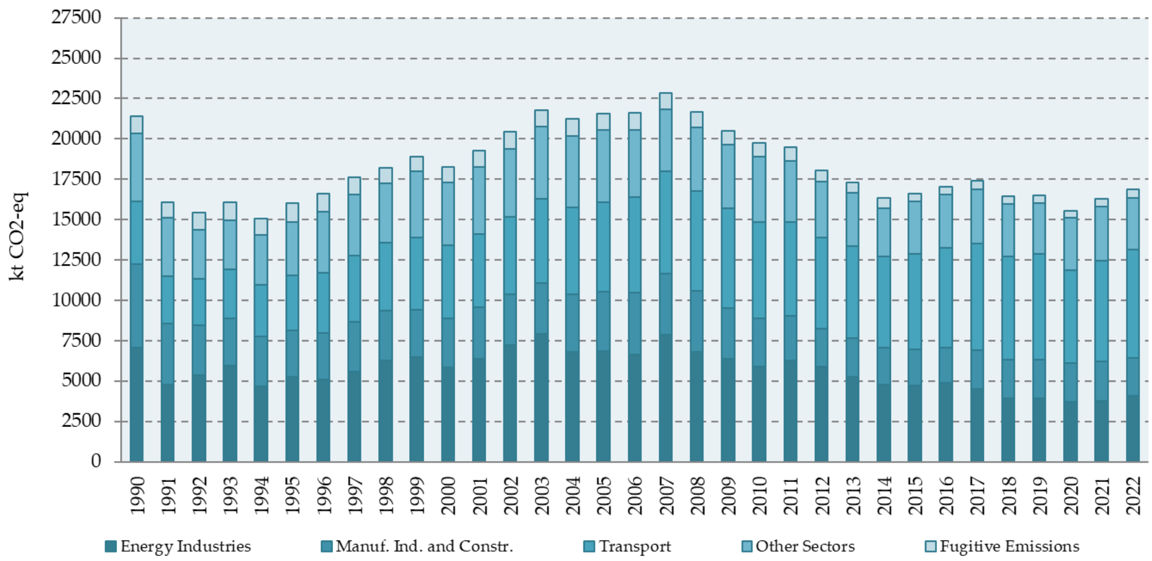
The fuel fugitive emission which is generated during production, transport, processing, storing and distribution of fossil fuels, is also estimated. These activities produce mainly the emission of $CH_4$, and smaller quantities of $CO_2$ and $N_2O$, NMVOC, CO and NOx.

Emissions from fossil fuel combustion comprise the majority (more than 95 %) of energy-related emissions. Contribution of individual subsectors to the emission of greenhouse gases, for the last estimated year (2022), is presented in the Table 3.1-4 while contribution of individual subsectors to GHG emission for the period 1990-2022 is presented in Figure 3.1-6.

Table 3.1-4: Contribution of individual subsectors to emission of greenhouse gases, for 2022

| GHG categories | kt | | | Total | |
|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$-eq (kt) | % |
| **ENERGY** | 16,121.65 | 19.59 | 0.76 | 16,871.72 | 100.00 |
| A. Fuel combustion activities | 15,765.56 | 14.04 | 0.76 | 16,360.24 | 96.97 |
| 1. Energy industries | 4,062.71 | 0.52 | 0.11 | 4,106.24 | 24.34 |
| a) Electricity and heat production | 3,060.92 | 0.50 | 0.11 | 3,102.88 | 18.39 |
| b) Petroleum refining | 695.24 | 0.02 | 0.00 | 696.51 | 4.13 |
| c) Manufacture of solid fuels | 306.56 | 0.01 | 0.00 | 306.86 | 1.82 |
| 2. Manufacturing ind. and constr. | 2,313.06 | 0.17 | 0.03 | 2,324.63 | 13.78 |
| 3. Transport | 6,667.33 | 0.31 | 0.21 | 6,730.95 | 39.89 |
| a) Civil aviation | 25.77 | 0.00 | 0.00 | 25.96 | 0.15 |
| b) Road transport | 6,442.07 | 0.29 | 0.18 | 6,499.17 | 38.52 |
| c) Railways | 46.52 | 0.00 | 0.02 | 51.34 | 0.30 |
| d) Navigation (domestic) | 152.98 | 0.01 | 0.00 | 154.48 | 0.92 |
| 4. Other sectors | 2,722.45 | 13.04 | 0.42 | 3,198.42 | 18.96 |
| 5. Other | NO | NO | NO | NO | NO |
| B. Fugitive emissions from fuels | 356.09 | 5.54 | 0.00 | 511.48 | 3.03 |
| 1. Solid fuels | NO | NO | NO | NO | NO |
| 2. Oil and natural gas | 356.09 | 5.54 | 0.00 | 511.48 | 3.03 |
| C. $CO_2$ transport and storage | NO | NO | NO | NO | NO |

Figure 3.1-6: $CO_2$-eq emissions from Energy sector by subsectors in 1990-2022




The largest part (39.9 %) of the emissions are a consequence of fuel combustion in Transport, then the combustion in Energy industries (24.3 % in 2022) and the combustion in small stationary energy sources, such as Commercial/Institutional, Residential and Agriculture/Forestry/Fishing (19.0 % in 2022). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 13.8

%, while Fugitive Emissions from Fuels contribute about 3.0 %. The majority of energy-related GHG emissions belong to $CO_2$ (91 to 95 %), then follows $CH_4$ (3 to 9 %) and $N_2O$ (less than 1 %).

Greenhouse gases are also generated during the combustion of biomass and biomass-based fuels. The $CO_2$ emission from biomass, in line with IPCC guidelines, is not included in the national emission totals because emitted $CO_2$ had been previously absorbed from the atmosphere for growth and development of biomass. Removal or emission of $CO_2$ due to the changes in the forest biomass is estimated in the Land Use, Land-use Change and Forestry sector.

The emission from fuel combustion in international air and waterborne transport is reported separately and it has not been included in the national emission totals.

#### 3.1.3.1. Energy sector key sources

In the Energy sector, fifteen source categories represent key source category regardless of LULUCF (detailed in Table 3.1-5).

Table 3.1-5: Key categories in Energy sector based on the level and trend assessment in 2022

| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, year = 2022) | | | | | | | |
|---|---|---|---|---|---|---|---|
| A<br>IPCC Source Categories | B<br>GHG | C<br>Key | D<br>If Column C is Yes, Criteria for Identification | | | | |
| **1. Energy** | | | | | | | |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Solid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.1 Fuel combustion - Energy Industries - Biomass | $N_2O$ | Yes | | T2e | | | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels | $CO_2$ | Yes | L1e | T1e T2e | L1i | T1i T2i | |
| 1.A.3.b Road Transportation | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |
| 1.A.3.b Road Transportation | $N_2O$ | Yes | L2e | | | | |
| 1.A.3.d Domestic Navigation - Liquid Fuels | $CH_4$ | Yes | L1e | | | | |
| 1.A.4 Other Sectors - Biomass | $CH_4$ | Yes | L1e L2e | T2e | L1i L2i | | |
| 1.A.4 Other Sectors - Biomass | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Gaseous Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $CO_2$ | Yes | L1e L2e | T1e T2e | L1i | T1i T2i | |
| 1.A.4 Other Sectors - Liquid Fuels | $N_2O$ | Yes | L2e | | | | |
| 1.A.4 Other Sectors - Solid Fuels | $CO_2$ | Yes | | T1e T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CO_2$ | Yes | | T2e | | T1i | |
| 1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil | $CH_4$ | Yes | | T1e T2e | | T1i T2i | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CH_4$ | Yes | L2e | T2e | | | |
| 1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas | $CO_2$ | Yes | L1e L2e | | L1i L2i | | |

L1e - Level excluding LULUCF Tier 1 T1e - Trend excluding LULUCF Tier 1
L2e - Level excluding LULUCF Tier 2 T2e - Trend excluding LULUCF Tier 2
L1i - Level including LULUCF Tier 1 T1i - Trend including LULUCF Tier 1
L2i - Level including LULUCF Tier 2 T2i - Trend including LULUCF Tier 2

#### 3.1.3.2. Ozone precursors and $SO_2$ emissions

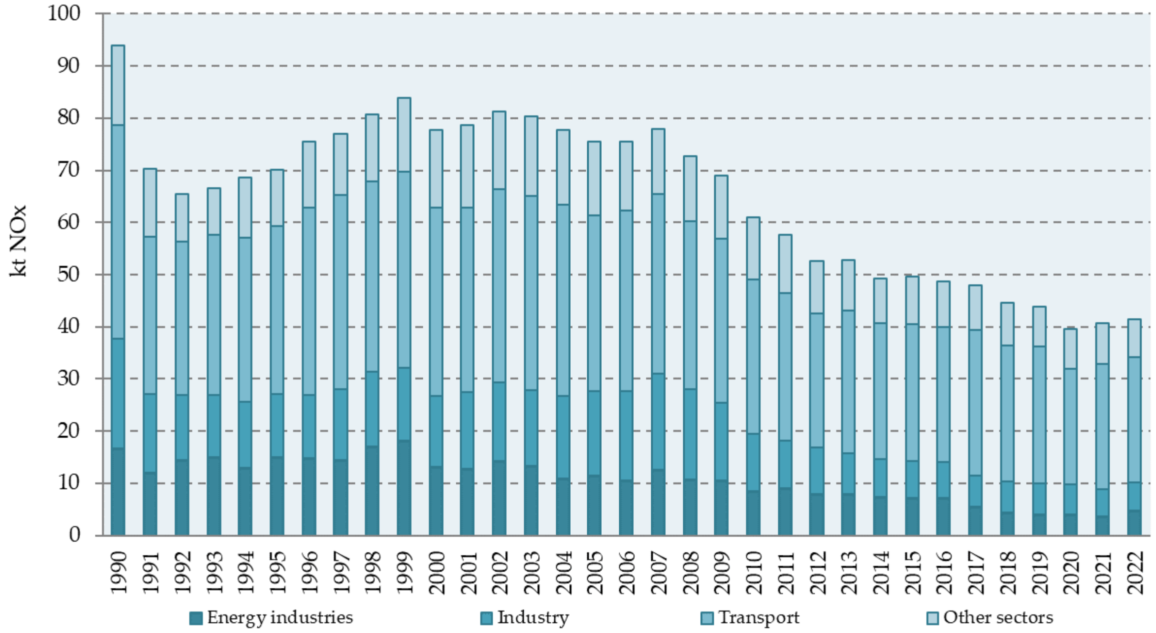
The emissions of indirect greenhouse gases ($NO_X$, CO and NMVOC) and $SO_2$ are described in this chapter. Ozone precursors are cause of greenhouse gas - tropospheric ozone, whereas $SO_2$ was added to a list of pollutants first time in Revised 1996 IPCC Guidelines for National GHG Inventories due to the importance of this gas from the position of acidification and eutrophication. Emissions of indirect GHGs for the whole time period, from 1990 to 2022 was set up according to the EMEP/EEA methodology. Emissions were obtained from the emission inventory report ‘Republic of Croatia Informative Inventory Report for 2022, under Convention on Long-range Transboundary Air Pollution (CLRTAP)’ which is

Croatia's obligation in the framework of the Long-range Transboundary Air Pollution Convention according to the Act on Air Protection (OG 127/19, 57/22).

$NO_X$ emissions

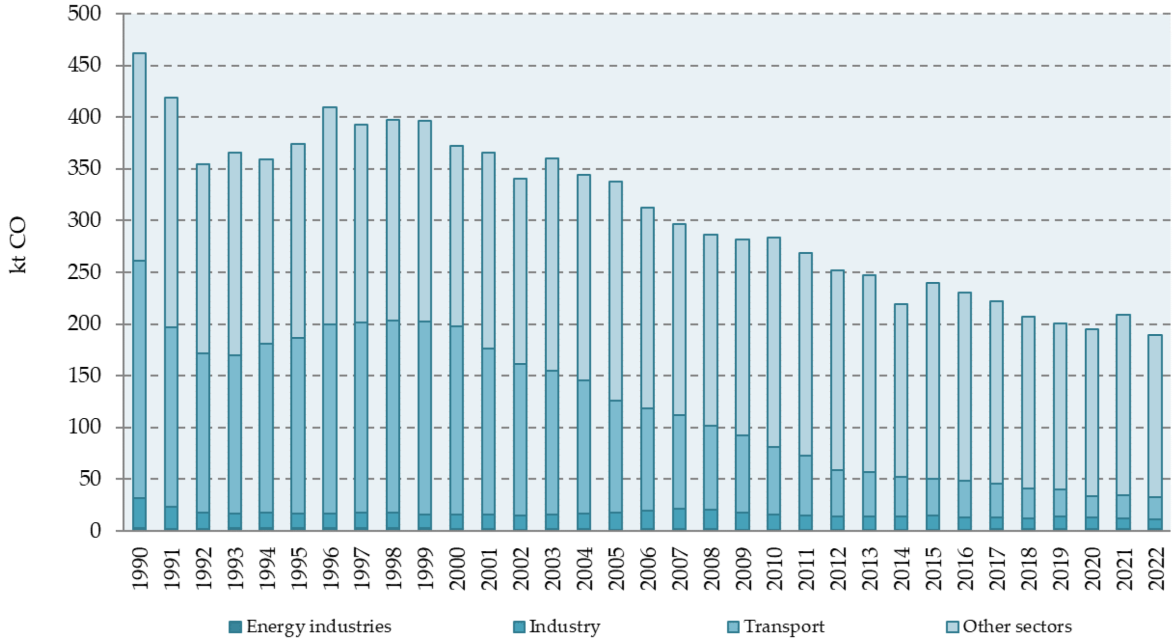
The $NO_X$ emission encompasses nitrogen monoxide and nitrogen dioxide emissions. The emissions are expressed as equivalents of $NO_2$. $NO_X$ is a pollutant that causes acidification and eutrophication. Together with volatile organic compounds and other reactive gases in the atmosphere, and in the presence of solar radiation, $NO_X$ takes part in ground ozone formation.

Figure 3.1-7: $NO_X$ emissions from Energy sector in the period 1990-2022




CO emissions

Figure 3.1-8: CO emissions from Energy sector in the period 1990-2022



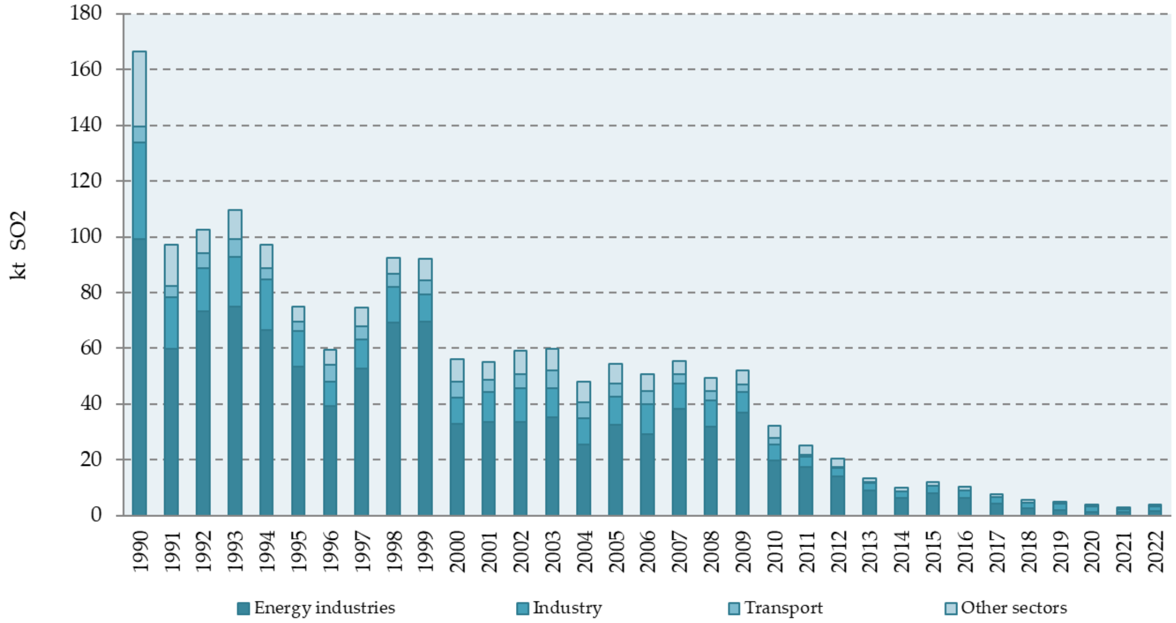
NMVOC emissions

Non-methane volatile organic compounds are important because they are precursors to tropospheric ozone formation. Some of them may have undesirable ecotoxicological properties, for example, benzene and xylene.

Figure 3.1-9: NMVOC emissions from Energy sector in the period 1990-2022


$SO_2$ emissions

Figure 3.1-10: $SO_2$ emissions from Energy sector in the period 1990-2022



## 3.2 Fuel combustion (CRF 1.A)

### 3.2.1. Comparison of the sectoral approach with the reference approach

The methodology used for estimating $CO_2$ emissions follows the 2006 IPCC Guidelines. The emission of $CO_2$ is calculated using two different approaches: the Reference approach and the Sectoral approach. Sectoral emission estimates are based on fuel consumption data given in National Energy Balance, where energy demand and supply is given a sufficiently detailed level, which allows emissions estimation by sectors and subsectors. In the Reference approach, the input data are production, import, export, international bunkers and stock change for primary and secondary fuel. Comparison between these approaches was made and presented in Annex 3. The total differences in fuel consumption and $CO_2$ emissions for the chosen years are given in Table 3.2-1.

Table 3.2-1: The fuel consumption and $CO_2$ emissions from fuel combustion (Reference & Sectoral approach)

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Fuel consumption (PJ) | | | | | | | | |
| SA | 279.52 | 239.73 | 281.19 | 262.39 | 221.38 | 213.39 | 221.94 | 228.86 |
| Appar. consum. | 286.87 | 235.45 | 280.13 | 262.61 | 220.06 | 212.72 | 221.77 | 226.86 |
| Diff.(%) | 2.63 | -1.79 | -0.38 | 0.08 | -0.60 | -0.31 | -0.08 | -0.88 |
| $CO_2$ emission (kt) | | | | | | | | |
| RA | 20164.71 | 16699.37 | 19977.27 | 18439.41 | 15749.39 | 14556.44 | 15379.13 | 16048.66 |
| SA | 19674.84 | 16636.44 | 19856.99 | 18233.13 | 15528.20 | 14513.05 | 15202.48 | 15765.56 |
| Diff.(%) | 2.49 | 0.38 | 0.61 | 1.13 | 1.42 | 0.30 | 1.16 | 1.80 |

The $CO_2$ emission calculated by the Sectoral approach is lower in comparison to the Reference approach. The difference is relatively small (less than 3 %). The most important difference between sectoral and reference approach is in liquid fuels consumption (Table 3.2-2.).

Table 3.2-2: The fuel consumption and $CO_2$ emissions from liquid fuels combustion (Reference & Sectoral approach)

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Fuel consumption (PJ) | | | | | | | | |
| SA | 176.65 | 152.20 | 172.64 | 142.54 | 127.15 | 109.01 | 114.77 | 124.63 |
| Appar. consum. | 181.52 | 147.92 | 172.01 | 142.94 | 125.84 | 108.34 | 114.60 | 124.66 |
| Diff.(%) | 2.76 | -2.81 | -0.37 | 0.28 | -1.03 | -0.61 | -0.15 | 0.03 |
| $CO_2$ emission (kt) | | | | | | | | |
| RA | 13080.71 | 11077.09 | 12840.74 | 10626.67 | 9497.26 | 8008.72 | 8558.99 | 9412.86 |
| SA | 12797.94 | 11040.38 | 12700.42 | 10412.13 | 9270.10 | 7953.18 | 8369.95 | 9126.46 |
| Diff.(%) | 2.21 | 0.33 | 1.10 | 2.06 | 2.45 | 0.70 | 2.26 | 3.14 |

The Sectoral Approach is based on sectoral energy consumption data whereas, the Reference Approach is based on net quantities of fuel imported and produced in Croatia. Apparent consumption (in tonnes) is derived from imports and exports of primary fuels (crude oil, natural gas, coal), secondary fuels (gasoline, diesel oil etc.) and stock changes. For crude oil, a single value for carbon content and net calorific value is applied, although these properties may vary depending on origin. For solid, gaseous, secondary liquid and other fuels, the same carbon content values and net calorific values are applied as in the Sectoral Approach.

In order to adequately compare the Reference and the Sectoral approach, some inconsistencies with the IPPU sector occur. Detailed elaboration of the comparison methodology is given for 2015. The total amount of natural gas used to calculate emissions of the Sectoral approach is calculated with top-down approach as Energy supplied – non-energy use - losses (87.16-17.15-1.1=68.92 PJ). From this amount, natural gas consumed in the Transformation sector in NGL plant (0.42 PJ) and Gasworks (0.01 PJ) should be subtracted because these amounts are used as feedstocks. Amount of $CO_2$ from natural gas in NGL plant is embedded in gasoline and the amount of $CO_2$ from natural gas in gas works is embedded in gas works gas. So the total amount of natural gas used in the Sectoral approach is 68.49 PJ which is identical to CRF value mentioned in the question.

To conciliate Reference with Sectoral approach in "Apparent energy consumption excluding Non-energy uses" amount of natural gas which is lost and amounts of natural gas used in Transformation sector in NGL plant (0.42 PJ) and Gasworks (0.01 PJ) are added to non-energy consumption. Total amount of natural gas that is not part of sectoral combustion processes for 2015 is 18.68 PJ (17.15+1.1+0.42+0.001).

In table 1A(b) amount of carbon not emitted is calculated as a multiplication 18.68 PJ and FE for C (15.3 kg/GJ).

In table 1.A(d) only amount of natural gas specified in Croatian energy balance as non-energy use-Petrochemical industry is entered. $CO_2$ emission is calculated using default carbon content. This $CO_2$ emission is lower than $CO_2$ specified in Table2(I)s1 because according to 2006 IPCC Guidelines amount of $CO_2$ recovered is subtracted.

The main cause of difference between Reference and Sectoral Approach is that the energy and carbon content of crude oil may vary over time. However, no data are available to quantify this effect.

In 2022 consumption of solid fuel and $CO_2$ emission are the same for both approaches as well as for gaseous fuels.

Small difference appear in Other fuels consumption because in the Sectoral approach fossil part of biodiesel is added but in the Reference approach is missing (Table 3.2-3.).

Table 3.2-3: The fuel consumption and $CO_2$ emissions from other fuels combustion (Reference & Sectoral approach)

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Fuel consumption (PJ) | | | | | | | | |
| SA | NO | NO | NO | 0.32 | 0.39 | 1.63 | 1.88 | 1.94 |
| Appar. consum. | NO | NO | NO | 0.32 | 0.39 | 1.63 | 1.88 | 1.94 |
| Diff.(%) | NO | NO | NO | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $CO_2$ emission (kt) | | | | | | | | |
| RA | NO | NO | NO | 45.63 | 55.77 | 233.13 | 270.48 | 276.71 |
| SA | NO | NO | NO | 46.07 | 59.67 | 243.63 | 282.72 | 280.07 |
| Diff.(%) | NO | NO | NO | -0.95 | -6.54 | -4.31 | -4.33 | -1.20 |

Comparison of the Croatian balance with IEA balance

In the ''Report of the individual review of the annual submission of Croatia submitted in 2013'', ERT noted some issues concerning discrepancies between the data submitted to IEA and the data reported in the Croatian energy balance. The reasons for the differences are:

Production of liquid fuels in Croatian balance is systematically lower by 4-20 % because - there is methodology differences in presenting total consumption of crude oil by IEA and Croatian energy balance. According to IEA, the only production of LPG, ethane and pentane (natural gas liquids) are reported as products of NGL plant. In the Croatian energy balance except output of NGL plant, input of natural gas and gas condensate are noted too.

Imports of sub-bituminous coal and lignite reported in the Croatian energy balance appear to all be classified as lignite in the IEA data. In the Croatian energy balance, there is a balance of bituminous coal, a balance of hard coal and a balance of lignite. Today, all amounts are from the import, while in past smaller production of solid fuels existed in Croatia. In IEA methodology, the balance of hard coal and lignite are presented together as lignite.

### 3.2.2. International bunker fuels

The $CO_2$ emissions from the consumption of fossil fuels for aviation and marine international transport activities, as required by the IPCC methodology, are reported separately and not included in national emission totals. The fuel consumption (PJ) and $CO_2$-eq emissions for International Aviation and Marine Bunkers are shown in the Table 3.2-4.

Table 3.2-4: Fuel consumption and $CO_2$-eq emissions for International aviation and marine bunkers

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Fuel consumption (TJ) | | | | | | | | |
| Aviation bunkers | 6945.68 | 2813.44 | 3604.72 | 4132.24 | 4884.02 | 2259.54 | 4114.66 | 7785.32 |
| Marine bunkers | 1936.81 | 757.39 | 1047.78 | 254.96 | 144.45 | 852.66 | 996.87 | 789.58 |
| Total bunkers | 8882.49 | 3570.83 | 4652.5 | 4387.2 | 5028.47 | 3112.2 | 5111.53 | 8574.9 |
| $CO_2$-eq emission (kt) | | | | | | | | |
| Aviation bunkers | 500.39 | 202.69 | 259.70 | 297.70 | 356.74 | 165.05 | 300.55 | 568.67 |
| Marine bunkers | 148.64 | 58.17 | 80.58 | 19.82 | 11.07 | 64.33 | 75.18 | 60.01 |
| Total bunkers | 649.03 | 260.86 | 340.27 | 317.52 | 367.81 | 229.38 | 375.73 | 628.68 |

Total $CO_2$-eq from the international bunker in 2022 amounted to 628.68 kt which is 67.3 % higher than in 2021 as a result of higher fuel consumption in the International aviation.

Marine bunkers

International marine bunkers are included in the Croatian energy balance for the period from 1994 to 2022, as separate data. Until the year 1994, international marine bunkers are based on expert estimation. From 1994 distribution of fuels in category marine bunkers in Croatia is handled by company INA - Oil Industry dd segment activity SD Retail trade. Questionnaire which is filled by the Croatian oil company INA on fuel consumed in domestic and international navigation is used for fuel statistics data.

In 2013 review process ERT noticed some discrepancies between the fuel consumption data in IEA and CRF tables for marine bunkers. Comparison of this data are given in table 3.2-5.

Table 3.2-5: Comparison of fuel consumption data for marine bunkers for the period from 1990 to 2012

| DataType | Product | Item1 | Flow | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gas-Diesel Oil** | | | | | | | | | | | | | | |
| BALANCE | GASDIES | BUNKERS | International marine bunkers | 19 | | | | 14 | 14 | 12 | 7 | 12 | 14 | 7 |
| HR balance | | | | 0 | 0 | 0 | 0 | 13.6 | 13.7 | 13.2 | 6.9 | 12.2 | 13.6 | 7.1 |
| difference | | | | -19.0 | 0.0 | 0.0 | 0.0 | -0.4 | -0.3 | 1.2 | -0.1 | 0.2 | -0.4 | 0.1 |
| **Residual Fuel Oil** | | | | | | | | | | | | | | |
| BALANCE | RESFUEL | BUNKERS | International marine bunkers | 28 | | | | 31 | 19 | 17 | 17 | 14 | 8 | 11 |
| HR balance | | | | 0 | 0 | 0 | 0 | 31.1 | 19.2 | 23.9 | 16.9 | 13.9 | 7.5 | 11.3 |
| difference | | | | -28.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 6.9 | -0.1 | -0.1 | -0.5 | 0.3 |

| DataType | Product | Item1 | Flow | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gas-Diesel Oil** | | | | | | | | | | | | | | | |
| BALANCE | GASDIES | BUNKERS | International marine bunkers | 13 | 11 | 6 | 8 | 9 | 7 | 4 | | 1 | 1 | 1 | |
| HR balance | | | | 13.3 | 11 | 6.2 | 7.8 | 9.1 | 6.4 | 4.4 | 0 | 1.4 | 0.7 | 1.3 | 0 |
| difference | | | | 0.3 | 0.0 | 0.2 | -0.2 | 0.1 | -0.6 | 0.4 | 0.0 | 0.4 | -0.3 | 0.3 | 0.0 |
| **Residual Fuel Oil** | | | | | | | | | | | | | | | |
| BALANCE | RESFUEL | BUNKERS | International marine bunkers | 16 | 13 | 16 | 16 | 16 | 13 | 20 | 22 | 6 | 6 | 23 | |
| HR balance | | | | 15.5 | 12.6 | 16 | 15.8 | 16.4 | 13.3 | 20.1 | 21.7 | 5.6 | 5.6 | 23.1 | 0 |
| difference | | | | -0.5 | -0.4 | 0.0 | -0.2 | 0.4 | 0.3 | 0.1 | -0.3 | -0.4 | -0.4 | 0.1 | 0.0 |

All data for the IEA must be rounded to whole numbers and data from the national energy balance are not rounded. This is result of small differences. Errors in fuel consumption data in the national report for the period from 1990 to 1994 and for 1996 are revised.

Aviation bunkers

In 2014 project named ''Technical assistance in the business statistics development, preparation of documents on the data quality and improving the data collection system'' by Energy Institute Hrvoje Požar was lunched. This project was launched in the framework of the IPA 2009 Programme and covered the area of energy statistics and improvement of methodologies of data collection in the final energy consumption sectors: households, services and transport. The aim of the project was to determine the energy consumption indicators based on the survey of energy consumption and according to EUROSTAT's list of variables and models for calculating energy efficiency. One of result was to determine actual consumption of fuel on domestic and international routes. The revised values of fuel consumptions were determined for the whole period from 1990 to 2014 and were used to calculate emissions from Aviation Bunkers.

### 3.2.3. Feedstocks and non-energy use of fuels

Non-energy fuel consumptions (fuels used as feedstock) and appropriate emissions, where one part or even the whole carbon is stored in product for a longer time and the other part oxidizes and goes to the atmosphere, are described here. The feedstock use of energy carriers occurs in chemical industry (natural gas consumption for ammonia production, production of naphtha, ethane, paraffin and wax), construction industry (bitumen production), and other products such as motor oil, industrial oil, grease etc. As a result of the non-energy use of bitumen in the construction industry, there is no $CO_2$ emission because all carbon is bound to the product.

### 3.2.4. Energy industries (CRF 1.A.1.)

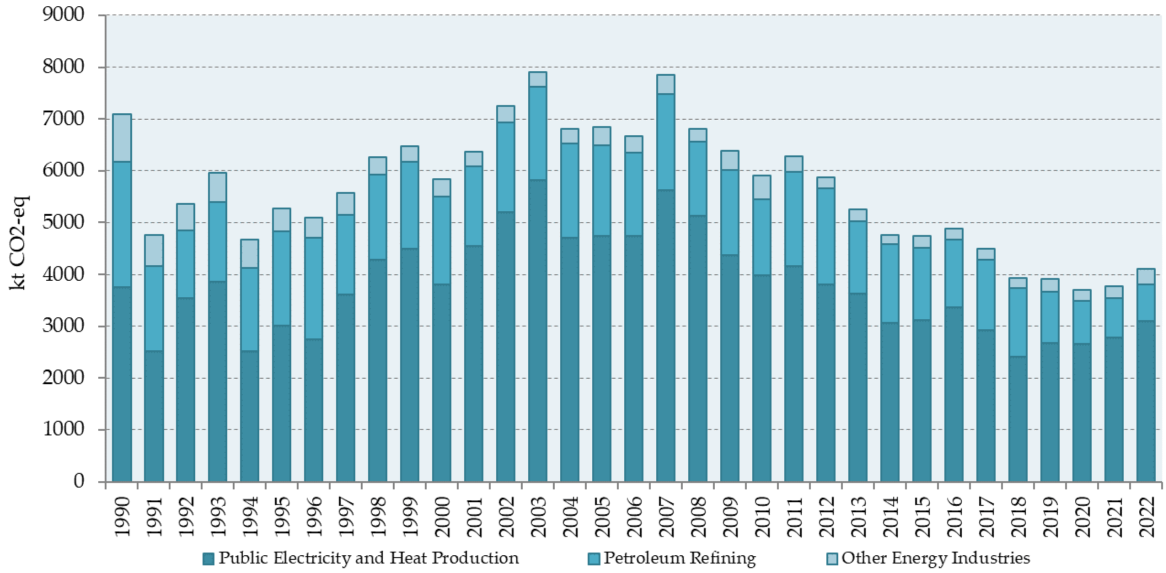
Category description

This subsector comprises emissions from fuel combustion in public electricity and heat production plants, petroleum refining plants, solid transformation plants, oil and gas extraction and coal mining. The total GHG emission from Energy Industries is given in the Table 3.2-6 and Figure 3.2-1.

Table 3.2-6: The $CO_2$-eq emissions (kt) from Energy Industries

| $CO_2$-eq emission (kt) | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Public Electr. and Heat Prod. | 3,745.3 | 3,806.5 | 4,751.1 | 3,989.3 | 3,116.8 | 2,658.6 | 2,787.4 | 3,104.9 |
| Petroleum Refining | 2,430.2 | 1,687.3 | 1,733.8 | 1,452.7 | 1,390.1 | 836.7 | 746.5 | 696.6 |
| Other Ener. Industries | 913.1 | 339.6 | 352.5 | 461.5 | 235.7 | 202.3 | 237.2 | 306.9 |
| Total Ener. Industries | 7,088.6 | 5,833.4 | 6,837.5 | 5,903.4 | 4,742.6 | 3,697.7 | 3,771.1 | 4,108.3 |

Figure 3.2-1: $CO_2$-eq emissions from Energy Industries




It should be stressed out that approximately 46-53 % of the electricity is generated in hydropower plants; therefore the emission from the Energy Industries sector is relatively small, 29-36 % of emission from the total Energy sector. The largest part (51-75 %) of the emission is a consequence of fuel combustion in thermal power plants, then the combustion in oil refineries 21-40 %. The remaining combustion in oil and gas fields, coal mines and the coke plant accounts for some 3-12 %.

Public Electricity and Heat Production (CRF 1.A.1.a)

By the end of 2022 electricity generation capacities in Croatia encompassed 17 locations with large hydropower plants, 7 with thermal power plants, one half of the installed capacities of the nuclear power plant Krško (located in the territory of Slovenia) and large number of Renewable Energy Systems (RES) (wind and sun). Thermal power plants use coal, gas and fuel oils. Most gas-fired power plants can use extra light fuel oil as a replacement fuel. The majority owner of the production capacities of the Republic of Croatia is the HEP Group (state-owned company). Private producers mostly own RES-powered power plants, which have been developing more intensively since 2006, i.e. after the introduction of the system of encouraging the production of electricity from RES.

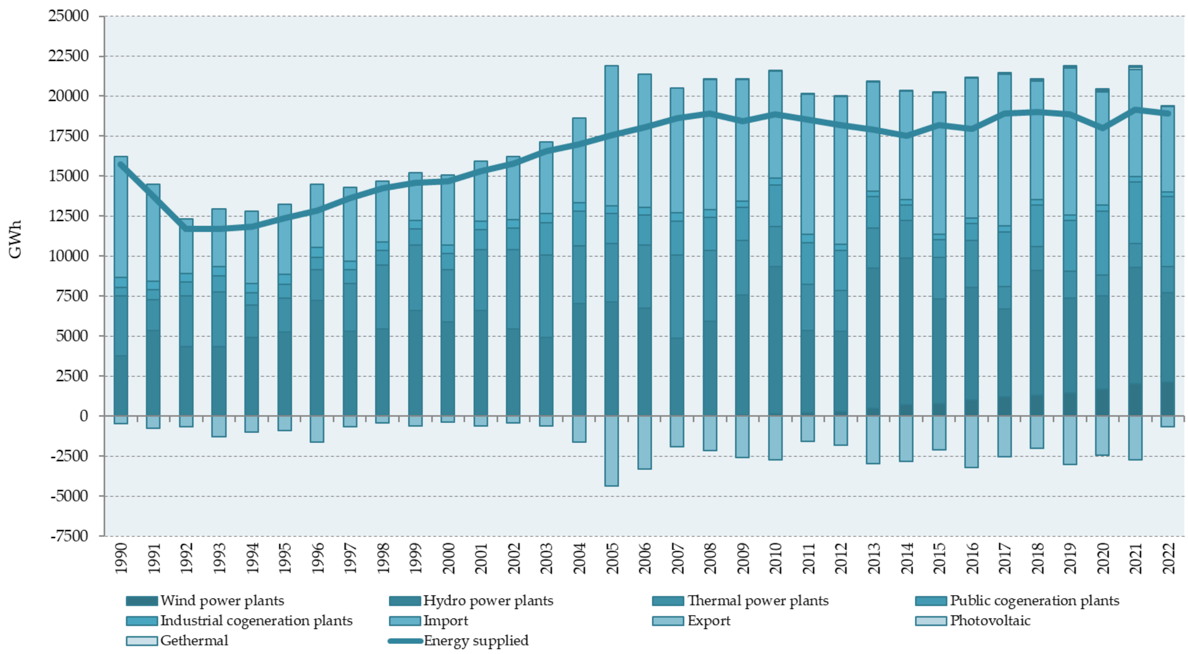
Total available capacities of all power plants in the Republic of Croatia by the end of 2022 amount to 4946.8 MW (including TE Plomin and without nuclear power plant Krško). Out of this amount, 1534.6 MW is placed in thermal power plants, 2203.4 MW in hydro power plants, 986.9 in wind power plants, 222.0 MW in solar power plants. There is also 348 MW in the nuclear unit Krško (50 % of total available capacity) used for Croatian power system. Generating capacities of the thermal power plants in Croatia are presented in the Table 3.2-7.

Table 3.2-7: Thermal power plants in the Republic of Croatia

| Facility | Available Power (MW), net output | Fuel type |
|---|---|---|
| HPPs | 2203.4 | - |
| NPP Krško* | 348 | uranium oxide ($UO_2$) |
| TPP Plomin 1 | - | coal |
| TPP Plomin 2** | 199 | coal |
| TPP Rijeka | 303 | fuel oil |
| CHP Sisak | 235 | fuel oil / natural gas |
| CHP Zagreb (east) | 300 | fuel oil / natural gas |
| CHP Zagreb (west) | 48 | fuel oil / natural gas / extra light oil |
| CPP Osijek | 66 | fuel oil / natural gas / extra light oil |
| KTE Jertovec | 76 | fuel oil / natural gas / extra light oil |
| Other biogas plants | 59.3 | biogas |
| Other biomass plants | 101.2 | biomass |
| Geothermal plants | 10.0 | |
| CHP in Industry | 132.8 | coal / natural gas / fuel oil/ wood |
| Other small CHP | 4.3 | natural gas |
| Total | 4086 | |
| * 50% of NPP Krško is owned by HEP,<br>** TPP Plomin 2 Ltd. (HEP and RWE Power Co-ownership – share 50% : 50%) | | |

During the observed period between 1990 and 2022 in Croatia, only 14 to 32 % of Croatian electricity demands were covered by thermal power plants. The largest contribution to electricity production in Croatia had hydropower plants 36 to 69 %. Nuclear power plant Krško delivered 50 % of its electricity to Croatian power system until 1998 after which was a four year period of non-delivery. The delivery of electricity from NPP Krško started again in 2003. The past few years the electricity demand was compensated with import. Therefore, in 2000 the electricity import was larger than production in all Croatian thermal power plants (TPPs). In 2022, the import of electricity was about 35% of the total electricity consumption in Croatia. Electricity supply for the period from 1990 to 2022 is presented in Figure 3.2-2.

Figure 3.2-2: Electricity supply for the period from 1990 to 2022



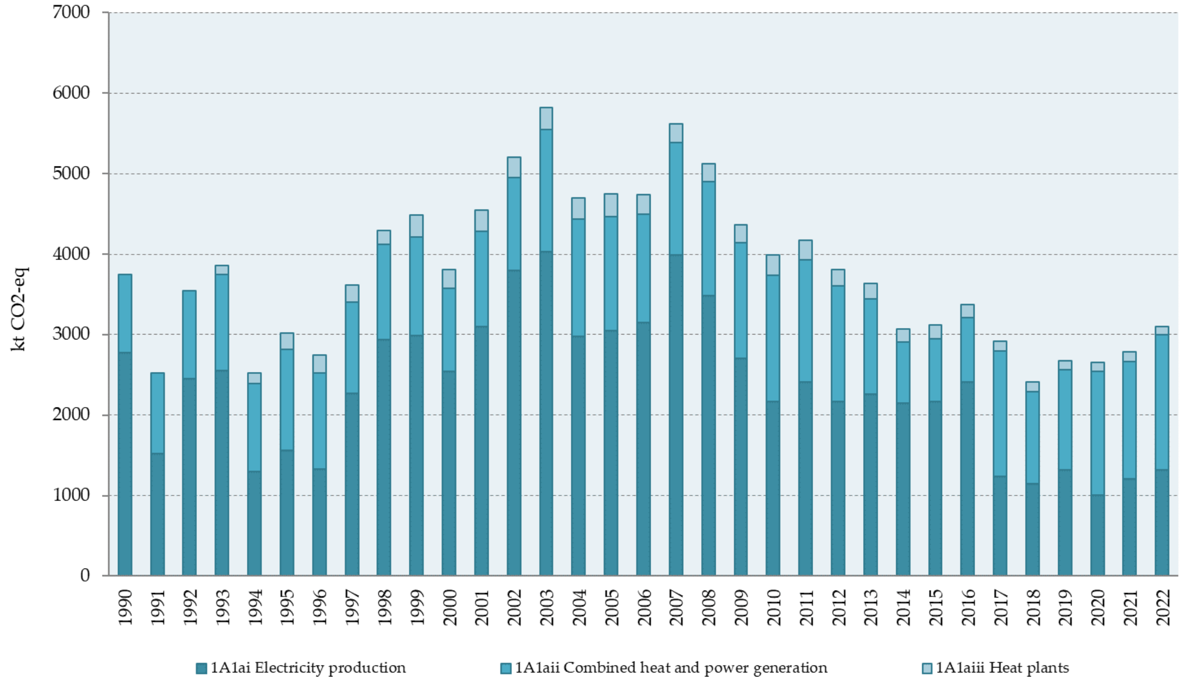
In this subsector there are few types of plants:

- Thermal Power Plants (TPPs), which produce only electricity
- Public Cogeneration Plants (PCPs), which produce combined heat and electricity
- Public Heating Plants (PHPs), which produce only heat.

TPP Plomin 2, which started to operate in 2000, has installation for flue gasses cleaning. By-product from process which cleans flue gasses from sulphur ($SO_2$ scrubbing process) is $CO_2$. $CO_2$ emission is calculated from the amount of $CaCO_3$ used for cleaning. Amounts of produced $CaCO_3$, as well as emitted $CO_2$ emission, are presented in the Industry sector (limestone and dolomite use).

The $CO_2$-eq emission from public electricity and heat production are presented in Figure 3.2-3 for the whole period from 1990 to 2022.

Figure 3.2-3: $CO_2$-eq emissions from Public Electricity and Heat Production subsectors

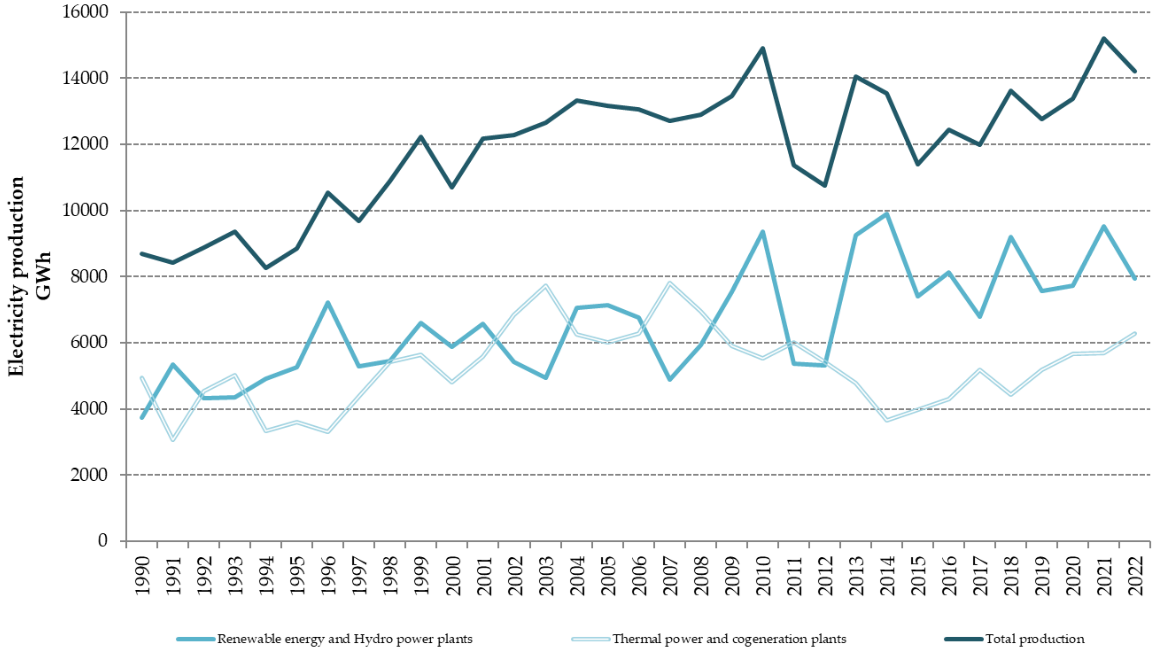



Production of electricity has increasing trend through the years, from 8 TWh (1990) to 15 TWh (2010) but $CO_2$ emission does not follow this trend. Approximately 51 % of electricity is generated in hydropower plants (HPP), but this per cent depends on hydrological conditions during the year. If hydrological conditions are unfavourable the lack of electricity must be supplemented by stronger engagement of thermal power plants, which consequently leads to large GHG emissions. Domestic production of electricity by sources for the period from 1990 to 2022 is presented in Figure 3.2-4. In 2022 the total electricity production was 1.3% lower than in the former year (Table 3.2-8).

Table 3.2-8: Differences between electricity production in 2021 and 2022

| ENERGY BALANCE | Electricity, GWh | | Difference 2022-2021 | Difference % |
|---|---|---|---|---|
| | 2021 | 2022 | | |
| Production | 15,210.4 | 14,220.5 | -989.9 | -6.5 |
| Hydro power plants | 7,228.7 | 5,573.7 | -1,655.0 | -22.9 |
| Wind power plants | 2,061.8 | 2,137.8 | 76.0 | 3.7 |
| Photovoltaic | 148.9 | 151.9 | 3.0 | 2.0 |
| Thermal power plants | 1,510.9 | 1,658.3 | 147.4 | 9.8 |
| Public cogeneration plants | 3,830.4 | 4,345.1 | 514.7 | 13.4 |
| Industrial cogeneration plants | 340.0 | 281.0 | -59.0 | -17.4 |
| Import | 6,700.0 | 5,336.2 | -1,363.8 | -20.4 |
| Export | -2,739.0 | -641.4 | 2,097.6 | -76.6 |
| Total consumption | 19,171.4 | 18,915.3 | -256.1 | -1.3 |

Figure 3.2-4: Domestic production of electricity by sources for the period from 1990 to 2022




Fuel consumption, net calorific values and emission factors used for estimating GHG emissions are presented in Tables A3-1 to A3-3 of the Annex 3.

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

Croatia has two oil refineries in Rijeka and Sisak, while lubricants are produced in Rijeka and Zagreb. Crude oil is produced from 38 oil fields and gas condensation products from 9 gas-condensations fields, which covers about 35 % of the total domestic demand. Processing capacities of the Croatian refineries, which belong to INA – oil and gas company, are shown in the Table 3.2-9.

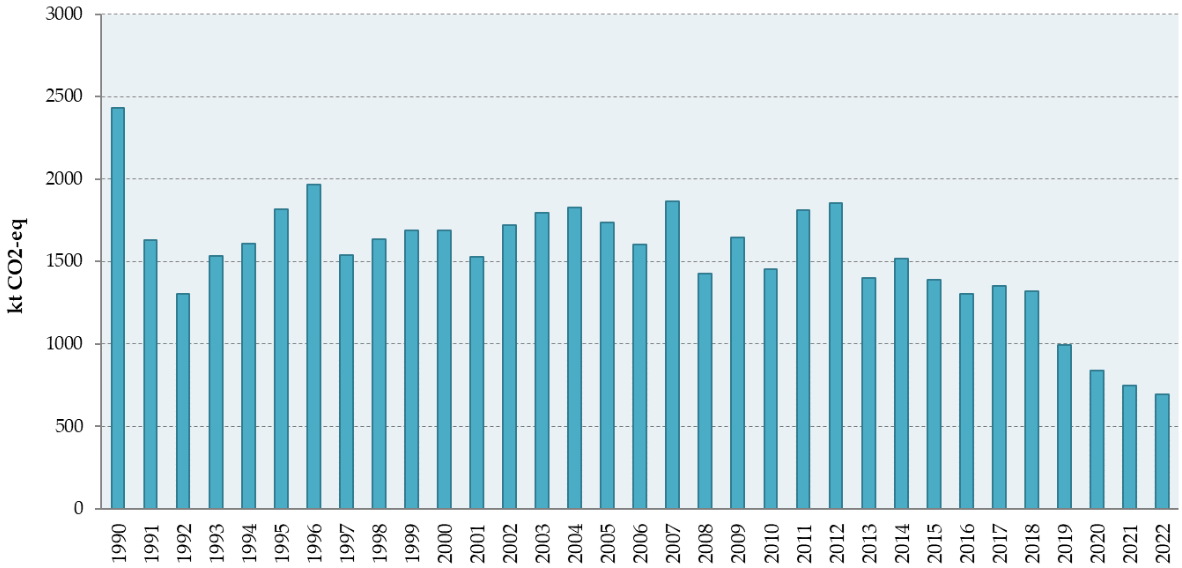
Table 3.2-9: Processing Capacities of Oil and Lube Refineries

| Processing Capacities | Installed (1000 t/year) |
|---|---|
| Oil Refinery Rijeka (Urinj) | |
| atmospheric distillation | 4500 |
| reforming | 563 |
| fluidized-bed catalytic cracking (FCC) | 689 |
| visbreaking | 600 |
| isomerization | 235 |
| hydrodesulfurization (HDS) | 1204 |
| mild hydrocracking (MHC) | 622 |
| hydrocracking | 2600 |
| Oil Refinery Sisak | |
| atmospheric distillation | 3800 |
| reforming | 670 |
| fluidized-bed catalytic cracking (FCC) | 490 |
| coking | 280 |
| vacuum distillation | 895 |
| bitumen | 200 |
| Lube Refinery Zagreb Ltd. | |
| lubricants | 60 |

In the refineries, there are two types of fuel combustion – for heating and/or cogeneration and for own use of energy for production processes. Emissions from both types of fuel combustion were calculated in this sector and presented in Figure 3.2-5.

Fuel consumption, net calorific values and emission factors used for estimating GHG emissions are presented in Table A3-4 of the Annex 3.

Figure 3.2-5: $CO_2$-eq emissions from Petroleum Refining subsector for the period from 1990 to 2022



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

In Croatia, the coal production in the period 1990-1998 was rather low. Last coal mines in Istria were closed in 1999. Coke-oven plant in Bakar, nearby Rijeka, was also closed in 1994.

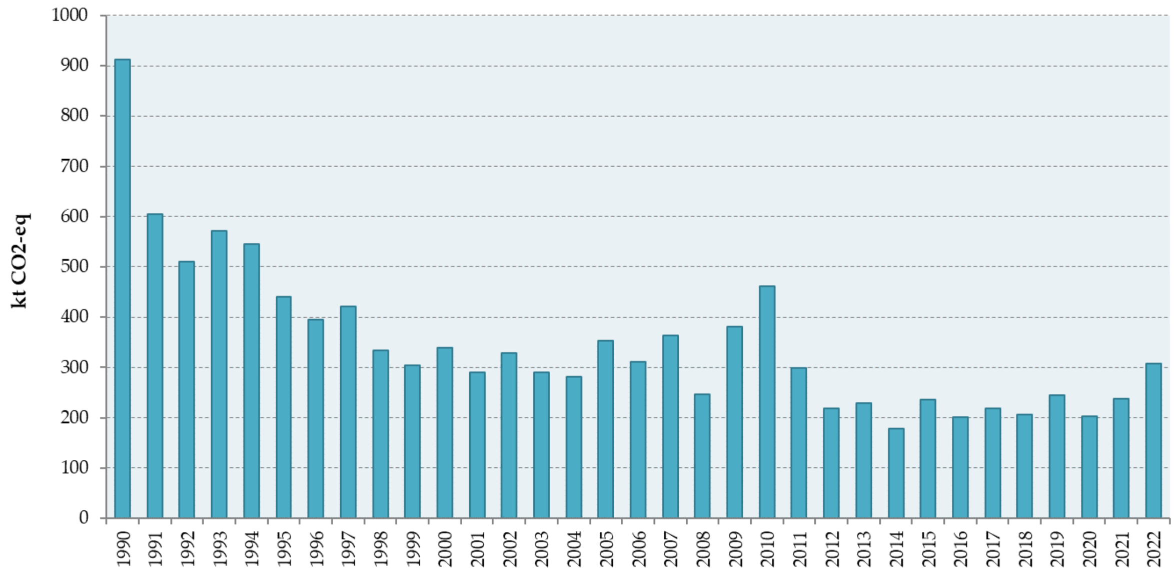
Natural gas is produced from 17 on-shore gas fields and 3 off-shore gas fields, which covers about 44.4% of total domestic demand in 2022. The largest share of gas is coming from fields Molve and Kalinovac. They include the units for processing and preparation of gas for transportation to Central Gas Stations (CGS) Molve I, II and III. Their capacities are:

- 1 mill. $m^3$/day for Molve I
- 3 mill. $m^3$/day for Molve II
- 5 mill. $m^3$/day for Molve III

The underground gas storage Okoli was designed with a nominal capacity of 553 million $m^3$. Maximum injection capacity is 3.8 million $m^3$/day and maximal withdrawal capacity is 5.8 million $m^3$/day.

$CO_2$-eq emissions from this subsector for the whole period from 1990 to 2022 are presented in Figure 3.2-6.

Figure 3.2-6: $CO_2$-eq emissions from Manufacturing of Solid Fuels and Other Energy Industries for the period from 1990 to 2022




Fuel consumption, net calorific values and emission factors used for estimating GHG emissions from Manufacturing of Solid Fuels and Other Energy Industries are presented in the Tables A3-5 to A3-7 of the Annex 3.

#### 3.2.4.1. Methodological issues

Methodology

- T1, T2 (1990-2022) -1A1a
- T1 (1990-2022) -1A1b
- T1 (1990-2022) -1A1c

Tier 1 Approach

Tier 1 approach is based on data on the amount of fuel combusted in the source category. Source of data on the amount of fuel combusted is national energy balance. Data from the national energy balance were recalculated from natural units into energy units by means of its net calorific values for each fuel. Calorific values are also taken from the energy balance. The emission factors used for calculation are taken from IPCC Guidelines (2006 IPCC Guidelines for National GHG Inventories). It is assumed that the combustion process is 100 % efficient, so the oxidation factor was 1.

For category 1A1b Petroleum refining, for $CO_2$ emissions, for the year 2019, the TERT noted that the ratio ETS/inventory is higher than 100% (102.7%, i.e. 26.2 kt $CO_2$). The difference occurs due to differences in ETS and EUROSTAT methodology for fuel consumption calculation. The amount of consumed petroleum coke shown in the energy balance for 2019 refers to the amount of coke produced as a by-product in the fluid catalytic cracking (FCC) process at the Rijeka Oil Refinery, while at the Sisak Oil Refinery there was no coke consumption - FCC suspended 2017.

Coke is deposited on the fluid catalyst and in the process of regeneration of the fluid catalyst the coke is burned, which leads to $CO_2$ emissions. However, $CO_2$ emissions for the EU ETS from this FCC process are not calculated from coke, but from the intake air and flue gas mass balance methodology, which is part of the specific monitoring rules and approved by the competent authority. Accordingly, the Annual ETS Report on Greenhouse Gas Emissions for 2019 does not show coke consumption in order to avoid double counting of $CO_2$ emissions. The material balance in its report presents the stated consumption of coke in the FCC catalyst regenerator as own consumption in accordance with the practice in the world oil industry.

Emissions of $CH_4$ and $N_2O$ have been identified by Tier 1 method in such a way that the fuel used in each sector is multiplied by the emission factor suggested in 2006 IPCC Guidelines for National GHG Inventories. The basis for the estimate is the fuel used in different energy sectors. The used fuel is grouped into basic fossil fuels categories according to its aggregate condition: coal, natural gas and oil, and biomass-based fuel. Data about quantities of the fuel used are taken from the national energy balance.

Tier 2 Approach

$CO_2$ emissions for 1A1ai and 1A1aii categories are calculated using country-specific emission factors for natural gas and hard coal which is obtained for each plant (TPPs and CHPs) from verified ETS reports for the period 2013-2022 For the period from 1990 to 2012 average emission factor based on verified reports are calculated and used for previous years.

#### 3.2.4.2. Uncertainties and time-series consistency

Uncertainty of $CO_2$ emissions

The $CO_2$ emission, from the fossil fuel combustion, depends on amount of fuel consumed (from energy balance), net calorific values (from energy balance), carbon emission factors (IPCC), the fraction of carbon stored (IPCC) and the fraction of carbon oxidised (IPCC).

The national energy balance is based on data from different available sources. The data from the Central Bureau of Statistics about production, usage of raw material and consumption of fuels in all industrial facilities in Croatia are used. The data from questionnaires about monthly use of natural gas in certain sectors from all distributive companies in Croatia, about annual consumption of coal in certain sectors and the data from Customs Administration about export and import of fossil fuels, are also used. The data from these sources and other necessary data are organised in related database. The estimated uncertainty of data from energy balance is below 5 %.

The accuracy of data on net calorific values, which are also taken from national energy balance, is high.

The other data needed for calculation, such as carbon emission factors, the fraction of carbon stored for non-energy uses of fuel and the fraction of carbon oxidized, are taken from 2006 IPCC Guidelines for National GHG Inventories.

Experts believe that $CO_2$ emission factors for fuels are generally well determined within 5 %, as they are primarily dependent on the carbon content of the fuel.

Uncertainty of $CH_4$ and $N_2O$ emissions

Estimates of $CH_4$ and $N_2O$ emissions are based on fuel (coal, natural gas, oil and biofuels) and aggregate emission factors for different sectors. Uncertainties in estimates are due to the fact that emissions are estimated on the base of emission factors representing only a limited subset of combustion conditions. Using the aggregate emission factors for each sector, the differences between various types of coal and especially liquid fuel are not included, nor are the differences in the technology and the contribution of equipment for emission reduction. Therefore, the uncertainties associated with emission estimates of these gases are greater than estimates of $CO_2$ emissions from fossil fuel combustion.

The uncertainty of $CH_4$ emission is estimated to ±40 %; while the uncertainty of $N_2O$ emission is estimated to factor 2 (the emission could be twice larger or smaller than the estimated one). The largest part of uncertainty refers to the emission factor applied while the fuel consumption data (national energy balance) are rather good.

Time-series consistency

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities is very consistent for the entire period.

#### 3.2.4.3. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates. Also, several checks have been carried out in order to ensure correct aggregation from lower to higher reporting level and correct use of conversion factors.

Regarding to QC Tier 2 activities, activity data were checked for key source categories. In Energy industries, Public Electricity and Heat Production, due to availability of detail information on fuel consumption in the facilities. Activity data from energy balance were compared with data provided by individual facilities. Results of this comparison showed that there is no significant difference between these two sets of data. These bottom-up data are still not available for other sub-categories therefore Tier 1 methodology was applied.

Also, the inventory team used country-specific fuel net calorific values for emission estimates. Calorific values from energy balance were compared with data from the IPCC Guidelines. Results of this comparison showed that there is no significant difference between these two sets of data.

#### 3.2.4.4. Category-specific recalculations

In this cycle there were no recalculations in this category.

### 3.2.4.5. Category-specific planned improvements

For 1A1b category is planned to compare ETS and EUROSTAT fuel consumption data for period from 2013 till 2022 and determine country specific $CO_2$ emission factors for fuels with the highest consumption.

## 3.2.5. Manufacturing industries and construction (1.A.2)

### 3.2.5.1. Category description

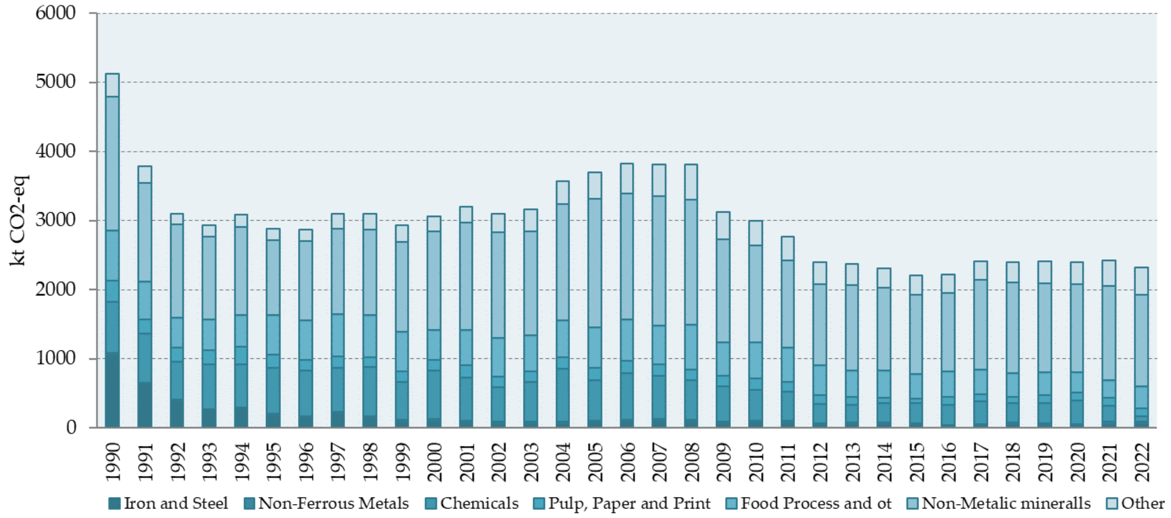
Manufacturing Industries and Construction includes emissions from fuel combustion in different industries, such as iron and steel industries, industries of non-ferrous metals, chemicals, pulp and paper, food processing, beverages and tobacco, construction and building material industries, petrochemical industries. This sector also includes the emissions from fuel used for the generation of electricity and heat in industry (industrial cogeneration plants and industrial heating plants). In national energy balance fuel consumed in industrial heating plants and cogenerations were not divided by appropriate industrial branches, so in addition to national energy balance so-called ‘Industry analysis balance’ was created, for the whole period from 1990 to 2022.

The total GHG emission from Manufacturing Industries and Construction is given in the Table 3.2-10 and Figure 3.2-7.

Table 3.2-10: The $CO_2$-eq emissions (kt) from Manufacturing Industries and Construction

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Iron and Steel Industry | 1,067.3 | 109.0 | 89.1 | 93.1 | 51.7 | 33.9 | 56.6 | 64.0 |
| Non-Ferrous Metals | 17.2 | 16.9 | 21.5 | 14.0 | 10.9 | 25.6 | 30.3 | 30.9 |
| Chemicals | 739.8 | 706.4 | 581.7 | 450.2 | 294.6 | 336.5 | 234.5 | 72.6 |
| Pulp, Paper and Print | 304.3 | 153.5 | 175.0 | 162.1 | 70.2 | 115.9 | 121.7 | 118.5 |
| Food Proc., Bev. and Tobac. | 732.1 | 432.5 | 594.2 | 515.3 | 351.8 | 295.9 | 243.1 | 315.7 |
| Non-metallic minerals | 1,937.2 | 1,422.1 | 1,856.9 | 1,409.2 | 1,153.4 | 1,266.2 | 1,371.6 | 1,321.9 |
| Other | 330.1 | 224.5 | 377.5 | 353.6 | 278.1 | 330.6 | 372.5 | 401.1 |
| Total Manuf. Ind. and Cons. | 5,127.9 | 3,065.0 | 3,695.8 | 2,997.6 | 2,210.8 | 2,404.5 | 2,430.4 | 2,324.6 |

Figure 3.2-7: $CO_2$-eq emissions from Manufacturing Industries and Construction




The emissions from this subsector contribute 16-27 % of the total emission from the Energy sector. The largest contributor to emissions is fuel combustion in industry of construction materials and petrochemical production (subsector: Non-metallic minerals in Figure 3.2-7), followed by food processing industry, paper industry, chemical industry, iron and steel industry and non-ferrous metal industry.

#### 3.2.5.2. Methodological issues

Methodology

- T1 (1990-2022)

The GHG emissions from this subsector were calculated using the Tier 1 approach.

In national energy balance, the fuel combustion in industrial cogeneration and heating plants is not divided on appropriate industrial branches, for which electricity and/or thermal energy is produced. The fuel consumed in industrial cogeneration and heating plants is divided by industrial subsectors for the period 1990-2022 (Industry analysis balance).

Data from the national energy balance were recalculated from natural units into energy units by means of its net calorific values for each fuel. Calorific values are also taken from the energy balance. The emission factors used for calculation are taken from IPCC Guidelines (2006 IPCC Guidelines for National GHG Inventories).

Fuel consumption, net calorific values and emission factors used for estimating GHG emissions from Manufacturing Industries and Construction by fuels are shown in Tables A3-8 and A3-9 of the Annex 3.

#### 3.2.5.3. Uncertainties and time-series consistency

Uncertainty of $CO_2$ emissions

The $CO_2$ emission, from the fossil fuel combustion, depends on amount of fuel consumed (from energy balance), net calorific values (from energy balance), carbon emission factors (IPCC), the fraction of carbon stored (IPCC) and the fraction of carbon oxidised (IPCC).

The national energy balance is based on data from different available sources. The data from the Central Bureau of Statistics about production, usage of raw material and consumption of fuels in all industrial facilities in Croatia are used. The data from questionnaires about monthly use of natural gas in certain sectors from all distributive companies in Croatia, about annual consumption of coal in certain sectors and the data from Customs Administration about export and import of fossil fuels, are also used. The data from these sources and other necessary data are organized in related database. The estimated uncertainty of data from energy balance is below 5 %.

The accuracy of data on net calorific values, which are also taken from national energy balance, is high.

The other data needed for calculation, such as carbon emission factors, the fraction of carbon stored for non-energy uses of fuel and the fraction of carbon oxidized, are taken from Revised 2006 IPCC Guidelines for National GHG Inventories. Experts believe that $CO_2$ emission factors for fuels are generally well determined within 5 %, as they are primarily dependent on the carbon content of the fuel.

For example, for the same primary fuel type (e.g. coal), the amount of carbon contained in the fuel per unit of useful energy can vary. Non-energy uses of the fuel can also create situations where the carbon is not emitted to the atmosphere (e.g. plastics, asphalt, etc.) or is emitted at a much-delayed rate. Additionally, inefficiencies in the combustion process, which can result in ash or soot remaining unoxidized for long periods, were also assumed. These factors all contribute to the uncertainty in the $CO_2$ estimates. However, these uncertainties are believed to be relatively small.

Overall uncertainty for $CO_2$ emission estimates from the fossil fuel combustion are considered accurate within 5 %.

Uncertainty of $CH_4$ and $N_2O$ emissions

Estimates of $CH_4$ and $N_2O$ emissions are based on fuel (coal, natural gas, oil and biofuels) and aggregate emission factors for different sectors. Uncertainties in estimates are due to the fact that emissions are estimated on the base of emission factors representing only a limited subset of combustion conditions.

Using the aggregate emission factors for each sector, the differences between various types of coal and especially liquid fuel are not included, nor are the differences in the technology and the contribution of equipment for emission reduction. Therefore, the uncertainties associated with emission estimates of these gases are greater than estimates of $CO_2$ emissions from fossil fuel combustion.

The uncertainty of $CH_4$ emission is estimated to ±40 %; while the uncertainty of $N_2O$ emission is estimated to factor 2 (the emission could be twice larger or smaller than the estimated one). The largest part of uncertainty refers to the emission factor applied while the fuel consumption data (national energy balance) are rather good.

Time-series consistency

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities is very consistent for the entire period.

#### 3.2.5.4. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates and on proper use of notation keys in the CRF tables. Also, several checks have been carried out in order to ensure correct aggregation from lower to higher reporting level and correct use of conversion factors.

### 3.2.5.5. Category-specific recalculations

In 2024 cycle there were recalculations in 1A2gvii Off road vehicless category. It was noticed that fuel consumptions are wrong calculated in Industry analysis balance. Differences in emissions due to recalculations are shown in Table 3.2-11.

Table 3.2-11: Differences in emissions due to recalculation in 1A2gvii Off road vehicless category

| Year | $CO_2$-eq NIR 2024 | $CO_2$-eq NIR 2023 | difference NIR 2024-NIR 2023 | % difference regard to total emission of 1A2 sector |
|---|---|---|---|---|
| 1990 | 330.11 | 436 | -105.89 | -2.06% |
| 1991 | 252.14 | 248.67 | 3.47 | 0.09% |
| 1992 | 145.63 | 141.84 | 3.79 | 0.12% |
| 1993 | 159.93 | 160.17 | -0.24 | -0.01% |
| 1994 | 178.96 | 179.05 | -0.09 | 0.00% |
| 1995 | 158.71 | 164.82 | -6.11 | -0.21% |
| 1996 | 164.71 | 174.23 | -9.52 | -0.33% |
| 1997 | 220.27 | 211.61 | 8.66 | 0.28% |
| 1998 | 239.32 | 213.07 | 26.25 | 0.85% |
| 1999 | 244.22 | 186.13 | 58.09 | 1.98% |
| 2000 | 224.55 | 233.48 | -8.93 | -0.29% |
| 2001 | 232.8 | 240.14 | -7.34 | -0.23% |
| 2002 | 262.94 | 235.07 | 27.87 | 0.90% |
| 2003 | 322.59 | 309.27 | 13.32 | 0.42% |
| 2004 | 329.56 | 309.27 | 20.29 | 0.57% |
| 2005 | 377.51 | 420.58 | -43.07 | -1.17% |
| 2006 | 429.41 | 478.02 | -48.61 | -1.27% |
| 2007 | 461.78 | 478.02 | -16.24 | -0.43% |
| 2008 | 511.62 | 586.58 | -74.96 | -1.97% |
| 2009 | 396.09 | 445.33 | -49.24 | -1.58% |
| 2010 | 353.68 | 385.78 | -32.1 | -1.07% |
| 2011 | 340.05 | 369.61 | -29.56 | -1.07% |
| 2012 | 312.14 | 336.94 | -24.8 | -1.03% |
| 2013 | 303.58 | 328.06 | -24.48 | -1.03% |
| 2014 | 275.32 | 299.16 | -23.84 | -1.03% |
| 2015 | 278.19 | 299.17 | -20.98 | -0.95% |
| 2016 | 271.82 | 289.95 | -18.13 | -0.82% |
| 2017 | 266.46 | 290.29 | -23.83 | -0.99% |
| 2018 | 295.07 | 315.42 | -20.35 | -0.85% |
| 2019 | 312.21 | 336.03 | -23.82 | -0.99% |
| 2020 | 330.62 | 319.77 | 10.85 | 0.45% |
| 2021 | 372.55 | 372.55 | 0 | 0.00% |

### 3.2.5.6. Category-specific planned improvements

On a long term basis, the inventory team is planning to apply more detailed Tier 2 approach for calculation $CO_2$ emissions from Manufacturing Industries and Construction. Since industries such as iron and steel industries, industries of non-ferrous metals, chemicals, pulp and paper, food processing, beverages and tobacco, construction and building material industries, petrochemical industries, are in ETS, verified annual emission report of each industrial plant are available. Tier 2 approach is based on bottom-up fuel consumption data from every industrial plant. In verified annual emission reports there are available data about yearly fuel consumption and detailed fuel characteristics data (net calorific value) and plant-specific emission factors.

Also, on a long term basis, the inventory team is planning to apply country-specific carbon content values and oxidation factor values to estimate emissions for the main fuel types.

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

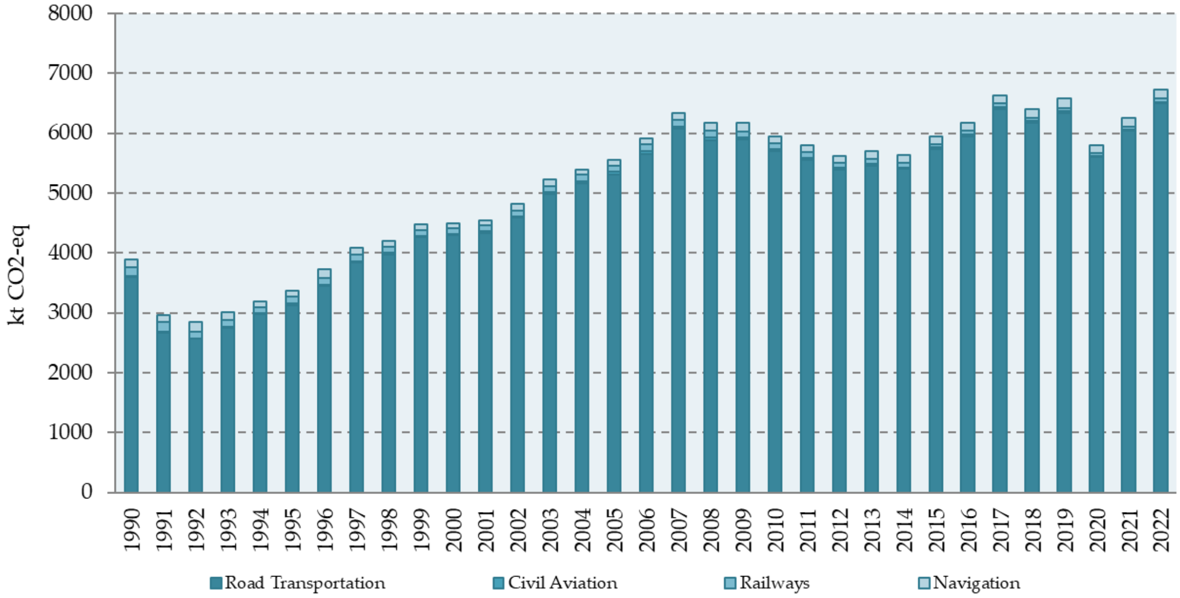
### 3.2.6.1. Category description of Transport sector

The emission from combustion and evaporation of fuel for all transport activities is included in this sector. In addition to road transport, this sector includes the emission from air, rail and marine transport as well. The total GHG emission from the Transport sector is given in the Table 3.2-12 and Figure 3.2-8.

Table 3.2-12: The $CO_2$-eq emissions (kt) from sector Transport

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Civil Aviation | 6.7 | 25.6 | 38.0 | 31.6 | 31.0 | 16.8 | 22.5 | 26.0 |
| Road Transport | 3,604.1 | 4,292.9 | 5,316.8 | 5,699.9 | 5,728.2 | 5,600.0 | 6,036.7 | 6499.2 |
| Railways | 152.1 | 95.3 | 106.5 | 99.5 | 61.1 | 46.4 | 49.9 | 51.3 |
| Navigation | 135.8 | 87.6 | 101.8 | 117.6 | 131.8 | 128.6 | 150.0 | 154.5 |
| **Total** | **3,898.6** | **4,501.4** | **5,563.1** | **5,948.7** | **5,952.1** | **5,791.9** | **6,259.1** | **6,730.9** |

Figure 3.2-8: The $CO_2$-eq emissions from Transport




The contribution from the Transport sector to the total $CO_2$-eq emissions from Energy sector in 2022 was 39.9 %. $CO_2$-eq emissions from the transport sector in 2022 amounted to 6,730.95, which is 7.5 % higher than in 2021 as a result of higher fuel consumption in road transport. Specifically, the emission of $CO_2$-eq emissions from the Road transport sector (CRF 1.A.3.b) was dominant one in the transport sector (CRF 1.A.3) in 2022 and contributed to the $CO_2$-eq emissions from the transport sector with 96.5 %. In 2022, the Navigation sector was contributed to the $CO_2$-eq emissions with 2.3 %, Railways with 0.8 % and Civil aviation (domestic) with 0.4 % and (Figure 2.3-8). In comparison with 1990, $CO_2$-eq emissions from the transport sector were increased by 72.6 % as a result of increasing the number of vehicles and also increase in annual millage.

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

The $CO_2$-eq emission from the sub-sector domestic civil aviation in 2022 amounted 26.0 kt, which is 15.5% higher than in 2021, as a result of jet kerosene consumption increase. In comparison with 1990, $CO_2$-eq emission was 3.9 times higher as a result of increase in fuel consumption.

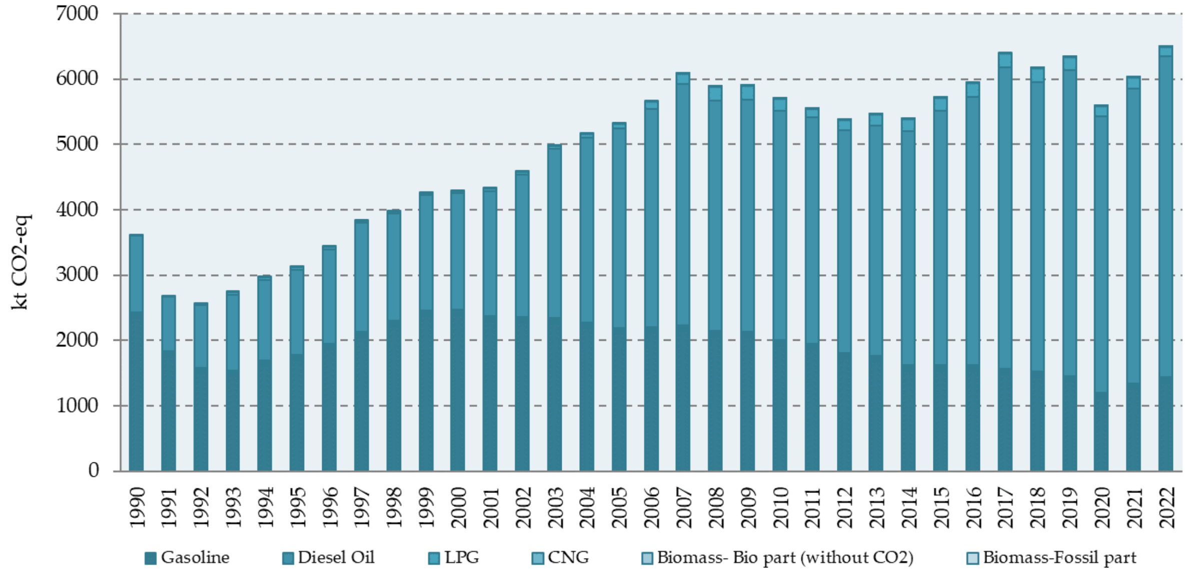
Road Transport (CRF 1.A.3.b)

Road transportation includes all types of passenger cars, light-duty vehicles, heavy-duty vehicles, buses, mopeds and motorcycles. These mobile sources use different types of liquid and gaseous fuels, mostly gasoline and diesel oil, and emit significant amounts of greenhouse gases and air pollutants. The contribution of road transportation to the total greenhouse gas emissions was 26.5 % in 2022 and 11.4 % in 1990. In the period from 1990 to 2022 emissions from road transportation raised by 80.3 % mainly due to increase in the numbers of vehicles (passenger cars mostly) and consumption of diesel oil in all types of vehicles. From 2008 onwards emissions from road transportation have slightly decreased due to lower fuel consumption caused by economic crises in Croatia as well as the implementation of measures for $CO_2$ emission reduction according to Integrated National Energy and Climate Plan for the Republic of Croatia from 2021 to 2030.

The $CO_2$-eq from the sub-sectors Road transport in 2022 amounted to 6,499.2 kt, which is 7.7 % higher than in 2021 as a result of increase in fuel consumption. In comparison with 1990, $CO_2$-eq increased by 80.3 % as a result of growing in diesel fuel consumption (by 1.8 times compared to 1990).

Trends of $CO_2$-eq emissions for fossil fuel type consumed in road transport for the period from 1990 to 2022 are shown in Figure 3.2-9.

Figure 3.2-9: The $CO_2$-eq emission from Road transport sub-sector by fossil fuel type




Railways (CRF 1.A.3.c)

The $CO_2$-eq from the sub-sectors Railways in 2022 amounted to 51.3 kt, which is 2.8 % higher than in 2021 as a result of a increase in diesel consumption. In comparison with 1990, $CO_2$-eq was decreased by 66.2 % as a result of a decrease in railways transportation and consequently decreases in fuel consumption.

Navigation (CRF 1.A.3.d)

The $CO_2$-eq from the sub-sectors Navigation in 2022 amounted to 154.5 kt, which is for 3.0 % higher than in 2021 as a result of increase in fuel consumption. In comparison with 1990, $CO_2$-eq increased by 13.7 % as a result of increase in navigation traffic and consequently increase in fuel consumption.

#### 3.2.6.2. Methodological issues

Methodology

- T1 (1990-2022) – 1A3a
- T1, T2 (1990-2022) – 1A3b
- T1 (1990-2022) – 1A3c
- T1 (1990-2022) – 1A3d

**Civil aviation**

The GHG emissions from sub-sectors Civil aviation were calculated using the Tier 1 approach based on jet fuel consumption and aviation kerosene provided by national energy balance and default IPCC emission factors.

In previous National Inventory Reports Croatia used ERTs' methodology which was prescribed during the in-country review process in 2008. The ERT strongly recommended that Croatia revise its emission estimates using the number of passengers travelled on domestic and international routes and average kilometres travelled per passenger on domestic and international routes, since these data are available from Croatia's national statistics. Croatia accepted this recommendation and emissions from domestic and international transport were estimate by using drivers such as the ratio of domestic/international passengers, taking into account average km travelled for passengers on domestic/international routes.

In 2013 and 2014 ARR ERT recommended that Croatia should improve the accuracy and transparency of its reporting in its next NIR by adopting an approach in accordance with IPCC Good Practice Guidance, such as using aviation fuel use surveys, sales statistics and origin-destination statistic to obtain actual jet kerosene consumption figures for domestic and international aviation. In 2014 Croatia lunched the project ''Development of methodologies for data assessments of emissions from transport with integrated impact assessment sector on the environment - phase 1. Information on activities for aviation and railways''. Through this project data on LTO Cycles in domestic and international transport was gathered for the period from 1990 to 2013. In cooperation with domestic airline companies and Croatian jet kerosene supplier, only data on fuel sold was available, data on fuel used in domestic and international transport was not available for all airline companies. For only one airline company which is in EU ETS system data on actual fuel consumption on domestic and international routes was available. Croatian fuel supplier has only data on fuel sold to domestic and in international carriers. So it was decided that the current approach was in that time the only way for dividing fuel consumed on domestic and international routes.

In 2014 new project named ''Technical assistance in the business statistics development, preparation of documents on the data quality and improving the data collection system'' by Energy Institute Hrvoje Požar was lunched. This project was launched in the framework of the IPA 2009 Programme and covered the area of energy statistics and improvement of methodologies of data collection in the final energy consumption sectors: households, services and transport. The aim of the project was to determine the energy consumption indicators based on the survey of energy consumption and according to EUROSTAT's list of variables and models for calculating energy efficiency. One of result was to determine actual consumption of fuel on domestic and international routes. Results of this project were published in the second quarter of 2016 and they were used as activity data for emission calculation. For the period from 2004 till 2016 data on fuel consumed in domestic transport were obtained from the Croatian Bureau of statistics from the Annual report on air transport. The obligation to submit a report is based on Article 38 of the Law on Official Statistics (OG 103/03, 75/09, and 59/12). This report MESDts all legal entities and parts that are registered in the activities of air transport and legal persons as well as registered in other activities but dealing with transporting passengers and cargo with aircraft. Entities are required to submit purchased and consumed fuel as a separate data. Consumed fuel has to be submitted in four categories:

- consumed in public domestic transport
- consumed in public international transport
- consumed in schooling and training
- consumed in other activities if exists

For the period from 1990 to 2003, a separate data on consumed fuel in domestic and international transport was not available so other statistical data were used to calculate drivers which were used to estimate fuel consumed. Four drivers were developed for domestic transport: fuel by number of passengers travelled, fuel by kilometres travelled, fuel by number of flight and fuel by aviation kilometres. Final driver, which was used for fuel consumed in civil aviation calculation, was determined graphically as average of all drivers.

Quantities of fossil fuel consumed their net calorific values and appropriate GHG emission factor and GHG emissions in the sub-sector Civil aviation for the years 1990, 2000, 2005, 2010, 2015 and for period 2020 - 2022 are shown in the Table A3-11 of the Annex 3.

**Road Transport**

Emissions of $CO_2$ from liquid and gaseous fuels in this inventory submission are calculated on the basis of the amount and type of fuel combusted using tier 1 (top-down) approach which is in line with the 2006 IPCC Guidelines. Amounts of all types of liquid and gaseous fuels consumed for the whole period from 1990 to 2022 were extracted from national energy balances. Emissions factors used for calculating $CO_2$ emissions from liquid and gaseous fuels are from 2006 IPCC Guidelines (page 3.16, Table 3.2.1.).

Emissions of $CH_4$ and $N_2O$ are calculated using the COPERT 5 model because emission factors depend on vehicle technology, fuel and operating characteristics (vehicle-kilometres, average trip speed, driving share on urban, rural and highway roads, etc.). The COPERT 5 model (Tier 2/3 method) requires a very detailed set of input activity data, including:

- type of vehicles (passenger cars, light-duty vehicles, heavy-duty vehicles, buses, mopeds, motorcycles)
- type of engine (gasoline four-stroke, gasoline two-stroke, diesel, rotation motor and electromotor)
- engine capacity (<0.8, 0,8-1.4L, 1.4-2.0L, >2.0L)
- weight class (Rigid<7.5 t, 7,5-12 t, 12-14 t, 14-20 t, 20-26 t, 26-28t, 28-32 t, >32t, Articulated 14-20 t, 20-28 t, 28-34 t, 34-40 t, 40-50 t, 50-60 t)
- age of vehicles (distribution of vehicles per ECE categories according to EC directives)

Main activity data provider is Ministry of Interior, which is responsible for the compilation of national motor vehicle database with detailed information on each registered vehicles in Croatia. Fuel consumption data were taken from national energy balances and average monthly temperatures from statistical yearbooks. Additional data, like highway, rural and urban transport mileage, average speed of different kind of vehicles and different road types, average daily trip distance and beta value (the fraction of the monthly mileage driven before the engine and any exhaust components have reached their nominal operation temperature) are expert judgments or default data from COPERT model.

Two assumptions/adjustments are applied in the COPERT model:

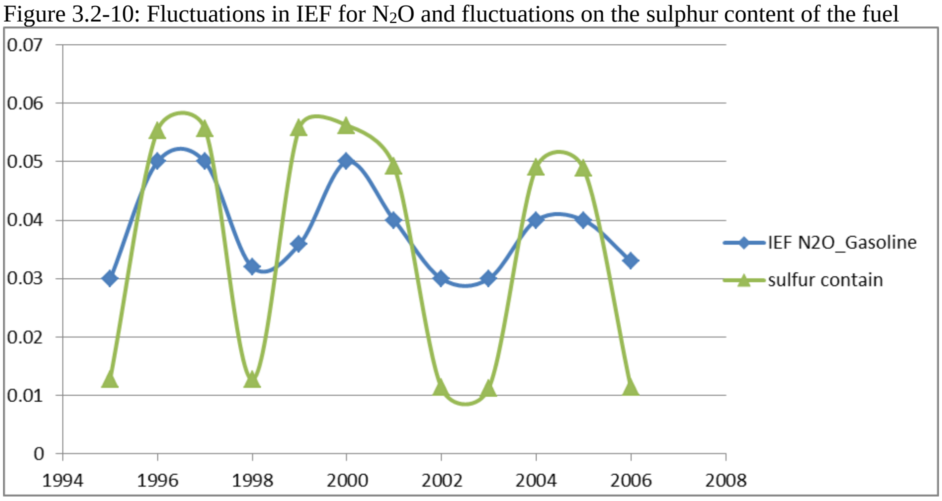
- Gasoline or diesel oil tank-filled abroad and consumed in Croatia is equal to the amount of the same type of fuels tank-filled in Croatia and consumed abroad (this is due to a large number of tourist destination and transit trips in Croatia), so the effect of this consumption pattern in neutral to fuel balance.
- Fuel consumption calculated by COPERT, taking into account number of vehicles and annual average vehicle mileage, should be to a highest possible degree equal to consumption of fuels from the national energy balance (the difference should not be greater than 1%).

The aggregate number of road motor vehicles per each major group (passenger cars, light and heavy-duty vehicles, buses, motorcycles and mopeds) for year 1990, 2000, 2005, 2010, 2015 and for period 2020 – 2022 are presented in the Table A2-10 of the Annex 3.

Comparing the total number of vehicles in 2022 with the number of vehicles in 1990 it can notice the increase of 44.2 %. The increase was largely the result of increase in the number of passenger cars by 40.9 %, constituting 82.7 % of the total number of road vehicles in 2022. Other classes of vehicles were also increased in this period: the number of Light Duty vehicles increased by 59.7%, Heavy Duty vehicles included buses increased by 15.9%, motorcycles and mopeds for 72.0 %. It is important to emphasize that number of registered vehicles gradually decreased in the period 2008-2014 due to economic crisis.

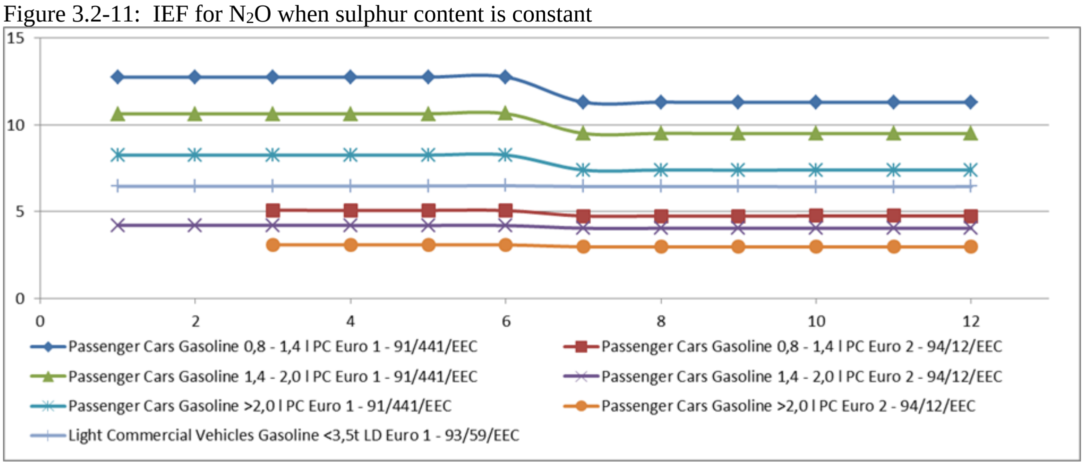
During review of NIR 2014, ERT noticed the fluctuation in the IEF values for the time period 1995-2006 for $N_2O$ emissions. Fluctuations occur only in Sector Passenger cars, subsector Gasoline 0,8-1,4 l, 1,4-2,0 l and >2,0 l, Technology PC Euro 1. These fluctuations are directly in line with fluctuations in sulphur contained of Gasoline fuel (see figure 3.2-10). Data on the sulphur content in fuels are given from Croatian Oil Company.

Figure 3.2-10: Fluctuations in IEF for $N_2O$ and fluctuations on the sulphur content of the fuel




For confirmation of this statement, $N_2O$ emission calculation with constant sulfur contain for Passenger Euro I Gasoline vehicles was performed. Obtained IEF for $N_2O$ did not have fluctuations (see figure 3.2-11).

Figure 3.2-11: IEF for $N_2O$ when sulphur content is constant




Amounts of fuels consumed, their net calorific values and appropriate GHG emission factors and GHG emissions in the sub-sector Road transport are shown in Table A3-12 Annex 3.

**Railways**

The GHG emissions from sub-sector Railways were calculated using the Tier 1 approach based on fossil fuel consumption data (from national energy balance) and default IPCC emission factors.

In 2014 Croatia lunched the project ‘’Development of methodologies for data assessments of emissions from transport with integrated impact assessment sector on the environment - phase 1. Information on activities for aviation and railways’’. Through this project data on the type of engine for locomotives were gathered for the period from 1999 to 2022 so default emission factors for $CH_4$ and $N_2O$ were modified depending on the engine design.

Quantities of fossil fuel consumed their net calorific values and appropriate GHG emission factor and GHG emissions in the sub-sector Railways are shown in the Table A3-13 of the Annex 3.

**Navigation**

The GHG emissions from Navigation sub-sector were calculated using the Tier 1 approach, based on fossil fuel consumption data (from national energy balance) and default IPCC emission factors.

Quantities of fossil fuel consumed their net calorific values and appropriate GHG emission factor and GHG emissions in the sub-sector Navigation 8 are shown in the Table A3-14 of the Annex 3.

**Pipeline transport**

In Croatia all compressor stations are electric, so no emissions occurred from this source for the whole period from 1990 to 2022. As a confirmation of this claim, in IEA and EUROSTAT energy balance data on consumption of all fuel used for pipeline transport can be found for the whole historical period. In IEA and EUROSTAT energy balance for the whole period, consumption of gas and oil in pipeline transport was 0 TJ. In 2015 for Pipeline transport 3 ktoe electricity is consumed.

In Croatian NGL plant, natural gas is consumed in compressor station, but according to IEA methodology, only fuel used in compressor stations for oil and natural gas transport through pipelines are part of Pipeline transport sector (excluding compressors on plant location).

Data on input and output fuels from NGL plant Ivanić Grad are collected via annual questionnaire (for the whole historical period). Although according to IEA methodology only input and output of fuels in NGL plant accounts in energy balance (excluding own use), in National energy balance own use of fuels in NGL plant are accounted too. Total amount of fuel used for own use in NGL plant is specified in national energy balance in section Energy sector own use-NGL plant (Tables A4-1 and A4-2 of Annex 2). For 2014 in NGL plant only natural gas was used in own use purposes ($3.3*10^6$ $m^3$). This amount of fuel with all other oil and gas extraction in energy industries are summed in 1A1cii sector.

#### 3.2.6.3. Uncertainties and time-series consistency

**Uncertainty of $CO_2$ emissions**

The $CO_2$ emission, from the fossil fuel combustion, depends on amount of fuel consumed (from energy balance), net calorific values (from energy balance), carbon emission factors (IPCC), the fraction of carbon stored (IPCC) and the fraction of carbon oxidised (IPCC).

The estimated uncertainty of data from energy balance is below 5 %. The accuracy of data on net calorific values, which are also taken from national energy balance, is high.

There are more uncertainties in data on international marine and aviation bunkers. Nevertheless, possible errors in estimated values do not significantly affect the accuracy of data of national emission, as marine and aviation transport have relatively small influence. The estimated $CO_2$ emissions for International Marine and Aviation Transport are not included in nationals totals.

The other data needed for calculation, such as carbon emission factors, the fraction of carbon stored for non-energy uses of fuel and the fraction of carbon oxidized, are taken from the 2006 IPCC Guidelines.

Experts believe that $CO_2$ emission factors for fuels are generally well determined within 5 %, as they are primarily dependent on the carbon content of the fuel.

**Uncertainty of $CH_4$ and $N_2O$ emissions**

Estimates of $CH_4$ and $N_2O$ emissions are based on fuel and aggregate emission factors for different sectors. Uncertainties in estimates are due to the fact that emissions are estimated on the base of emission factors representing only a limited subset of combustion conditions.

The uncertainty of $CH_4$ emission is estimated to ±40 %; while the uncertainty of $N_2O$ emission is estimated to factor 2 (the emission could be twice larger or smaller than the estimated one). The largest part of uncertainty refers to the emission factor applied while the fuel consumption data (national energy balance) are rather good.

Implementation of Tier 2/3 approach for estimation of $CH_4$ and $N_2O$ emissions from Road transport (CRF 1.A.3.b) lead to certain uncertainty reduction.

**Time-series consistency**

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities is very consistent for the entire period.

#### 3.2.6.4. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates.

Also, the inventory team used country-specific fuel net calorific values for emission estimates. Calorific values from energy balance were compared with data from the IPCC Guidelines. Results of this comparison showed that there is no significant difference between these two sets of data.

Source-specific quality check in road transportation included a comparison of results of emission calculation obtained independently with Tier 1 (top-down) and Tier 2/3 (COPERT model) approach for $CO_2$ emissions from liquid fuels. This is in line with recommendation from the IPCC Good Practice Guidance. The difference between these two approaches is 0.57 % for combined $CO_2$ emissions from gasoline and diesel oil in 2013, with positive difference for gasoline and negative for diesel oil (3.53 and -1.06 % respectively) and less than 1 % difference in fuel balance. For the entire time-series (1990-2013) average difference between Tier 1 and Tier 2/3 approach is 1.15 % (1.91 % for gasoline and 0.59 % for diesel oil). It could be concluded that difference is not significant and that Tier 1 approach yields slightly higher emission estimates than Tier 2/3 approach. Secondly, we can conclude that COPERT model is in general reliable and accurate, and estimates for other greenhouse gases, i.e. $CH_4$ and $N_2O$ are reliable and accurate as well.

#### 3.2.6.5. Category-specific recalculations

For $CH_4$ and $N_2O$ emissions from Road transport sector new version of Copert model was used.

#### 3.2.6.6. Category-specific planned improvements

Civil aviation

In 2014 Croatia lunched the project ‘’Development of methodologies for data assessments of emissions from transport with integrated impact assessment sector on the environment - phase 1. information on activities for aviation and railways’’. Through this project data on LTO Cycles in domestic transport was gathered for the period from 1990 to 2013.

Long term basis improvements

Inventory team is planning to further explore differences between Tier 1 and Tier 2/3 approach with particular focus on emission factors used in COPERT model for $CO_2$ emissions from gasoline and diesel oil, and reasons for high uncertainties of emission factors for $CH_4$ and $N_2O$.

### 3.2.7. Other sectors (CRF 1.A.4)

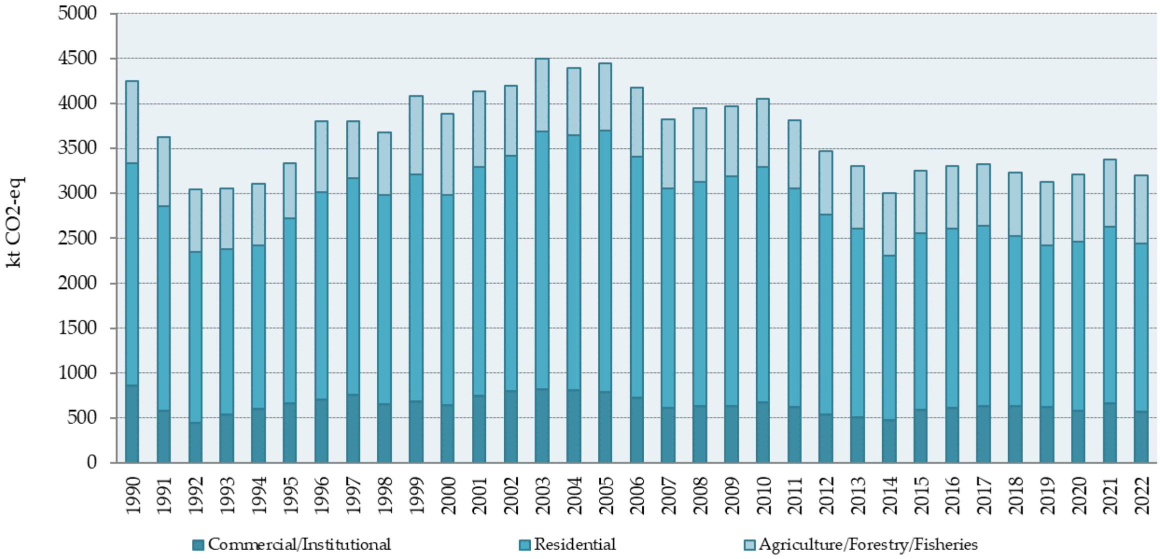
#### 3.2.7.1. Category description

This sector includes emissions from fuel combustion in commercial and institutional buildings, residential sector and agriculture, forestry and fishing. The total GHG emissions from above mentioned Small Stationary Energy Sources are shown in the Table 3.2-13 and Figure 3.2-12.

Table 3.2-13: The $CO_2$-eq emissions (kt) from Small Stationary Energy Sources

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2000 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Comm./Instit. | 859.0 | 644.0 | 792.9 | 674.6 | 588.1 | 578.0 | 661.1 | 570.4 |
| Residential | 2,473.9 | 2,335.4 | 2,901.8 | 2,617.4 | 1,968.6 | 1,887.5 | 1,963.0 | 1,869.6 |
| Agr./For./Fishing | 912.3 | 907.5 | 756.8 | 763.3 | 693.6 | 743.0 | 750.3 | 758.4 |
| **Total** | **4,245.2** | **3,887.0** | **4,451.4** | **4,055.4** | **3,250.3** | **3,208.4** | **3,374.4** | **3,198.4** |

Figure 3.2-12: The $CO_2$-eq emissions from Small Stationary Energy Sources




The $CO_2$-eq emissions from these subsectors were about 16-20 % of the total emissions from the Energy sector. Most of the emission comes from small household furnaces and boiler rooms (54-62 %), then from the service sector (17-22 %), while the combustion of fuel in agriculture, forestry and fishing accounts for 18 to 25 % for the period from 1990 to 2022.

#### 3.2.7.2. Methodological issues

The GHG emissions from these subsectors were calculated using the Tier 1 approach, based on fuel consumption data (national energy balance) and default IPCC emission factors. Data from the national energy balance were recalculated from natural units into energy units by means of its net calorific values for each fuel. Calorific values are also taken from the energy balance.

In 2014 project named ''Technical assistance in the business statistics development, preparation of documents on the data quality and improving the data collection system'' by Energy Institute Hrvoje Požar was lunched. This project was launched in the framework of the IPA 2009 Programme and covered the area of energy statistics and improvement of methodologies of data collection in the final energy consumption sectors: households, services and transport. The aim of projects was to determine the energy consumption indicators based on the survey of energy consumption and according to EUROSTAT's list of variables and models for calculating energy efficiency. One of result was to determine actual consumption of biomass fuel in households. As expected, the amount of consumed biomass in households increased in 2014 by 30 PJ compared to 2013. Amount of consumed biomass increased for the whole period from 1990 to 2013 approximately by 30 PJ. Data for whole historical trend were included in this submission.

#### 3.2.7.3. Uncertainties and time-series consistency

Uncertainty of $CO_2$ emissions

The $CO_2$ emission, from the fossil fuel combustion, depends on amount of fuel consumed (from energy balance), net calorific values (from energy balance), carbon emission factors (IPCC), the fraction of carbon stored (IPCC) and the fraction of carbon oxidised (IPCC). The estimated uncertainty of data from energy balance is below 5 %. The accuracy of data on net calorific values, which are also taken from national energy balance, is high.

The other data needed for calculation, such as carbon emission factors, the fraction of carbon stored for non-energy uses of fuel and the fraction of carbon oxidized, are taken from the 2006 IPCC Guidelines.

Experts believe that $CO_2$ emission factors for fuels are generally well determined within 5 %, as they are primarily dependent on the carbon content of the fuel.

Uncertainty of $CH_4$ and $N_2O$ emissions

Estimates of $CH_4$ and $N_2O$ emissions are based on fuel and aggregate emission factors for different sectors. Using the aggregate emission factors for each sector leads to greater uncertainties associated with estimates of $CH_4$ and $N_2O$ emissions from the fossil fuel combustion.

The uncertainty of $CH_4$ emission is estimated to ±40 %; while the uncertainty of $N_2O$ emission is estimated to factor 2 (the emission could be twice larger or smaller than the estimated one).

Time-series consistency

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities is very consistent for the entire period.

#### 3.2.7.4. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness, consistency and comparability of activity data, emission factors and emission estimates.

Also, the inventory team used country-specific fuel net calorific values for emission estimates. Calorific values from energy balance were compared with data from the IPCC Guidelines. Results of this comparison showed that there is no significant difference between these two sets of data.

#### 3.2.7.5. Category-specific recalculations

In Other sectors, no recalculations were performed in NIR 2024.

#### 3.2.7.6. Category-specific planned improvements

Long term basis improvements

On a long term basis, the inventory team is planning to apply country-specific carbon content values and oxidation factor values to estimate emissions for the main fuel types.

### 3.2.8. Other (CRF 1.A.5)

#### 3.2.8.1. Category description

<u>Methodology</u>

- T1 (1990-2022)

During 2016 centralised review ERT a TERT noticed that military fuel used has not been included in NIR. It is recommended that this part should be done in a way to improve the transparency of reporting without affecting the confidentiality of information.

In national energy balance military aviation and military water-borne is included under domestic aviation and navigation sector. Data on fuel sold on each airport/marina are collected via annual questionnaire by Croatian statistical office. This amount of fuel include as well fuel used for military purposes.

Dividing military from domestic aviation/navigation sector is not possible because data for military only are not available and it is not economically justified because the fuel used for military purposes is negligibly small for the whole historical period. Domestic aviation sector contributes only with 0.4% (in 2022) to total emissions of Croatia while navigation contributes with 2.3 % (in 2022). It is most likely that the contribution of military aviation and navigation is below the threshold of significance. Emissions from the military are all included in 1A3a amd 1A3d sector. For transparency purposes in subsector 1A5b, two subsectors were created:

- 1A5b-military aviation component
- 1A5b-military water-borne component.

These two categories were to be completed with IE notation key.

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

This section describes the fugitive emission of greenhouse gases from coal, oil and natural gas activities. This category includes all emissions from mining, production, processing, transportation and use of fossil fuels. During all stages from the extraction of fossil fuels to their final use, the escape or release of gaseous fuels or volatile components may occur.

### 3.3.1. Solid fuels (CRF 1.B.1)

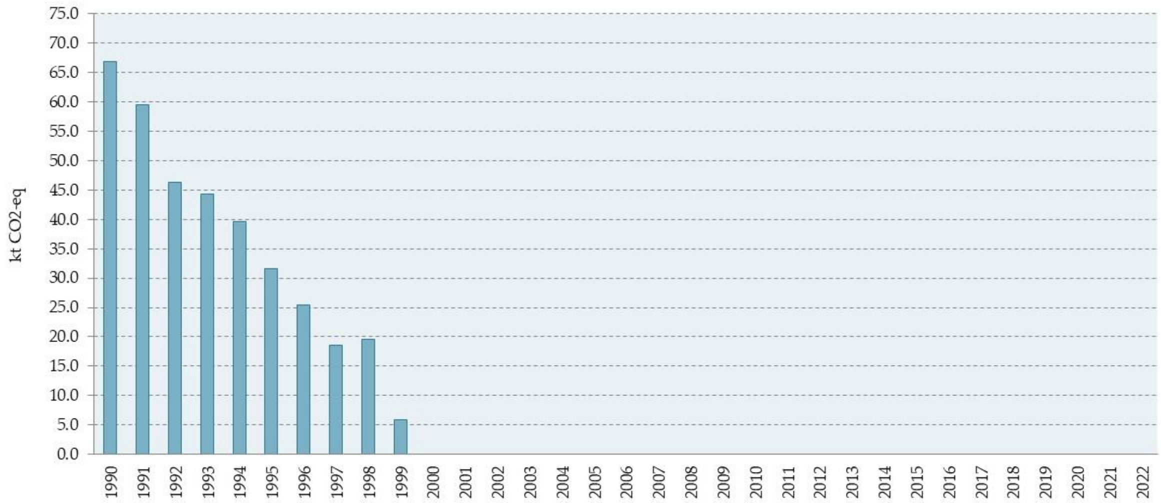
#### 3.3.1.1. Category description

All underground and opencast coal mines release methane during their regular operation. The amount of methane generated during mining is primarily a function of the coal rank and mining depth, as well as other factors such as moisture. After the coal has been mined, small amounts of methane retained in coal are released during post-mining activities, such as coal processing, transportation and utilization.

In Croatia, the coal production was steadily decreasing in the period 1990-1999. Until 1999 only underground coal mines in Istria were in operation (Tupljak, Ripenda and Koromačno) and they produced some 0.015 to 0.174 mill. tons of coal.

The emissions of methane from mining and post-mining activities are shown in the Figure 3.3-1.

Figure 3.3-1: The fugitive emissions of methane from coal mines




#### 3.3.1.2. Methodological issues

For estimating the fugitive emission from coal the simplest procedure has been used (Tier 1). Emission calculations were based on fuel production data, average IPCC emission factors and IPCC conversion factor.

Data about quantities of the mined coal is taken from the national energy balance.

The emission factors and conversion factor used for calculation are taken from the 2006 IPCC Guidelines. Used emission factors are an average value of the range proposed in the IPCC Guidelines.

For underground mines, for mining activities emission factor of 18.0 $m^3CH_4/t$ was used and for Post-mining activities, 2.5 $m^3CH_4/t$ was used. Conversion factor amounted 0.67 kt $CH_4$ /million $m^3$.

In 2006 IPCC Guidelines new activity Abandoned underground coal mines is included. Numbers of abandoned mines and technology of closing were gathered for the period from 1951 till 2022. For the period from 1901 to 1950 were not available. According to the 2006 IPCC Guidelines, it is good practice to include mines that are known to be fully flooded in databases and other records used for inventory development, but they should be assigned an emission of zero as the emissions from such mines are negligible (2006 IPCC, page 4.23) so data on abandoned mines are given in Table 3.3-1.

Table 3.3-1: Number of abandoned underground mines with closing technology for the period 1901-2022

| Period | Number of abandoned underground mines | Closing technology | | $CH_4$ emission |
|---|---|---|---|---|
| | | Closing technology | Number of mines | |
| 1901-1925 | - | Fully Flooded Mines | - | - |
| | | Partially Flooded Mines | - | - |
| | | Unflooded | - | - |
| 1926-1950 | - | Fully Flooded Mines | - | - |
| | | Partially Flooded Mines | - | - |
| | | Unflooded | - | - |
| 1951-1975 | 35 | Fully Flooded Mines | 35 | 0 |
| | | Partially Flooded Mines | - | - |
| | | Unflooded | - | - |
| 1976-1999 | 8 | Fully Flooded Mines | 8 | 0 |
| | | Partially Flooded Mines | - | - |
| | | Unflooded | - | - |
| 2000-2022 | 1 | Fully Flooded Mines | 1 | 0 |
| | | Partially Flooded Mines | - | - |
| | | Unflooded | - | - |

The coal production data and emissions of methane from mining and post-mining activities are shown in Table A3-18, Annex 3.

#### 3.3.1.3. Uncertainties and time-series consistency

The fugitive emission of methane from coal mining and handling is determined by the use of Global Average Method (Tier 1), which is based on the multiplication of coal produced and emission factor. The amount of coal produced is taken from energy balance and that value is very accurate. The main uncertainty of calculation depends on the accuracy of the used emission factor. The arithmetic average value of the emission factor has been chosen from the 2006 IPCC Guidelines for the region to which Croatia belongs. The estimated uncertainty of methane emissions, for underground mining, may be as a high as a factor of 2 and for post-mining activities a factor of 3.

Time-series consistency

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities is very consistent for the entire period.

#### 3.3.1.4. Category-specific QA/QC and verification

In this sub-sector, only general (Tier 1) quality control procedures were applied, since the coal production was stopped in 1999.

#### 3.3.1.5. Category-specific recalculations

In sector 1B1 recalculations were not performed.

#### 3.3.1.6. Category-specific planned improvements

For estimation of fugitive emissions from coal mines, a Tier 1 method was applied. For emission estimation data on saleable coal was used. On a long term basis, the inventory team is planning to determine the amount of production of coal that is washed.

### 3.3.2. Oil and natural gas (CRF 1.B.2)

#### 3.3.2.1. Category description

This category includes the fugitive emission from production, refining, transportation, processing and distribution of crude oil or oil products and gas. The fugitive emission also includes the emission which is the result of incomplete combustion of gas during flaring and the emission from venting during oil and gas production.

Also, emission of $CO_2$ from natural gas scrubbing in Central Gas Station Molve, are included in this sub-sector.

1.B.2.a. Oil

Exploration production and transport of oil in the Republic of Croatia is carried out by company INA - Oil Industry d.d. in the segment activity SD Exploration & Production of oil and gas (formerly INA NAFTAPLIN). In Croatia, 38 oil fields are active, and the maximum amount of oil came from 8 most important fields, that contain 83% of the total reserves discovered in Croatia. During the war (1991 - 1995) from 34 oil fields, only 22 of them worked. All oil fields in Croatia are “onshore” fields.

Refining/storage in the Republic of Croatia is carried out in an oil refinery owned by a company INA - Oil Industry d.d. at two locations in Rijeka (INA - RNR) and Sisak (INA - RNS). Production capacities of the Croatian refineries are shown in Table 3.2-9.

1.B.2.b. Natural gas

In Croatia, the production/processing, and transmission of natural gas takes place in private facilities. Extraction and production of natural gas in Croatia carried out by INA - Oil Industry d.d. in the segment activity SD Exploration & Production (formerly INA NAFTAPLIN). The main gas fields with 70% of total reserves are located in the three largest gas and gas-condensate fields, namely Molve, Kalinovac and Stari Gradac in the western part of the Drava depression, along the border with Hungary. The work site "Molve" provides between 70% and 75% of gas and condensate per year in Croatia, satisfying about 50% of the needs. One of the old gas fields around the Sava Depression turned into underground gas storage capacity of 500 mil. $m^3$.

Molve processing gas facilities include a plant for treatment and preparation of gas for transportation. In addition to Molve, gas has been processed since 2013 at the Ivanić Grad faction facility as well. Natural gas from gas condensate reservoirs "deep Podravine" except hydrocarbons contains a range of harmful substances ($CO_2$, $H_2S$, RSH, Hg, sedimentary water). In order to satisfy the quality of output and safety of the processing plants, harmful impurities is necessary to isolate and eventually disposed of without harm to the environment. Natural gas produced in Croatian gas fields (Molve and Kalinovac) contains a large amount of $CO_2$, more than 15 %, and before coming to commercial pipeline has to be cleaned (scrubbed). Since the maximum volume content of $CO_2$ in commercial natural gas is 3 %, it is necessary to clean the natural gas before transporting through pipeline to end-users. Because of that, the Scrubbing Units exist at the largest Croatian gas field.

The basic technological processes at the plant include gas preparation by removing acid gases ($CO_2$ and H2S), separation of the hydrocarbon mixture by fractionation into pure components and isomerization of the separated hydrocarbon mixture.

The gas from production wells is transported trough over six gas collection and transmission systems delivered to the processing facilities Molve.

The gas treatment process is divided into several phases:

- separation - the gas phase is separated of liquid (saltwater and gas condensate) - saltwater is pumped in negative wells and condensate is shipped to the refinery
- removal of mercury from gas with adsorption activated carbon impregnated with sulfur
- separation of $CO_2$ and $H_2S$ from gas with absorption using 40% solution of methyldiethanolamine. Process solution passes the cleaning process (regeneration) in striper-column. Cleaned and freed of $CO_2$ gas is returned back into the system. Acid gases are dispatched to the Lo-Cat unit
- gas dehydration with molecular sieves (CPS III), or with triethylene glycol (CPS II and I) removes the remaining moisture
- NGL section – with supercooling gas process heavier hydrocarbons than ethane are liquefied to higher hydrocarbons. C3 + fraction is sent to fractionation facility Ivanic Grad for further processing, and the remaining gas goes into the distribution system or for internal consumption
- Lo-Cat plant processes the current $CO_2$ and $H_2S$ released from metyldiatomaceous solution. $H_2S$ is oxidized to the elemental sulphur
- EOR compressors -Part of $CO_2$ with remaining $H_2S$ is sent to the compression where the pressure from 150 mbar is raised to 30 bar, dehydrates and sent to the plant OFIG where the pressure raised to 90 bar and then to 180 bar with compression. Compressed gas is sent by pipeline to the oil fields Ivanić and Žutica where gas is used as a propellant to raise oil production
- RTO units -Part of $CO_2$ with remaining $H_2S$ goes to RTO units. In the oxidation process at 800-900°C $H_2S$ is converted to $SO_2$ and released to the atmosphere (drain height 60 m). Regenerative thermal oxidizer (RTO) is a type of thermal oxidizers whose work is on autothermal principle (without the use of burner). RTO used layers of ceramic media to achieve thermal efficiency. Ceramic material absorbs the heat from the exhaust gas and use the captured heat to heat incoming cold gas. In a regulated cycle using two or more layers which operate alternately to the heating of input gas or cooling output gas.

$CO_2$ balance for the period from 2010 till 2015 is given in Table 3.3-2.

Table 3.3-2: $CO_2$ material balance for the period 2010-2015

| Year | Average annual amount of $CO_2$ in input gas, vol% | Average annual amount of $CO_2$ in the output gas, ppm | Quantity of gas, input, $m^3$/year | Quantity of gas, output, $m^3$/year | water intake gas obtained at stripping MDEA solution $m^3$ / year | $CO_2$ from balance, $m^3$/year | $CO_2$ from balance, kg/year | $CO_2$ obtained by measuring, $m^3$/year | $CO_2$ obtained by measuring, released to atmosphere, kg/god | $CO_2$ obtained by calculation, $m^3$/year | Compressed in EOR unit, $m^3$/year | Difference of calculated a measured $CO_2$, % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 25.55 | 9 | 1,041,050,600 | 785,655,500 | 8,543,900 | 246,851,200 | 461,611,744 | 260,567,592 | 487,261,397 | 265,988,428 | 0 | 5 |
| 2011 | 26.88 | 8 | 1,010,863,066 | 653,903,801 | 7,621,100 | 349,338,165 | 653,262,369 | 275,200,410 | 514,624,767 | 271,719,992 | 0 | -27 |
| 2012 | 24.96 | 7 | 932,917,400 | 576,545,600 | 6,339,400 | 350,032,400 | 654,560,588 | 229,515,426 | 429,193,847 | 232,856,183 | 0 | -53 |
| 2013 | 25.06 | 7 | 962,809,200 | 696,967,200 | 6,295,400 | 259,546,600 | 485,352,142 | 218,919,822 | 409,380,067 | 241,279,986 | 0 | -19 |
| 2014 | 26.78 | 7 | 817,973,320 | 585,844,400 | 4,894,900 | 227,234,020 | 424,927,617 | 239,663,586 | 397,082,883 | 219,053,255 | 27,319,798 | 5 |
| 2015 | 28.46 | 9 | 786,636,100 | 561,619,600 | 4,896,347 | 220,120,153 | 411,624,686 | 223,559,815 | 192,349,451 | 223,876,634 | 120,699,146 | 2 |

$CO_2$ density on 15ºC is 1.87 kg/$m^3$

The estimated $CO_2$ emissions, by the material balance method, are presented in Table 3.3-3

Table 3.3-3: The $CO_2$ emissions (kt) from natural gas scrubbing in CGS Molve

| $CO_2$ emission (kt) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Central Gas Station Molve | 415.95 | 455.83 | 477.33 | 676.12 | 604.87 | 739.27 | 716.40 | 667.17 | 589.17 | 579.32 | 633.02 |
| Ivanić Grad fraction facility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL | 415.95 | 455.83 | 477.33 | 676.12 | 604.87 | 739.27 | 716.40 | 667.17 | 589.17 | 579.32 | 633.02 |

| $CO_2$ emission (kt) | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Central Gas Station Molve | 687.64 | 702.08 | 657.51 | 709.58 | 691.25 | 700.25 | 663.33 | 575.82 | 516.44 | 487.26 | 509.04 |
| Ivanić Grad fraction facility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL | 687.64 | 702.08 | 657.51 | 709.58 | 691.25 | 700.25 | 663.33 | 575.82 | 516.44 | 487.26 | 509.04 |

| $CO_2$ emission (kt) | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Central Gas Station Molve | 429.19 | 409.38 | 397.08 | 192.35 | 157.07 | 232.16 | 207.05 | 157.76 | 173.72 | 163.76 | 244.96 |
| Ivanić Grad fraction facility | 0.00 | 0.02 | 1.61 | 10.05 | 29.19 | 29.26 | 29.26 | 83.28 | 73.69 | 81.44 | 73.61 |
| TOTAL | 429.19 | 409.40 | 398.69 | 202.40 | 186.26 | 261.42 | 236.30 | 241.04 | 247.40 | 245.19 | 318.57 |

Transport system carried out by transport system operator (OTS) company Plinacro Ltd. and by distribution system operators (34 company). The transport system managed by the transmission system operator Plinacro d.o.o., consists of international, main, regional and developable pipeline and facilities to the pipeline, measuring reduction stations (MRS) of various capacities and other facilities and systems that enable reliable and secure transport system. Basic data of the Croatian transport system are shown in Table 3.3-4.

Table 3.3-4: Basic data on the natural gas transport system of the Republic of Croatia

| Natural gas transport system of the Republic of Croatia | |
|---|---|
| Number of transmission system operators | 1 |
| The total length of the pipeline gas transport system | 2 693 km |
| Interconnection / transmission system operator: | Rogatec / Plinovodi d.o.o. (SLO)<br>Drávaszerdahely / FGSZ Ltd. (HU) |
| Underground gas storage / gas storage system operator: | Okoli / Podzemno skladište plina d.o.o. |

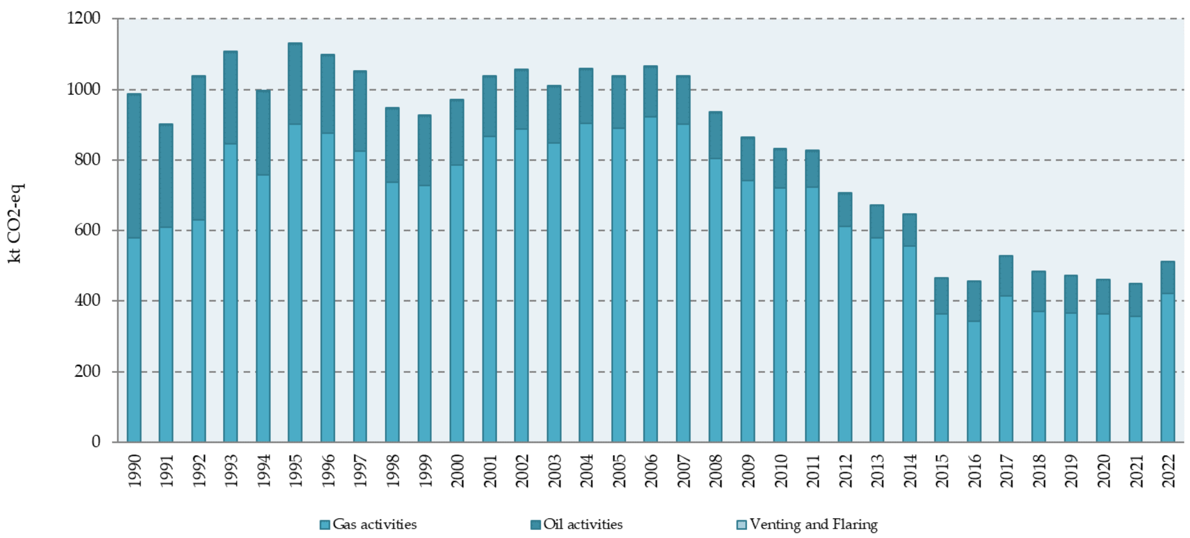
| Natural gas transport system of the Republic of Croatia | |
|---|---|
| Inputs from domestic production / gas producer | UMS CPS Molve / INA - d.d.<br>UMS Etan, Ivanić Grad / INA - d.d.<br>UMS PS Ferdinandovac / INA - d.d.<br>UMS PS Gola / INA - d.d.<br>UMS PS Hampovica / INA - d.d.<br>UMS Terminal Pula / INAGIP Ltd |
| Number of connections for end-users connection to the transmission system: | 34 |
| Number of connections to the distribution systems and the number of distribution system operators: | Number of ports: 153<br>Number of operators DS: 37 |
| Number of balancing zones: | 1 |

The total GHG fugitive emission from oil and natural gas systems are shown in the Table 3.3-5 and Figure 3.3-2.

Table 3.3-5: The $CO_2$-eq emissions (kt) from oil and gas systems

| | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Oil activities | 404.7 | 183.9 | 144.6 | 110.3 | 102.5 | 96.4 | 92.2 | 89.2 |
| Gas activities | 579.8 | 785.3 | 890.6 | 719.6 | 364.1 | 364.2 | 357.0 | 422.2 |
| Venting and Flaring | 1.2 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 |
| **Total** | **985.7** | **969.6** | **1,035.6** | **830.2** | **466.8** | **460.8** | **449.4** | **511.5** |

Figure 3.3-2: The fugitive emissions from oil and gas activities




The $CO_2$-eq emissions from this sub-sector were 3.0 % of the total emissions from Energy sector in 2022. From 2006 oil and gas production is continuously decreasing consequently $CO_2$-eq emission is decreasing too. In 1990 41% of total fugitive emission arises from oil activities while in 2022 only 17.4% of total fugitive emissions arises from oil activities.

The activity data and emission factors used to calculate fugitive emissions from oil and gas are shown in Table A3-19 and A3-20, Annex 3.

Fugitive emission of ozone precursors and $SO_2$

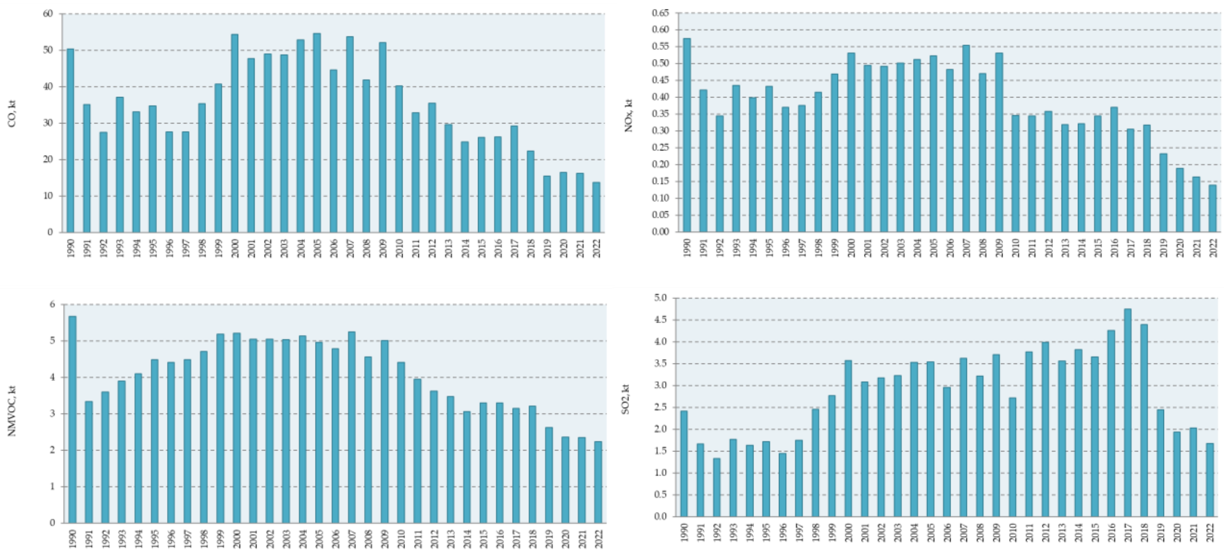
Emissions of indirect GHGs for the whole time period (1990-2022) was set up according to the EMEP/CORINAIR methodology. Emissions were obtained from the emission inventory report 'Republic of Croatia Informative Inventory Report for 2022, under Convention on Long-range Transboundary Air Pollution (CLRTAP)' which is Croatia's obligation in the framework of the Long-range Transboundary Air Pollution Convention according to the Act on Air Protection (OG 127/19, 57/22).

A summary of estimated results of the fugitive emissions of CO, $NO_X$, NMVOC and $SO_2$ are illustrated in the Table 3.3-6 and Figure 3.3-3.

Table 3.3-6: The fugitive emissions of ozone precursors and $SO_2$ from fugitive emissions sector

| Emissions (kt) | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| CO emission | 50.36 | 54.33 | 54.66 | 40.26 | 26.16 | 16.47 | 16.24 | 13.77 |
| NOx emission | 0.58 | 0.53 | 0.52 | 0.35 | 0.34 | 0.19 | 0.16 | 0.14 |
| NMVOC emission | 5.68 | 5.21 | 4.96 | 4.41 | 3.30 | 2.36 | 2.35 | 2.23 |
| SO2 emission | 2.41 | 3.57 | 3.54 | 2.72 | 3.66 | 1.93 | 2.03 | 1.68 |

Figure 3.3-3: The fugitive emissions of CO, $NO_X$, NMVOC and $SO_2$




#### 3.3.2.2. Methodological issues

**<u>Fugitive emission of $CH_4$</u>**

For estimating the fugitive emission of methane from oil and gas the simplest procedure has been used (Tier 1), which is based on production, unloading, processing and consumption of oil and gas. According to the IPCC, all countries are divided into regions with relatively homogenous characteristics of oil and gas systems. Croatia used emission factor for developed countries (2006 IPCC Guidelines, pages 4.48-4.53, table 4.2.4.). For some activities range for emission factor is given in Table 4.2.4., in that case, average values were used as emission factors.

Data about quantities of production, unloading, processing, storing and consumption of oil and gas are taken from the national energy balance. Data on oil transported by pipelines were obtained from JANAF d.d. (Jadranski naftovod). Data on oil transported by tankers were obtained from INA d.d. (Industrija nafte).

**Fugitive emission of $CO_2$ and $N_2O$**

For estimating the fugitive emission of $CO_2$ and $N_2O$ from oil and gas the simplest procedure has been used (Tier 1), which is based on production, unloading, processing and consumption of oil and gas. According to the IPCC, all countries are divided into regions with relatively homogenous characteristics of oil and gas systems. Croatia used emission factor for developed countries (2006 IPCC Guidelines, pages 4.48-4.53, table 4.2.4.). For some activities range for emission factor is given in Table 4.2.4., in that case, average values were used as emission factors.

Data about quantities of production, unloading, processing, storing and consumption of oil and gas are taken from the national energy balance. Data on oil transported by pipelines were obtained from Statistical yearbook, CBS. Data on oil transported by tankers were obtained from INA d.d. (Industrija nafte).

Fugitive emissions from oil transported by Tanker trucks and Rail cars were estimated for the whole period from 1990 to 2022.

$N_2O$ emission from Oil production was reported under 1B2c2i section because CRF reporter has no possibility of entering $N_2O$ emissions under 1B2a category.

All $N_2O$ emissions from Natural gas production, Processing and Transmission were reported under 1B2c2ii section because CRF reporter has no possibility of entering $N_2O$ emissions under 1B2b category.

**$CO_2$ emission from natural gas scrubbing**

The methodology for estimating $CO_2$ emission from natural gas scrubbing is not given in IPCC Guidelines. The $CO_2$ emission is determined on the base of differences in $CO_2$ content before and after scrubbing units and quantity of scrubbed natural gas.

The fugitive emissions from oil and gas activities are shown in Table A3-19, Annex 3.

**'IE' Notation key for $CO_2$ emissions in 1.B.2.c.2 (Flaring)**

In CRF Application in cell comments, all necessary comments are entered. Because of a bug in CRF application comments are not transferred to CRF tables properly. Data in category 1.B.2.c.2 are allocated in 1.B.2.b category.

#### 3.3.2.3. Uncertainties and time-series consistency

The simplest procedure (Tier 1) is used to determine fugitive emission from oil and natural gas activities. This approach is based on activity data (production, transport, refining and storage of fossil fuels) and average emission factors. Due to the complexity of the oil and gas industry, it is difficult to quantify the uncertainties. The uncertainty of calculation is linked mostly to the emission factor, just like the determination of fugitive emission of methane from coal mining and handling. The expert estimated that the accuracy of the calculation of fugitive emission from oil is better than from fugitive emission from gas, but the uncertainty of both estimations is pretty high.

The $CO_2$ emission from the scrubbing of natural gas is also shown here. The calculation is based on material balance which gives much better accuracy (±5 %).

Time-series consistency

Activity data, emission factors and methodology implied for GHG emission calculation from fuel combustion activities are consistent for the entire period.

#### 3.3.2.4. Category-specific QA/QC and verification

For fugitive emissions from oil and gas operations, a Tier 1 method was applied and emission factor is value proposed in the 2006 IPCC Guidelines. The $CO_2$ emission from natural gas scrubbing in CGS Molve was estimated using country-specific methodology since IPCC Guidelines does not provide methodology for this source category.

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness, consistency, comparability, recalculation and uncertainty of activity data, emission factors and emission estimates.

#### 3.3.2.5. Category-specific recalculations

Recalculations were not performed in NIR 2024.

#### 3.3.2.6. Category-specific planned improvements

For estimation of fugitive emissions from oil and natural gas operations, a Tier 1 method was applied. Used emission factors are an average value of the range proposed in the IPCC Guidelines. However, fugitive emission from natural gas is key source and implementation of rigorous source-specific evaluations approach (Tier 2) is necessary. On a long term basis, the inventory team is planning to apply Tier 2 approach for calculation of fugitive emissions from oil and natural gas operations.

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

$CO_2$ transport and $CO_2$ storage is not occurring in Croatia.

# Chapter 4: Industrial processes and product use (CRF sector 2)

## 4.1. Overview of sector

GHG emissions reported under CRF sector 2 refer to emissions released from the physical and chemical process of transforming raw materials into industrial products, from the use of GHGs in products, and from non-energy uses of fossil fuel carbon.

The following subcategories are included in CRF sector 2: Mineral industry, Chemical industry, Metal industry, Non-energy products from fuels and solvent use, Electronic Industry, Product uses as substitutes for ODS and Other product manufacture and use.

Generally, only process-related emissions are considered in this sector. Emissions due to fuel combustion in manufacturing industries are for the most part allocated to the Energy sector (IPCC Category 1.A.2 Fuel Combustion – Manufacturing Industries and Construction). Moreover, emissions due to consumption of certain fuels (e.g. coke or coal) as feedstock in various production processes, are allocated to the Energy sector as well, since they have been accounted for as fuel consumption in the national energy balance and reported in the Energy sector (for detailed explanation see chapter 3.1.1.)

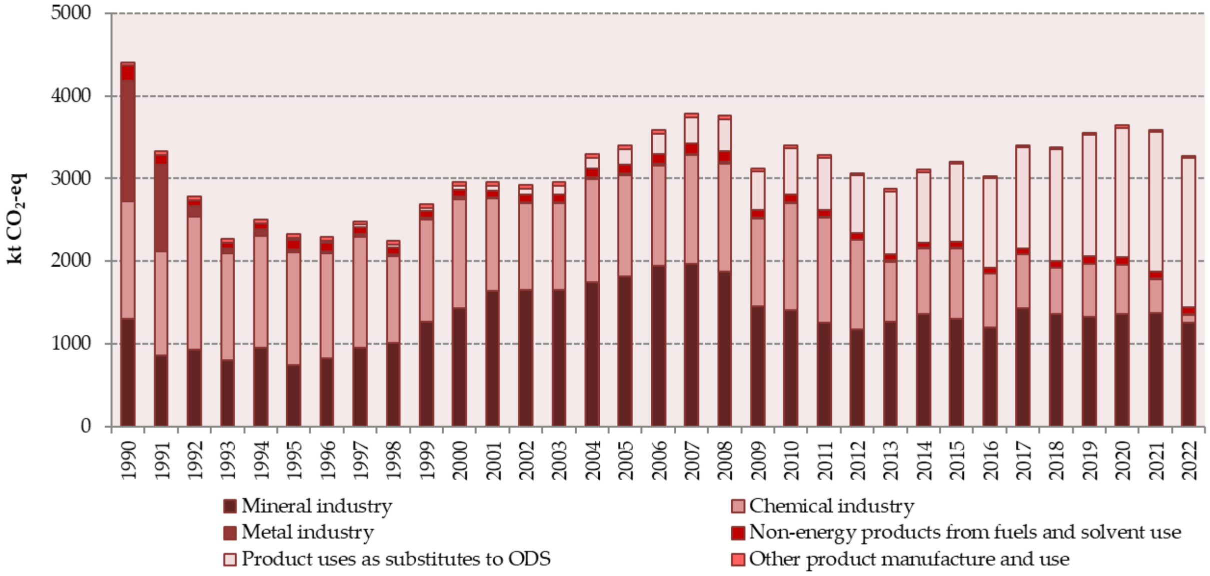
For the installations subject to reporting obligations under the EU ETS, emissions are taken from verified EU ETS annual emissions reports (available since 2013). Categories that include verified ETS data in this sector are: 2.A.1 Cement Production; 2.A.2 Lime Production; 2.A.3 Glass Production; 2.A.4 Other Process Uses of Carbonates; 2.B.2 Nitric acid production and 2.C.1 Iron and Steel Production (for details on the reasons for excluding the verified ETS data from ammonia manufacturer from this sector see chapter 4.3.1.2).

For other activities, activity data are generally taken from statistics or are obtained directly from the operators. All data provided by operators are presented in this report only to the extent that confidentiality concerns permit.

### 4.1.1. Emission trends

Annual GHGs emissions from the IPPU sector, expressed in kt $CO_2$-eq, are shown in Figure 4.1-1.

Figure 4.1-1: Emissions of GHGs from Industrial Processes and Product Use



Regarding emissions trends in this sector, it is necessary to point out a few general facts. The Republic of Croatia was the federal unit of SFR Yugoslavia until 1991. After the breakup of Yugoslavia and Croatian independence, the transition from a socialist economy into a system based on private ownership and open market economy was slowed down due to war aggression on Croatia (1991-1995). In addition to adapting economic policy to defence needs during the war period, the post-war economic development was burdened by major war damages.

After overcoming direct war problems, Croatia experienced GDP growth, with the highest annual growth rate recorded in 2002, to reach the pre-war level in 2003. The GDP growth trend continued until 2008, when it declined and then stagnated, which was caused primarily by the world economic crisis, after which it started to slowly recover over the last few years. All this has reflected on industrial production trends in Croatia, and consequently on emissions trends in this sector.

It should also be noted that during the war, some of the factories were directly affected by warfare, and their production activities were discontinued or significantly reduced, with frequent interruptions. In many cases, these facilities were devastated, along with their archives, which contained data needed to calculate the emissions. Since it was an atypical period of production, estimates of missing data are hampered by incomparability with other, non-war years, as well as incomparability with plants that were in operation in areas that were not affected by warfare to this degree.

Moreover, some of the statistical data which were available in the base year are no longer being collected in the same form, i.e., with changed statistical standards during the reporting period, certain data are now covered by different classifications and aggregation levels. Therefore, it was necessary to apply some of the methods for data estimation in accordance with the Guidelines (2006 IPCC Guidelines, Volume 1: General Guidance and Reporting), which is described in detail by source categories in the following chapters.

In Industrial processes and product use sector, source categories shown below represent key source categories (detailed in Table 4.1-1).

Table 4.1-1: Key categories in Industrial processes and product use sector based on the level and trend assessment in 2022[1]

| Table | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, 2022) | | | | | | | |
| IPCC Source Categories | GHG | Key source | If Column C is Yes, Criteria for Identification | | | | Com. |
| 2.A.1 Cement Production | $CO_2$ | Yes | L1e | T1e | L1i | T1i | |
| 2.B.1 Ammonia Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.B.2 Nitric Acid Production | $N_2O$ | Yes | | T1e | | T1i | |
| 2.B.8 Petrochemical and Carbon Black Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.2 Ferroalloys Production | $CO_2$ | Yes | | T1e | | T1i | |
| 2.C.3 Aluminium Production | $CO_2$ | Yes | | | | T1i | |
| 2.C.3 Aluminium Production | PFCs | Yes | | T1e | | T1i | |
| 2.F.1 Refrigeration and Air conditioning | F-gases | Yes | L1e L2e | T1e T2e | L1i L2i | T1i T2i | |

L1e - Level excluding LULUCF - Tier1 T1e - Trend excluding LULUCF - Tier1
L2e - Level excluding LULUCF - Tier2 T2e - Trend excluding LULUCF - Tier2
L1i - Level including LULUCF - Tier1 T1i - Trend including LULUCF - Tier1
L2i - Level including LULUCF - Tier2 T2i - Trend including LULUCF - Tier2

[1] Data on key categories are taken from Annex 1 Key categories (Tier 1 and Tier 2)

## 4.2. Mineral industry (CRF 2.A)

### 4.2.1. Cement production (2.A.1)

#### 4.2.1.1. Category description

In cement production, process emissions originate from calcium carbonate (and to a lesser degree from magnesium carbonate) in raw materials that release $CO_2$ by heating. The resulting calcium oxide is heated to form clinker which is then ground and mixed with gypsum and other additives to form cement as a final product.

During the reporting period, there were seven factories in operation in Croatia. Four factories were active throughout the entire period (1990-2022). One of them produces aluminate cement, while other factories (including those that are inactive today) produced portland cement. In the aluminate cement production plant, portland cement was also produced in the second production line until 1997.

One factory was closed in July 1994, and two operated with intermittent interruptions (one was active during periods 1990-1995 and since 1998, and the other during 1990-2009 and during 2014).

Production varied depending on the economic situation and demand on the market, thus overall production at the national level decreased in the period 1991-1995 as a result of the war. In the period 1996-2007, production increased with the escalation in construction sector activities. The trend after 2008 is a result of the economic crisis followed by a slow recovery after 2012.

Since 2013, all active cement plants are covered by EU ETS (five factories in the period 2013-2022 and one factory only in 2014, since it was not in operation in other years).

#### 4.2.1.2. Methodological issues

Methodology

- T2 (1990-2012)
- T2, T3 (2013-onward)

$CO_2$ emission for the period 1990-2012 (before inclusion into the EU ETS) is calculated using the Tier 2 method (2006 IPCC Guidelines), which includes multiplying emission factor (expressed in tonnes of $CO_2$ released per tonne of clinker produced) by annual clinker production adjusted for the clinker fraction „lost“ as cement kiln dust (CKD). In this way, the emission is calculated for each plant individually.

$$CO_2 \text{ emission [t]} = \text{clinker production [t]} \times \text{EF [t } CO_2\text{/t clinker]} \times \text{CKD correction factor}$$

Since 2013, data on emissions and used calculation methodologies, which are verified by independent accredited verifiers, are delivered to the Ministry of Economy and Sustainable Development as part of the annual emission report under the EU ETS. The Ministry then delivers these data to IPPU sector experts and all verified data are included in the inventory without any adjustments. Two of the factories covered by the EU ETS for their emission calculation use the method based on the input of raw material to the kiln[2], which is comparable to Tier 3 method from the 2006 IPCC Guidelines, while the other factories use method based on clinker production[3], which is comparable to Tier 2 IPCC method.

[2] Method A according to 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 IV

[3] Method B according to 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 IV

Emission factors

- PS (1990-2022 – six factories)
- D (1990-1994 – one factory)

For the period 1990-2012, the emission factor was determined for each plant separately (plant-specific EF) based on the CaO and MgO content of carbonates in the clinker produced.

CaO and MgO content from carbonates in the produced clinker was calculated by subtracting CaO and MgO originating from non-carbonate sources from the total CaO and MgO content of clinker. CaO and MgO content from carbonates was then multiplied by the molecular weight ratio of $CO_2$ to CaO or MgO, as follows:

$$EF = EF_{CaO} + EF_{MgO} = (CaO_{cl} - CaO_{ns}) \times 0.785 + (MgO_{cl} - MgO_{ns}) \times 1.092$$

Where:

$EF_{CaO}$ and $EF_{MgO}$ - emission factors for CaO and MgO from carbonates [t $CO_2$/t clinker]

$CaO_{cl}$ and $MgO_{cl}$ - total CaO and MgO content of clinker [t/t clinker]

$CaO_{ns}$ and $MgO_{ns}$ - CaO and MgO content of clinker from non-carbonate sources [t/t clinker]

0.785 - molecular weight ratio $CO_2$/CaO

1.092 - molecular weight ratio $CO_2$/MgO

Total CaO and MgO content in clinker is measured by all factories in their internal laboratories on a daily basis, except for one factory that ceased to measure this parameter after its inclusion in the EU ETS, since it uses the kiln input-based methodology for the calculation of its emissions.

For one factory (which ceased operations in 1994), data on CaO and MgO content of clinker are unavailable and default emission factor (2006 IPCC Guidelines) was used for the calculation. Also, within one factory there were two production lines, one of which was suspended in 1997 and no data on non-carbonate sources are available for it, and therefore it is assumed that this factory did not use non-carbonate sources for clinker production in the period 1990-2012.

Aluminate cement/clinker is produced by melting a mixture of limestone and bauxite, thus the $CO_2$ emission factor is considerably lower than in portland cement (about 0.3 t $CO_2$/t clinker), but its production in Croatia makes on average less than 4% of total produced clinker.

Cement kiln dust correction factor ($CF_{ckd}$) depends on production technology. For three factories, due to insufficient data, default $CF_{ckd}$ (2% of total $CO_2$ emissions from clinker production, 2006 IPCC Guidelines) was used for the whole time series prior to ETS inclusion. In one factory, in the periods 1990-1995 and since 2008, all CKD was recycled, therefore $CF_{ckd}$=1, and default $CF_{ckd}$ was used for the period 1996-2007. In the remaining three factories, for technological reasons, there is no dust lost from the kiln and $CF_{ckd}$=1 for the whole time series[4].

Since 2013, calculations of verified emissions for all plants include all data in accordance with EU-ETS requirements and Tier 2/Tier 3 methodology from the 2006 IPCC Guidelines[5].

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[4] Data required for $CF_{ckd}$ calculation were obtained from the factories but since the uncertainty of these (estimated) data was extremely high, default factor was used instead. For all plants for which $CF_{ckd}$=1, data were collected directly from the plants. As part of the verification of the emissions reports (EU ETS), visits made to these plants confirmed that they do not „lose“ CKD in the production process.

[5] For the period after the inclusion in the EU ETS, data on non-carbonate sources are available, however, as data significantly differ over the years (type and quantity of raw material), it was not possible to estimate missing data for other years on the basis of this data.

Activity data

For the period 1990-2006, data on clinker production, CaO and MgO content of clinker and CKD were collected within two projects conducted in 2007 and 2008 – the study: Croatian Cement Industry and Climate Change[6] (includes six factories); and the programme: $CO_2$ Emission Reduction Programme for Istra cement plant[7] (includes one factory). All data were collected by a direct survey of the factories.

For the period since 2007, required data are submitted by the factories, also in the form of completed questionnaires, to the Ministry of Economy and Sustainable Development, and then delivered to IPPU sector experts.

In communication with the operators, the unavailability of older historical data on non-carbonate sources was established. Availability varies by factory, but data for the period up to 1998 are not available for any factory in Croatia. For individual plants, there are data on the consumption of non-carbonate raw materials, but no analyses of the composition of the raw material, or the content of Cao and MgO in individual materials, have been carried out. The estimate of missing data was performed in accordance with methodology from the 2006 IPCC GL guidelines (Volume 1: General Guidance and Reporting, Chapter 2: Approaches to Data Collection), depending on the level of data availability for each year and each individual plant. In the estimation of missing data, average data for the nearest time period with known data was used, i.e., mostly data of 10 nearest years with available data were used.

From the submitted data, it can be concluded that bauxite, slag and pyrite are the most commonly used non-carbonate sources of CaO and MgO in Croatia. Limestone and marl are the most commonly used carbonate raw materials in the production of clinker.

Since 2013, together with data from verified emission reports, the Ministry also delivers completed questionnaires from the factories, which are mainly used as a source of data on produced clinker.

Factories calculate clinker production from raw material inputs, except for one factory that uses a combination of methods, inter alia, by determining the volume of clinker pile.

Table 4.2-1 gives an overview of total annual clinker production in Croatia and resulting emissions. Since there is only one factory that produces aluminate cement, due to confidentiality, separate production data by each type of clinker cannot be presented in this report.

Table 4.2-1: Total clinker production and process emissions of $CO_2$

| Year | Total clinker production (kt) | Total process $CO_2$ emission (kt) |
|---|---|---|
| 1990 | 2,062.4 | 1,086.2 |
| 1991 | 1,337.1 | 704.2 |
| 1992 | 1,566.3 | 826.6 |
| 1993 | 1,305.1 | 682.4 |
| 1994 | 1,583.7 | 834.0 |
| 1995 | 1,197.6 | 622.6 |
| 1996 | 1,306.3 | 682.6 |
| 1997 | 1,533.8 | 801.9 |
| 1998 | 1,649.1 | 861.1 |
| 1999 | 2,151.0 | 1,128.6 |
| 2000 | 2,382.1 | 1,257.0 |
| 2001 | 2,739.2 | 1,443.3 |

[6] The study was made on the initiative of the Croatia Cement g.i.u. association (prepared by EKONERG Ltd.).
[7] Programme was ordered by Istra cement Plc. and prepared by EKONERG Ltd.

| Year | Total clinker production (kt) | Total process $CO_2$ emission (kt) |
|---|---|---|
| 2002 | 2,698.6 | 1,423.5 |
| 2003 | 2,692.1 | 1,426.9 |
| 2004 | 2,852.2 | 1,510.0 |
| 2005 | 2,926.6 | 1,541.9 |
| 2006 | 3,104.4 | 1,635.1 |
| 2007 | 3,160.5 | 1,661.5 |
| 2008 | 2,995.1 | 1,567.8 |
| 2009 | 2,439.1 | 1,247.0 |
| 2010 | 2,320.5 | 1,210.2 |
| 2011 | 2,071.7 | 1,081.9 |
| 2012 | 1,996.5 | 1,034.7 |
| 2013 | 2,198.3 | 1,141.0 |
| 2014 | 2,318.5 | 1,225.1 |
| 2015 | 2,155.8 | 1,169.2 |
| 2016 | 2,055.2 | 1,076.5 |
| 2017 | 2,411.1 | 1,287.3 |
| 2018 | 2,325.8 | 1,210.7 |
| 2019 | 2,272.4 | 1,184.1 |
| 2020 | 2,350.7 | 1,212.9 |
| 2021 | 2,406.0 | 1,204.8 |
| 2022 | 2,252.9 | 1,099.1 |

#### 4.2.1.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data and emission factors amounts to 2 %, according to values given in the 2006 IPCC Guidelines.

Emissions from Cement Production for each factory were calculated using the same methodology and the same basic data source (factories) for the period 1990- 2012. For factories and years for which data on non-carbonate sources are not (currently) available, it is assumed that there was no use of non-carbonate sources in the production of clinker. For one factory, which was in operation until 1994, only data on clinker production were available and default emission factor was used.

Verified $CO_2$ emissions reported after 2013 have been defined in accordance with EU ETS requirements and the same methodology was used for the calculation of these emissions for each factory for all years. Only two factories used Tier 3 methodology. Although for the years after 2013, data required for the Tier 3 approach are available for these factories, since it refers only to the period of five years, estimates of data that would enable the transition to a higher tier for the years 1990-2012 were not made and Tier 2 has been retained for this period.

#### 4.2.1.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to category-specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

Since 2013, although they are no longer needed for calculation of emissions, questionnaires from the factories are still being collected to identify and document possible changes in the operation of individual plants. It should be noted that some of the factories that use the methodology based on the input of the raw material to the kiln are no longer analysing the clinker composition and it is not possible to make a comparison of emissions according to Tier 2 methodology.

#### 4.2.1.5. Category-specific recalculations

There were no recalculations.

#### 4.2.1.6. Category-specific planned improvements

There are no improvements planned for this category.

### 4.2.2. Lime production (2.A.2)

#### 4.2.2.1. Category description

In lime production, $CO_2$ is generated during the calcination stage, when limestone ($CaCO_3$) or dolomite ($CaCO_3$*$MgCO_3$) are heated to high temperatures (900-1.200°C) in a kiln to produce quicklime (CaO) or dolomitic lime (CaO*MgO).

During the reporting period, five lime factories were active in Croatia; two of them were producing both quicklime and dolomitic lime and three were producing only quicklime. Lime production fluctuated over the years. One factory ceased its operations in 2009 and one in 2011. Furthermore, factories that are still active had a varying production and even periods of halted operations over the years (one did not produce lime from 1992 to 1997, as it was severely damaged during the war, and the second one during 2009 due to technical reasons. Also, one factory ceased production in 2010 and restarted its operations in 2019). Entire production of dolomitic lime was stopped in the period 1991-1995.

Since 2013, all active lime factories (three factories) are covered by the EU ETS (due to minor lime production, sugar factories are not included in the EU ETS in this category).

During 1990 and 1991, a certain amount of non-marketed quicklime reagent was also produced in pig iron production plant.

Apart from the abovementioned, there is no other identified non-marketed lime production in Croatia.

Production trend is very similar to trends in the cement industry due to the same dependence on the economic situation and market demands.

#### 4.2.2.2. Methodological issues

<u>Methodology</u>

*Lime factories*

- T2 (1990-2012)
- T3 (2013-onward)

$CO_2$ emission for the period 1990-2012 (before inclusion into the EU ETS) for all lime factories is calculated using the Tier 2 method (2006 IPCC Guidelines), which includes multiplying emission factor (expressed in tonnes of $CO_2$ released per tonne of lime produced) by annual lime production. Since all production data used in calculations refer to total non-hydrated lime produced in each factory, the application of correction factor for hydrated lime was not needed.

In this way, the emission was calculated for each plant individually, with the exception of two factories whose activity data for the period 1990-2004 could not be collected separately (they were owned by the same manufacturer), thus emissions for this period were calculated for both factories together.

Only one of the lime producing factories (including pig iron manufacturer) uses a rotary kiln, but all lime kiln dust (LKD) in this factory is being returned to the kiln. Other factories use vertical shaft kilns that generate negligible amounts of LKD. Therefore, correction factor for LKD was not used in calculations for any of the factories.

Since 2013, data on emissions and used calculation methodologies, which are verified by independent accredited verifiers, are taken from the annual emission report under the EU emission trading system. All verified data are included in the inventory without any adjustments. Factories covered by the EU ETS for their emission calculation use the methodology based on the input of raw material to the kiln[8], which is comparable to Tier 3 methodology from the 2006 IPCC Guidelines.

*Pig iron manufacturer*

- T1 (1990-1991)

Emissions from quicklime production for the needs of pig iron manufacturing process in one plant during 1990 and 1991 were calculated using the Tier 1 method (2006 IPCC Guidelines), i.e. by multiplying a default emission factor by annual lime production, due to the unavailability of data needed for Tier 2.

<u>Emission factors</u>

- PS (1990-2022 – lime factories)
- D (1990-1991 – pig iron factory)

For the period 1990-2012, the emission factor was determined for each plant separately (plant-specific EF) based on the CaO content of quicklime and CaO*MgO content of dolomitic lime produced. Non-carbonate feeds to lime kiln were not taken into account since only negligible quantities are used, as reported by factories. CaO /CaO*MgO content of lime was then multiplied by the molecular weight ratio of $CO_2$ to CaO or CaO*MgO, as follows:

$$EF_{ql} = CaO_{ql} \times 0.785$$

$$EF_{dl} = CaO{*}MgO_{dl} \times 0.913$$

Where:

| | |
|---|---|
| $EF_{ql}$ and $EF_{dl}$ | - emission factors for quicklime and dolomitic lime [t $CO_2$/t lime] |
| $CaO_{ql}$ | - CaO content of quicklime [t CaO/t quicklime] |
| $CaO{*}MgO_{dl}$ | - CaO*MgO content of dolomitic lime [t CaO*MgO/t dolomitic lime] |
| 0.785 | - molecular weight ratio $CO_2$/CaO |
| 0.913 | - molecular weight ratio $CO_2$/ CaO*MgO |

As for the quicklime production within the pig iron manufacturing facility, default emission factor of 0.75 tonnes, $CO_2$ per tonne lime (2006 IPCC Guidelines) was used for the calculation.

[8] Method A according to 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 IV

Since 2013, calculations of verified emissions for all plants include all data in accordance with EU-ETS requirements and Tier 3 methodology from the 2006 IPCC Guidelines.

Activity data

For the period 1990-2007, data on non-hydrated lime production in lime factories and CaO/CaO*MgO content of lime were collected within the project conducted in 2008 – the study: Croatian Lime Industry and Climate Change[9] (includes all lime factories). All data for this study were collected by a direct survey of the lime factories.

Required data for the period after 2007, lime factories submitted in the form of completed questionnaires to the Ministry of Economy and Sustainable Development, which then delivered the data to IPPU sector experts.

In addition, data on lime production in 1990 and 1991 were collected directly from the pig iron producer.

For this submission, additional verification of all historical data was requested from the manufacturers and minor adjustments were made (for three factories) for the period 2005-2010.

CaO/CaO*MgO content of lime is measured by internal-factory laboratories or external laboratories. For one lime factory, for the period 1990-2007, only a producer's estimate of the CaO content of lime was available (i.e. this parameter was not measured), while data from this factory submitted for the years after 2007 were acquired by the analysis performed by an accredited laboratory. Due to the inconsistency of these estimates with data for the rest of the time series (and with the range provided by the Guidelines), the average value of the CaO content for the years for which the measured data was submitted was used in emission calculations.

Since 2013, together with data from verified emission reports, the Ministry also still delivers completed questionnaires from the factories.

Summarized data on lime production, emission factors and calculated emissions are given in Tables 4.2-2 and 4.2-3.

Emissions declined after 1990 as a result of the war, after which a rapid growth is recorded mostly due to the increase in construction sector activities, which were slowed down by the economic crisis after 2008. Moreover, termination of pig iron production in 1991 contributed to a drop in emissions in 1992.

Table 4.2-2: Lime production

| Year | Quicklime production in lime factories (kt) | Dolomitic lime production in lime factories (kt) | Quicklime production in pig iron plant (kt) | Total lime production (kt) |
|---|---|---|---|---|
| 1990 | 193.2 | 7.5 | 18.6 | 219.3 |
| 1991 | 143.6 | NO | 11.7 | 155.3 |
| 1992 | 106.4 | NO | NO | 106.4 |
| 1993 | 116.9 | NO | NO | 116.9 |
| 1994 | 117.2 | NO | NO | 117.2 |
| 1995 | 113.5 | NO | NO | 113.5 |
| 1996 | 109.2 | 38.1 | NO | 147.3 |
| 1997 | 100.9 | 55.2 | NO | 156.0 |
| 1998 | 105.3 | 53.4 | NO | 158.6 |
| 1999 | 90.8 | 52.7 | NO | 143.5 |

[9] The study was ordered by PROMINS g.i.u. and prepared by EKONERG Ltd.

| Year | Quicklime production in lime factories (kt) | Dolomitic lime production in lime factories (kt) | Quicklime production in pig iron plant (kt) | Total lime production (kt) |
|---|---|---|---|---|
| 2000 | 105.4 | 68.6 | NO | 173.9 |
| 2001 | 118.2 | 84.8 | NO | 203.0 |
| 2002 | 129.1 | 94.4 | NO | 223.5 |
| 2003 | 124.6 | 96.2 | NO | 220.8 |
| 2004 | 181.3 | 56.7 | NO | 238.0 |
| 2005 | 169.9 | 78.7 | NO | 248.6 |
| 2006 | 199.1 | 98.2 | NO | 297.3 |
| 2007 | 194.2 | 110.3 | NO | 304.5 |
| 2008 | 167.9 | 118.4 | NO | 286.2 |
| 2009 | 111.0 | 84.9 | NO | 195.9 |
| 2010 | 72.3 | 87.4 | NO | 159.7 |
| 2011 | 62.9 | 71.8 | NO | 134.7 |
| 2012 | 43.5 | 59.3 | NO | 102.8 |
| 2013 | 44.9 | 52.9 | NO | 97.8 |
| 2014 | 40.0 | 53.4 | NO | 93.4 |
| 2015 | 52.0 | 46.2 | NO | 98.2 |
| 2016 | 44.2 | 42.2 | NO | 86.4 |
| 2017 | 39.9 | 67.0 | NO | 106.9 |
| 2018 | 40.1 | 75.1 | NO | 115.2 |
| 2019 | 82.5 | 38.5 | NO | 121.0 |
| 2020 | 39.8 | 89.2 | NO | 129.0 |
| 2021 | 35.7 | 117.5 | NO | 153.2 |
| 2022 | 36.0 | 102.8 | NO | 138.8 |

Table 4.2-3: Emission factors and $CO_2$ emissions from lime production

| Year | Quicklime EF – average, all lime factories (t/t) | Dolomitic lime EF - average, all lime factories (t/t) | Quicklime EF - pig iron plant (t/t) | IEF – total lime production (t/t) | Total emissions from the production of lime (kt) |
|---|---|---|---|---|---|
| 1990 | 0.71 | 0.87 | 0.75 | 0.72 | 156.8 |
| 1991 | 0.71 | * | 0.75 | 0.72 | 111.2 |
| 1992 | 0.72 | * | * | 0.72 | 76.7 |
| 1993 | 0.73 | * | * | 0.72 | 84.8 |
| 1994 | 0.73 | * | * | 0.73 | 85.2 |
| 1995 | 0.74 | * | * | 0.73 | 83.4 |
| 1996 | 0.72 | 0.86 | * | 0.74 | 111.7 |
| 1997 | 0.72 | 0.85 | * | 0.76 | 119.6 |
| 1998 | 0.71 | 0.87 | * | 0.77 | 121.7 |
| 1999 | 0.71 | 0.87 | * | 0.77 | 110.6 |
| 2000 | 0.71 | 0.89 | * | 0.77 | 135.7 |
| 2001 | 0.71 | 0.89 | * | 0.78 | 159.7 |
| 2002 | 0.72 | 0.89 | * | 0.79 | 176.8 |
| 2003 | 0.71 | 0.88 | * | 0.79 | 173.6 |
| 2004 | 0.72 | 0.89 | * | 0.79 | 181.5 |
| 2005 | 0.73 | 0.88 | * | 0.76 | 192.3 |
| 2006 | 0.72 | 0.90 | * | 0.77 | 231.9 |
| 2007 | 0.73 | 0.90 | * | 0.78 | 240.2 |
| 2008 | 0.75 | 0.90 | * | 0.79 | 232.6 |

| Year | Quicklime EF – average, all lime factories (t/t) | Dolomitic lime EF - average, all lime factories (t/t) | Quicklime EF - pig iron plant (t/t) | IEF – total lime production (t/t) | Total emissions from the production of lime (kt) |
|---|---|---|---|---|---|
| 2009 | 0.71 | 0.86 | * | 0.81 | 152.0 |
| 2010 | 0.72 | 0.90 | * | 0.78 | 130.8 |
| 2011 | 0.69 | 0.89 | * | 0.82 | 107.6 |
| 2012 | 0.69 | 0.88 | * | 0.80 | 82.1 |
| 2013 | 0.65 | 0.85 | * | 0.80 | 74.3 |
| 2014 | 0.64 | 0.86 | * | 0.76 | 71.5 |
| 2015 | 0.64 | 0.86 | * | 0.77 | 73.4 |
| 2016 | 0.62 | 0.86 | * | 0.75 | 63.8 |
| 2017 | 0.63 | 0.85 | * | 0.74 | 82.1 |
| 2018 | 0.64 | 0.84 | * | 0.77 | 88.9 |
| 2019 | 0.73 | 0.84 | * | 0.77 | 92.7 |
| 2020 | 0.70 | 0.85 | * | 0.80 | 103.7 |
| 2021 | 0.70 | 0.83 | * | 0.80 | 123.0 |
| 2022 | 0.71 | 0.83 | * | 0.80 | 111.3 |

* There was no production in the given year

#### 4.2.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with both activity data and emission factors amounts to 2 %, according to values from the 2006 IPCC Guidelines.

Emissions from Lime Production for each factory were calculated using the same methodology and the same basic data source (factories) for the period 1990-2012. For one factory, which was in operation until 1991, only data on lime production were available and default emission factor was used.

Verified $CO_2$ emissions reported after 2013 have been defined in accordance with EU ETS requirements and the same methodology was used for the calculation of these emissions for each factory for all years. Two ETS-included factories use Tier 3 methodology. Although for the years after 2013, data required for the Tier 3 approach are available for these factories, since it refers only to the period of five years, estimates of data that would enable the transition to a higher tier for the years 1990-2012 were not made, and Tier 2 has been retained for this period.

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

Activities related to category-specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

Since 2013, although they are no longer needed for calculation of emissions, questionnaires from the factories are still being collected to identify and document possible changes in the operation of individual plants.

#### 4.2.2.5. Category-specific recalculations

There are no category-specific recalculations.

#### 4.2.2.6. Category-specific planned improvements

There are no category-specific improvements planned.

### 4.2.3. Glass production (2.A.3)

#### 4.2.3.1. Category description

In glass production, carbonate raw materials (most commonly used are limestone, dolomite and soda ash) release $CO_2$ emissions during the melting process in the furnace. Other minor carbonate raw materials and certain amounts of recycled scrap glass are also used in glass production.

During the reporting period, two glass factories were in operation in Croatia; one of them producing container glass and the other producing flat glass. In 2009, the second factory has ceased its glass production operations and since then, together with several other factories in Croatia, it only processes imported glass (using operations like cutting, grinding, paint application, laminating etc.), which does not result in GHGs emissions. During a short period in 2010, the furnace of the second factory was restarted for testing purposes, which was also included in the emissions calculation for this source category.

Since 2013, the factory which is still in operation (container glass manufacturer) is covered by the EU ETS[10].

#### 4.2.3.2. Methodological issues

<u>Methodology</u>

- T3 (1990-2022)

$CO_2$ emission for the whole time series (including the EU ETS period) for both factories is calculated using the Tier 3 method (2006 IPCC Guidelines), i.e. multiplying emission factor for each carbonate (expressed in tonnes of $CO_2$ released per tonne of carbonate) by annual consumption (mass) of each carbonate used (mined). Since the fraction calcination achieved for particulate carbonates is not known, it is assumed that the fraction calcination is equal to 1.00. In this way, the emission was calculated by summing up emissions from all carbonates used, for each plant individually.

Since 2013, data on emissions and used calculation methods, which are verified by independent accredited verifiers, are taken from the annual emission reports under the EU emission trading system. All verified data are included in the inventory without any adjustments. The factory covered by the EU ETS for its emission calculation uses the method based on the input of raw material, which is comparable to the Tier 3 method from the 2006 IPCC Guidelines.

<u>Emission factors</u>

- PS (1990-2022)

The Tier 3 emission factors are based on actual carbonates consumed in the melting furnace in each of the factories, and since they use different carbonates, emission factors are considered to be plant-specific, even though default values of carbon dioxide contents of carbonate species were used.

One factory used limestone, dolomite and soda ash during the whole time series. Second factory, that ceased its glass production operations in 2009 used dolomite and soda ash in the period 1990-2009.

[10] Names of the sectors that operators use in their ETS reports do not entirely correspond to IPCC categories. ETS reports for 2013 and 2014 in the category 2.A.3 include one glass producer together with two rock wool produces. This has resulted in emissions from the category 2.A.3 reported in the NIR being significantly lower than emissions reported under the EU ETS.

During the short period in 2010, this factory restarted its furnace and used lithium carbonate as raw material.

For calculation of $CO_2$ emissions from 1990 to 2012, the IPCC 2006 default emission factors of 0.41492 t $CO_2$/t soda ash, 0.43971 t $CO_2$/t limestone and 0.47732 t $CO_2$/t dolomite were used. For lithium carbonate, emission factor of 0.596 was used, taken from 2007/589/EC Commission Decision of 18 July 2007 establishing guidelines for the monitoring and reporting of GHG emissions pursuant to Directive 2003/87/EC (Annex IX, tabl. 1).

Since 2013, calculations of verified emissions include all data in accordance with EU-ETS requirements and Tier 3 methodology from the 2006 IPCC Guidelines. EU ETS background data provided more detailed information on the actual carbon content of the carbonates used. Therefore, the IEFs from 2013 onwards are slightly different compared to IPCC default values.

Activity data

Carbonate consumption is reported as activity data.

For one factory, data on carbonates consumed in the period 1990-2012 were collected by a direct survey of the manufacturer. These data were submitted by the factory in the form of completed questionnaires, to the Ministry of Economy and Sustainable Development, and then delivered to IPPU sector experts.

For the second factory, which ceased its production in 2010, data from the factory are available only since 1997. Prior to that period, the plant was working discontinuously due to the war and all documentation which was at that time written by hand was destroyed in the war. Since the factory did report on its carbonate use to the Central Bureau of Statistics, data from the first factory were subtracted from aggregated national statistical data in order to make the estimate for the second factory.

Since 2013, together with data from verified emission reports, the Ministry also still delivers completed questionnaires from the active factory.

Since there are only two factories covered by this category, and they use different carbonates as raw materials, due to confidentiality, the consumption data by each carbonate cannot be presented in this report. All documentation is available for internal communication with ERT.

The most significant emission drop was after 1990 as a result of the war (see Table 4.2-4). Other fluctuations of emissions trend were basically dependent on one factory's production fluctuations since the second factory had very low carbonate consumption and thus low emissions through its entire operating period covered by this report (on average this factory accounted for 6.5% of total emissions from glass production).

Table 4.2-4: Carbonates consumption and emissions from Glass production

| Year | Total carbonates consumption (kt) | Total emissions from glass production (kt) |
|---|---|---|
| 1990 | 98.9 | 43.2 |
| 1991 | 88.2 | 38.5 |
| 1992 | 48.3 | 21.1 |
| 1993 | 48.5 | 21.2 |
| 1994 | 65.2 | 28.4 |
| 1995 | 63.1 | 27.6 |
| 1996 | 60.5 | 26.5 |
| 1997 | 50.6 | 22.2 |
| 1998 | 61.2 | 26.9 |

| Year | Total carbonates consumption (kt) | Total emissions from glass production (kt) |
|---|---|---|
| 1999 | 55.6 | 24.5 |
| 2000 | 54.1 | 23.8 |
| 2001 | 60.5 | 26.6 |
| 2002 | 62.3 | 27.3 |
| 2003 | 73.0 | 32.1 |
| 2004 | 84.0 | 36.9 |
| 2005 | 88.1 | 38.7 |
| 2006 | 77.5 | 34.0 |
| 2007 | 68.9 | 30.2 |
| 2008 | 70.9 | 31.1 |
| 2009 | 74.3 | 32.6 |
| 2010 | 82.4 | 36.1 |
| 2011 | 74.2 | 32.5 |
| 2012 | 67.6 | 29.6 |
| 2013 | 68.2 | 29.5 |
| 2014 | 70.7 | 30.5 |
| 2015 | 70.8 | 30.7 |
| 2016 | 75.7 | 32.6 |
| 2017 | 73.7 | 31.9 |
| 2018 | 71.4 | 30.5 |
| 2019 | 68.3 | 29.4 |
| 2020 | 59.2 | 25.6 |
| 2021 | 66.6 | 28.9 |
| 2022 | 70.1 | 30.4 |

#### 4.2.3.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to 2 %. Uncertainty estimate associated with emission factors amounts to 2 %, according to values in the 2006 IPCC Guidelines.

Regarding time-series consistency, different sets of activity data were used for emissions estimates. For one factory, data on carbonates consumed in the period 1990-2012 were collected by a direct survey of the manufacturer, and since 2013, activity data and emissions were taken from verified emission reports. For the second factory, which ceased its production in 2010, data from the factory are available only since 1997. Before that period, data were obtained from national statistics.

#### 4.2.3.4. Category-specific QA/QC and verification

Activities related to category-specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

Since 2013, although they are no longer needed for calculation of emissions, questionnaires from the active factory are still being collected to identify and document possible changes in the operation.

#### 4.2.3.5. Category-specific recalculations

There were no source-specific recalculations in this category.

#### 4.2.3.6. Category-specific planned improvements

There are no source-specific improvements currently planned for this category.

### 4.2.4. Other process uses of carbonates (2.A.4)

#### 4.2.4.1. Category description

This category addresses $CO_2$ emissions from the following sources:

- ceramics (2.A.4.a),
- other uses of soda ash (2.A.4.b),
- non-metallurgical magnesium production (2.A.4.c) – not present in Croatia, and
- other uses of carbonates (2.A.4.d)

*Ceramics (2.A.4.a)*

In Croatia, this source encompasses production of bricks and roof tiles, refractory products, wall and floor tiles, as well as household, sanitary and technical ceramics. Process-related $CO_2$ emissions from ceramics result from the calcination of carbonates (particularly $CaCO_3$ and $CaMg(CO_3)_2$) in the clay raw material, and certain additives, which are heated to high temperatures in a kiln.

During the reporting period, 17 ceramics producers, which used carbonates in their production, were in operation in Croatia. Several other producers reported using only non-carbonate clay as raw material.

Both production and emissions trends fluctuated over the years with new factories starting their production and some of the factories stopping the use of carbonate raw materials or stopping their production altogether.

Since 2013, 12 factories (with larger production) are covered by the EU ETS, while smaller factories are excluded from the EU ETS but are still accounted for in this report.

*Other uses of soda ash (2.A.4.b)*

Soda ash is primarily sodium carbonate and its use in production processes of the above-mentioned industries results in the release of $CO_2$.

Identified activities in which $Na_2CO_3$ is used in Croatia as part of industrial processes are production of glass, porcelain and ceramics and production of soaps and detergents.

An extensive research of data on other uses of soda ash has been conducted since the last submission. No use has been identified in chemical industry or in activities covered by category 2.A.4.d Other (only limestone is used for the needs of the thermal power plant). Also, no process emissions of $CO_2$ have been identified in pulp and paper production. All inputs related to the activity of soap and detergent production were further investigated and detailed explanations were requested from the factories, including a description of the technologies and processes used. As a result, it was determined that in all plants of soap and detergent manufacturers there is no $CO_2$ emission into the air from production processes, thus these emissions were excluded from the calculation. The information obtained from the manufacturers shows that the entire amount of soda ash in their plants is used in a closed system with dry mixing, without generating greenhouse gas emissions. As there are no other plants in Croatia identified under this category, emissions for category 2.A.4.b are reported as “NO”.

*Other (2.A.4.d)*

Emissions from the use of carbonates may result from a number of other source categories that are not included in the above-mentioned sources. In Croatia, this refers to limestone consumption in desulphurization process in one thermal power plant since 2000, and dolomite consumption in the production of insulation materials (rock wool) in two plants (one was in operation since 2008 and the other one during the whole time series). In the second plant since 2022, sodium hydrogen carbonate and Linz slag were also used as raw materials.

Since 2013, all of these three plants are covered by the EU ETS.

#### 4.2.4.2. Methodological issues

Methodology

*Ceramics (2.A.4.a)*

- T3 (1990-2022)

$CO_2$ emission for the whole time series (including the EU ETS period) for all factories is calculated using the Tier 3 approach (2006 IPCC Guidelines), which includes multiplying emission factor for each carbonate (expressed in tonnes of $CO_2$ released per tonne of carbonate) by annual consumption (mass) of each carbonate used. Since the fraction calcination achieved for particulate carbonates is not known, it is assumed that the fraction calcination is equal to 1.00.

In this way, the emission was calculated by summing up emissions from all carbonates used, for each plant individually.

Since 2013, data on emissions and used calculation methodologies, which are verified by independent accredited verifiers, are taken from the annual emission reports under the EU ETS. All verified data are included in the inventory without any adjustments. Factories covered by the EU ETS for their emission calculation uses the methodology based on the input of raw material, which is comparable to the Tier 3 method from the 2006 IPCC Guidelines.

*Other (2.A.4.d)*

- T3 (2000-2022)

$CO_2$ emission for the whole time series (including the EU ETS period) for all plants is calculated using the Tier 3 method (2006 IPCC Guidelines), by multiplying emission factor for each carbonate (expressed in tonnes of $CO_2$ released per tonne of carbonate) and annual consumption (mass) of each carbonate used. Since the fraction calcination achieved for particulate carbonates is not known, it is assumed that the fraction calcination is equal to 1.00.

In this way, the emission was calculated for each plant individually for the period of their operations until 2012. Since 2013, data on emissions and used calculation methods, which are verified by independent accredited verifiers, are taken from the annual emission reports under the EU ETS. All verified data are included in the inventory without any adjustments. For their emission calculation, plants use the method based on the input of raw material, which is comparable to the Tier 3 method from the 2006 IPCC Guidelines.

Emission factors

*Ceramics (2.A.4.a)*

- PS (1990-2022)

The Tier 3 emission factors are based on the actual carbonates consumed in the kiln in each factory, thus emission factors are considered to be plant-specific[11].

Carbonates contained in clay and other carbonates raw material reported/used in this industry during the time series are $CaCO_3$, $MgCO_3$, $CaMg(CO_3)_2$, and $Na_2CO_3$.

For calculation of $CO_2$ emissions from 1990 to 2012, the default values of carbon dioxide contents of carbonate species were used (0.43971 t $CO_2$/t $CaCO_3$, 0.52197 t $CO_2$/t $MgCO_3$, 0.47732 t $CO_2$/t $CaMg(CO_3)_2$ and 0.41492 t $CO_2$/t $Na_2CO_3$).

Since 2013, calculations of verified emissions include all data in accordance with EU-ETS requirements and Tier 3 method from the 2006 IPCC Guidelines. For the factories not included in the ETS, the calculation of emissions is the same as for the period prior to 2013.

*Other (2.A.4.d)*

- PS (1990-2022)

Thermal power plant used limestone (since 2000), while rock wool factories used dolomite.

For calculation of $CO_2$ emissions from 1990 to 2012, the IPCC 2006 default emission factors of 0.43971 t $CO_2$/t limestone and 0.47732 t $CO_2$/t dolomite were used.

Since 2013, calculations of verified emissions include all data in accordance with EU ETS requirements and Tier 3 method from the 2006 IPCC Guidelines. EU ETS background data provided more detailed information on the actual carbon content of the carbonates used. Therefore, the IEFs from 2013 onwards are slightly different.

<u>Activity data</u>

*Ceramics (2.A.4.a)*

Activity data on annual consumption of all carbonate species contained in clay and other carbonates raw material in each factory were collected by a survey of manufacturers. These data were submitted by factories in the form of completed questionnaires to the Ministry of Economy and Sustainable Development and then delivered to IPPU sector experts. The factories provided all the data available in their archives, but a smaller part of the data was not available and the estimation was made (by linear interpolation or by applying the mean values of known data, where applicable).

Prior to 2010, in some of the factories, clay analysis was not being performed and these factories reported their carbonate consumption estimates according to more recent years when clay analysis data were available since it was mostly clay from the same deposits. Since 2013, data from verified emission reports for the factories covered by the EU ETS, and data from completed questionnaires from the factories not covered by the EU ETS are used.

Most of the plants in this category produce bricks, ceramic tiles and roof tiles. Carbonate contained in clay used in brick production is $CaCO_3$. In production of ceramic tiles, identified are $CaCO_3$ and $MgCO_3$ from clay and also from dolomite sludge, granite and dolomite. In roof tiles production, identified is $CaCO_3$ from clay and also from humus soil, other soil material and sand/clay material. Use of raw materials containing $CaMg(CO_3)_2$ and $Na_2CO_3$ is present only in one plant, which produces tiles and household, sanitary and technical ceramics.

[11] Similarly to emission factors in glass production category, since the factories use different carbonates, emission factors are considered to be plant-specific, even though default values of carbon dioxide contents of carbonate species were used.

*Other (2.A.4.d)*

Data on carbonates consumed in the period 1990-2012 were collected by a direct survey of the plants. These data were submitted by the plants in the form of completed questionnaires, to the Ministry of Economy and Sustainable Development, and then delivered to IPPU sector experts.

For one rock wool plant, data on the used raw material for the period before 2012 are not available. Missing data are estimated based on the ratio of the amount of raw material used and the rock wool produced for the 10 nearest years with known data.

Since 2013, data from verified ETS reports are used.

Summarized data on carbonates consumption and calculated emissions from production of ceramics and other uses of carbonates are given in Tables 4.2-5 and 4.2-6.

It should be noted that in the ceramics industry, production (and emission trends) varied depending on the economic situation and demand on the market, thus emissions at the national level decreased since 1990 as a result of the war, after which they increased with the growth in construction sector activities. The trend after 2008 is the result of the economic crisis and ceased operations of several facilities.

Table 4.2-5: Carbonates consumption and $CO_2$ emissions from the production of ceramics

| Year | Total carbonates consumption (kt) | Total emissions from ceramics production (kt) |
|---|---|---|
| 1990 | 20.5 | 9.1 |
| 1991 | 10.7 | 4.9 |
| 1992 | 9.2 | 4.2 |
| 1993 | 9.5 | 4.3 |
| 1994 | 8.7 | 3.9 |
| 1995 | 8.7 | 3.9 |
| 1996 | 8.6 | 3.8 |
| 1997 | 7.1 | 3.1 |
| 1998 | 5.4 | 2.4 |
| 1999 | 4.4 | 1.9 |
| 2000 | 9.0 | 4.0 |
| 2001 | 18.2 | 8.0 |
| 2002 | 20.6 | 9.1 |
| 2003 | 22.1 | 9.8 |
| 2004 | 23.7 | 10.5 |
| 2005 | 63.1 | 28.1 |
| 2006 | 64.0 | 28.6 |
| 2007 | 58.0 | 25.9 |
| 2008 | 55.2 | 24.5 |
| 2009 | 30.3 | 13.6 |
| 2010 | 30.6 | 13.6 |
| 2011 | 34.4 | 15.2 |
| 2012 | 20.8 | 9.3 |
| 2013 | 13.5 | 6.1 |
| 2014 | 24.7 | 11.0 |
| 2015 | 30.9 | 13.7 |
| 2016 | 23.7 | 10.5 |

| Year | Total carbonates consumption (kt) | Total emissions from ceramics production (kt) |
|---|---|---|
| 2017 | 17.9 | 8.0 |
| 2018 | 25.9 | 11.5 |
| 2019 | 9.6 | 4.2 |
| 2020 | 10.5 | 4.6 |
| 2021 | 6.2 | 2.7 |
| 2022 | 8.5 | 3.7 |

Table 4.2-6: Carbonates consumption and $CO_2$ emissions from other uses

| Year | Total carbonates consumption (kt) | Total emissions from other uses of carbonates (kt) |
|---|---|---|
| 1990 | 4.6 | 2.2 |
| 1991 | 4.1 | 2.0 |
| 1992 | 4.2 | 2.0 |
| 1993 | 4.2 | 2.0 |
| 1994 | 4.6 | 2.2 |
| 1995 | 4.7 | 2.2 |
| 1996 | 4.8 | 2.3 |
| 1997 | 4.0 | 1.9 |
| 1998 | 4.7 | 2.2 |
| 1999 | 6.1 | 2.9 |
| 2000 | 13.0 | 6.0 |
| 2001 | 15.4 | 7.0 |
| 2002 | 19.0 | 8.6 |
| 2003 | 21.5 | 9.7 |
| 2004 | 20.5 | 9.3 |
| 2005 | 19.5 | 8.9 |
| 2006 | 20.1 | 9.1 |
| 2007 | 19.3 | 8.8 |
| 2008 | 26.8 | 12.2 |
| 2009 | 22.1 | 10.3 |
| 2010 | 27.9 | 13.0 |
| 2011 | 40.0 | 18.4 |
| 2012 | 37.8 | 17.5 |
| 2013 | 43.6 | 20.4 |
| 2014 | 34.0 | 16.1 |
| 2015 | 40.8 | 19.3 |
| 2016 | 38.1 | 17.8 |
| 2017 | 34.8 | 16.4 |
| 2018 | 32.4 | 16.8 |
| 2019 | 31.0 | 14.5 |
| 2020 | 26.7 | 12.5 |
| 2021 | 27.3 | 12.9 |
| 2022 | 25.4 | 10.9 |

#### 4.2.4.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to 2 %, and uncertainty estimate associated with emission factors amounts to 3 %, according to values recommended by the 2006 IPCC Guidelines.

Emissions from production of ceramics until 2012, were calculated using activity data that may not be complete, as it is not known how many factories were active during this period, and therefore questionnaires were sent only to plants which are still active or have recently been shut down. Since 2013, data from verified emission reports for the factories covered by the EU ETS, and data from completed questionnaires from the active factories not covered by the EU ETS are used.

Emissions from other uses of carbonates have been calculated by using the same methodology for the whole time series.

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

Activities related to category-specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.2.4.5. Category-specific recalculations

There were no recalculations.

#### 4.2.4.6. Category-specific planned improvements

There are no planned improvements in this category.

## 4.3. Chemical industry (CRF 2.B)

### 4.3.1. Ammonia production (2.B.1)

#### 4.3.1.1. Category description

One ammonia manufacturer has been in operation in Croatia during the whole time series. Ammonia is produced by catalytic steam reforming of natural gas in which hydrogen is chemically separated from natural gas and combined with nitrogen to produce ammonia ($NH_3$). Conversion of CO is carried out in stages, with appropriate catalysts. The resulting $CO_2$ is removed from the synthesis gas by absorption. The absorbed $CO_2$ is separated by stripping. Finally, ammonia is produced by the synthesis of elemental hydrogen and nitrogen at high temperatures and pressures. $CO_2$ is then released into the atmosphere or used as raw material in other production processes (production of urea and NPK fertilizers).

#### 4.3.1.2. Methodological issues

<u>Methodology</u>

- T3 (1990-2022)

Natural gas is used as both feedstock and fuel in ammonia production and GHG emissions from both uses have been calculated for this subsector. Since natural gas used in ammonia production is included in the energy balance under the “non-energy use” category (see Annex 4), double-counting in regards to Energy sector does not occur.

Tier 3 method (2006 IPCC Guidelines) is used for $CO_2$ emission calculation. The basis for calculation is plant-specific total fuel data. The quantity of $CO_2$ recovered for downstream use in the production of urea and NPK fertilizers is subtracted from the total quantity of $CO_2$ generated to derive $CO_2$ emitted.

Taking into account the aforesaid, $CO_2$ emissions are calculated using the following equation:

$$E_{CO2} = (TFR_{NG} \text{ x } CCF_{NG} \text{ x } COF_{NG} \text{ x } 44/12) - R_{CO2}$$

Where:

$E_{CO2}$ - emissions of $CO_2$ [kg]

$TRF_{NG}$ - total fuel requirement for natural gas [GJ]

$CCF_{NG}$ - carbon content factor of natural gas [kg C/GJ]

$COF_{NG}$ - carbon oxidation factor of natural gas [fraction]

44/12 - ratio of molecular weights, $CO_2$ to carbon

$R_{CO2}$ - $CO_2$ recovered for downstream use (urea and NPK fertilizers production) [kg]

<u>Emission factors and activity data</u>

- PS (1990-2022)

Data on annual consumption, average annual composition, lower heating value and carbon oxidation factor of natural gas were collected by a survey of ammonia manufacturer, who submitted the requested data to the Ministry of Economy and Sustainable Development, and which were then delivered to IPPU sector experts.

Consumption of natural gas for ammonia production process in the plant is measured by the measuring screen where the output is compensated with respect to pressure and temperature in the Distributed Control System (DCS). Data on natural gas consumption, together with data on ammonia production which is measured by a mass flowmeter, are collected in the DCS during the 24-hour work regime and stored on an annual basis.

Natural gas composition is being determined by an accredited chromatographic “in-house” method (in the internal accredited laboratory). Calculations of lower heating value, density and molar mass are being performed in line with normative documents accepted by Croatian Standards Institute. Carbon content of natural gas for each year is subsequently calculated based on measured volume fractions of different gases in natural gas (annual average) and the aforementioned calculated parameters. Since daily measurements are performed at standard conditions (1 atm, 15°C), the molar volume of gas used in calculations equals 23.64 $dm^3/mol$[12].

In this way, carbon content was estimated by the operator for the years since 2010, and prior to that year, it was estimated by IPPU sector experts based on data submitted by the operator. Carbon oxidation factor, as submitted by the operator, for all years equals 1.

Changes in the composition of natural gas are reflected in changes in $CO_2$ IEFs.

The amount of $CO_2$ transferred to downstream use in the production of urea and NPK fertilizers plants is regularly measured by differential pressure flowmeters[13]. Data are collected in the DCS during the 24-hour work regime and stored on an annual basis.

[12] Calculated by using general gas equation V=n*R*T/p; where n is number of moles, R is a gas constant of 8.314 $JK^{-1}mol^{-1}$, T is temperature and p is pressure.

[13] Dall tube, the accuracy of the measurement: ± 3%

Total annual consumption and average annual composition of natural gas and emissions from Ammonia Production are shown in Table 4.3-1.

Table 4.3-1: Consumption and composition of natural gas and resulting $CO_2$ emissions from Ammonia Production

| Year | Total natural gas consumption (TJ) | Carbon content of natural gas (kg C/GJ) | Total $CO_2$ emissions from Ammonia Production (kt) |
|---|---|---|---|
| 1990 | 13,879.5 | 15.2 | 558.7 |
| 1991 | 13,701.3 | 15.2 | 510.9 |
| 1992 | 17,272.7 | 15.2 | 687.9 |
| 1993 | 14,238.9 | 14.8 | 559.5 |
| 1994 | 14,179.2 | 15.1 | 567.3 |
| 1995 | 14,759.5 | 15.1 | 573.7 |
| 1996 | 14,459.2 | 15.1 | 529.4 |
| 1997 | 15,815.6 | 15.0 | 587.7 |
| 1998 | 11,991.2 | 15.0 | 441.7 |
| 1999 | 15,383.1 | 15.1 | 564.2 |
| 2000 | 15,873.6 | 15.1 | 600.1 |
| 2001 | 12,733.9 | 15.1 | 492.7 |
| 2002 | 11,221.3 | 15.1 | 440.2 |
| 2003 | 12,934.8 | 15.1 | 461.3 |
| 2004 | 15,394.1 | 15.0 | 541.3 |
| 2005 | 15,126.6 | 15.0 | 542.3 |
| 2006 | 14,738.2 | 15.0 | 521.8 |
| 2007 | 16,036.6 | 15.0 | 569.3 |
| 2008 | 16,255.5 | 15.0 | 570.4 |
| 2009 | 13,854.6 | 15.0 | 455.4 |
| 2010 | 16,013.6 | 15.1 | 552.6 |
| 2011 | 16,148.3 | 15.0 | 552.8 |
| 2012 | 14,948.7 | 15.1 | 502.0 |
| 2013 | 15,199.8 | 15.1 | 509.3 |
| 2014 | 16,461.2 | 15.1 | 559.8 |
| 2015 | 16,417.3 | 15.1 | 572.3 |
| 2016 | 15,321.5 | 15.1 | 547.9 |
| 2017 | 16,585.2 | 15.2 | 566.8 |
| 2018 | 14,293.7 | 15.1 | 513.1 |
| 2019 | 16,989.5 | 15.1 | 594.6 |
| 2020 | 16,175.9 | 15.1 | 535.3 |
| 2021 | 10,818.1 | 15.1 | 365.5 |
| 2022 | 2,080.0 | 15.1 | 83.9 |

It should be noted that since 2013, the ammonia production plant is covered by the EU ETS. However, ETS emission reporting methodology is different from the one specified in the 2006 IPCC Guidelines for inventory purposes. According to ETS methodology, a part of $CO_2$ from natural gas used for ammonia production without energy part is specified by CRF 2.B.1. code and a part of $CO_2$ from natural gas used for ammonia production with energy part is specified by CRF code 1.A.2.f., together with natural gas used in boilers.

According to IPCC methodology, all-natural gas used in ammonia production should be included 2.B.1 sector with the quantity of $CO_2$ recovered for downstream use subtracted from total amount (which is not the case in EST methodology). The remaining part of $CO_2$ emission (emission from boilers) is included in the Energy sector, 1.A.2.f.[14]

$CH_4$ emission has not been confirmed by actual measurements and it is currently not possible to calculate emissions. The 2006 IPCC Guidelines do not provide a default emission factor. Thus, $CH_4$ emission was not calculated.

Emissions of CO $NO_x$ and NMVOC are taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'.

Only emissions from natural gas used as feedstock are included in this category. Emissions from natural gas used as fuel are included in the Energy sector. Emissions calculations were performed in line with the EMEP/EEA methodology (EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2023). Tier 2 EFs from the Guidebook were used for CO and NMVOC. For NOx, plant-specific annual EFs were used since 1998, while for the years prior to 1998, an average EF was calculated based on available direct NOx emissions measurements.

#### 4.3.1.3. Uncertainties and time-series consistency

Uncertainty of $CO_2$ emission estimate associated with activity data amounts to 2 %, based on information provided by the manufacturer. Along with questions on activity data, data sources, competent authorities, methodology for data collection and other important information, Annual data collection plan includes questions on the uncertainties of submitted data. For each measured data that is included into emissions calculation, ammonia manufacturer has submitted uncertainty of measurement devices according to which uncertainty of activity data has been estimated.

Uncertainty of $CO_2$ emission estimate associated with emission factor amounts to 2 %, according to the value recommended by the 2006 IPCC Guidelines.

Emissions from Ammonia Production have been calculated using the same methods and data sets for every year in the time series. Therefore, emissions from ammonia production have been estimated in a consistent manner throughout the time-series.

#### 4.3.1.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.3.1.5. Category-specific recalculations

There were no category-specific recalculations.

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[14] For example, in 2016, a part of $CO_2$ from feedstock-related natural gas use equals 510.22 kt $CO_2$-eq and a part of $CO_2$ from fuel-related use equals 340.6 kt $CO_2$-eq (excluding natural gas used in boilers). Data on $CO_2$ used for urea production equals 302.9 kt $CO_2$-eq. Therefore, in CRF 2.B.1. category, emission for 2016 was calculated by equation:

$CO_2$ (total in NIR IPPU) = $CO_2$(ETS 2.B.1) + $CO_2$(ETS 1.A.2.f) - $CO_2$ (urea application)

= 510.2 + 340.6 - 302.9 = 547.9 kt $CO_2$-eq

The remaining part (emission from boilers, 287 kt) of $CO_2$ emission is included in the Energy sector, 1.A.2.f.

#### 4.3.1.6. Category-specific planned improvements

In addition to $CO_2$ recovered being used as a feedstock in the production of urea and NPK fertilizers, there are some information on its use in dry ice production as well. However, there is no available information on the dry ice production process, and, for now, Croatia has no accurate information on where dry ice is applied (in the country or abroad). Since according to the 2006 IPCC Guidelines, the amount of $CO_2$ recovered from ammonia production used in freezing applications is not accounted for separately and because it should be assumed that all the $CO_2$ will be released in the producing country, currently $CO_2$ recovered for this use is not included in calculations. If additional resources will be available, this matter will be further investigated and it is currently specified as a long term plan for improvement.

### 4.3.2. Nitric acid production (2.B.2)

#### 4.3.2.1. Category description

There is one manufacturer of nitric acid in Croatia, with two units-plants, one of which has two production lines. In the production process, ammonia, which is used as a feedstock, is vaporized, mixed with air and burned over a platinum/rhodium alloy catalyst. Nitrogen monoxide (NO) is formed and oxidized to nitrogen dioxide ($NO_2$) at medium pressures and absorbed in water at high pressure to give nitric acid ($HNO_3$). During the oxidation stage, nitrous oxide ($N_2O$) is formed as a by-product and released from reactor vents into the atmosphere.

Both plants utilize dual-pressure production processes, i.e. the absorption stage takes place at a higher pressure than the oxidation stage.

Abatement technologies (Selective Catalytic Reduction-SCR) were installed in 2013 at Plant 1 (both production lines) and at Plant 2 at the end of 2012, which has resulted in a reduction of $N_2O$ emissions.

Since 2013, both plants are covered by EU ETS.

#### 4.3.2.2. Methodological issues

Methodology

- T3 (1990-2022)

Emissions of $N_2O$ from nitric acid production for the period 1990-2012 have been calculated using the Tier 3 method specified by the 2006 IPCC Guidelines, i.e. by multiplying annual nitric acid production by plant-specific EFs that are based on real measurement data. Abatement technologies were not used during that period, thus destruction factor and abatement system utilisation factor for abatement technology were not taken into consideration. In this way, emissions were calculated for both plants individually.

Since 2013, direct measurements of $N_2O$ emissions are being performed at both plants, along with the use of abatement technologies. Sum of measured emissions derived from the concentration of $N_2O$ in monitored emissions for each recorded monitoring interval is taken into account. Data on emissions and used methodologies, which are verified by independent accredited verifiers, are delivered to the Ministry of Economy and Sustainable Development as part of the annual emission report under the EU ETS. The Ministry then delivers these data to IPPU sector experts and all verified data are included in the inventory.

Global warming potential values from the IPCC Fifth Assessment Report (AR5) have been used in this submission.

Emission factors

- PS (1990-2022)

For the period 1990-2012, data on plant-specific EFs for each plant (7.5 kg $N_2O$/tonne nitric acid for Plant 1 and 7.8 kg $N_2O$/tonne nitric acid for Plant 2) have been obtained from the operator. These EFs were calculated based on a series of measurements performed in 1999 and confirmed by the ERT during the 2008 in-country review, after the analysis of information on technology and relevant parameters provided by the operator.

Data from more recent measurements (performed since 2013) cannot be used due to the application of abatement technologies in the recent years.

Since 2013, the operator uses continuous emission measurement systems for $N_2O$ emissions for both plants[15]. The principle for $N_2O$ measurement is non-dispersion infrared method (NDIR).

Activity data

Activity data is based on 100 % $HNO_3$. Data on nitric acid production is collected by a survey of manufacturer, who submitted the requested data to the Ministry of Economy and Sustainable Development, and which were then delivered to IPPU sector experts. Production quantities are determined by a mass flowmeter for plant 2, and by calculations from design production capacity and measured quantities of ammonia input for plant 1. Since 2013, together with data from verified emission reports, the Ministry also delivers completed questionnaires from the operator.

Reduction of $N_2O$ emissions since 2013 is a result of abatement technologies (see Table 4.3-2). The causes of the fluctuation in emissions were technical problems associated with the operation of the installed SCR (loss of catalyser and system reconstruction, as well as frequent shutdowns and start-ups of the plants).

Table 4.3-2: Nitric acid production and related emissions

| Year | Nitric acid production - TOTAL (kt) | $N_2O$ emission - TOTAL (kt) |
|---|---|---|
| 1990 | 332.5 | 2.5 |
| 1991 | 292.0 | 2.2 |
| 1992 | 381.8 | 2.9 |
| 1993 | 287.8 | 2.2 |
| 1994 | 311.2 | 2.4 |
| 1995 | 299.3 | 2.3 |
| 1996 | 278.7 | 2.1 |
| 1997 | 292.9 | 2.2 |
| 1998 | 220.5 | 1.7 |
| 1999 | 260.2 | 2.0 |
| 2000 | 306.2 | 2.3 |
| 2001 | 257.5 | 2.0 |
| 2002 | 250.0 | 1.9 |
| 2003 | 235.6 | 1.8 |

[15] All measurements are carried out applying methods based on the following standards: EN 14181 Stationary source emissions - Quality assurance of automated measuring systems, EN 15259 Air quality - Measurement of stationary source emissions - Requirements for measurement sections and sites and for the measurement objective, plan and report, and other corresponding EN standards.

| Year | Nitric acid production - TOTAL (kt) | $N_2O$ emission - TOTAL (kt) |
|---|---|---|
| 2004 | 287.6 | 2.2 |
| 2005 | 280.7 | 2.1 |
| 2006 | 277.6 | 2.1 |
| 2007 | 306.6 | 2.3 |
| 2008 | 312.9 | 2.4 |
| 2009 | 261.5 | 2.0 |
| 2010 | 336.8 | 2.6 |
| 2011 | 332.7 | 2.5 |
| 2012 | 288.2 | 2.2 |
| 2013 | 297.5 | 0.8 |
| 2014 | 307.3 | 0.9 |
| 2015 | 344.6 | 1.0 |
| 2016 | 293.3 | 0.4 |
| 2017 | 322.2 | 0.3 |
| 2018 | 289.5 | 0.2 |
| 2019 | 302.1 | 0.2 |
| 2020 | 293.8 | 0.2 |
| 2021 | 160.1 | 0.1 |
| 2022 | 45.3 | 0.05 |

In addition, emissions of $NO_x$ for the period until 2020 were taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'. Emissions were calculated using Tier 2 EMEP/EEA methodology. Since 1998, specific emission factors have been calculated from directly measured NOx emissions (occasional measurement) and annual production capacity. For the years in the period from 1990 to 1997, an average NOx emission factor was calculated based on the available direct NOx emissions.

#### 4.3.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to 2 %, based on information provided by the manufacturer. Uncertainty estimate associated with emission factors amounts to 20 % for 1990 and 2 % for 2022, based on expert judgements and information provided by the manufacturer (detailed in Annex 1).

Emissions from Nitric Acid Production have been calculated using the same method and data sets for the period 1990 – 2012 and direct measurements were taken into account since 2013.

#### 4.3.2.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.3.2.5. Category-specific recalculations

There were no category-specific recalculations.

#### 4.3.2.6. Category-specific planned improvements

There are no category-specific planned improvements.

### 4.3.3. Adipic acid production (2.B.3)

This category does not exist in Croatia.

### 4.3.4. Caprolactam, glyoxal and glyoxylic acid production (2.B.4)

This category does not exist in Croatia.

### 4.3.5. Carbide production (2.B.5)

This category does not exist in Croatia.

### 4.3.6. Titanium dioxide production (2.B.6)

This category does not exist in Croatia.

### 4.3.7. Soda ash production (2.B.7)

This category does not exist in Croatia.

### 4.3.8. Petrochemical and carbon black production (2.B.8)

#### 4.3.8.1. Category description

Petrochemicals are chemical products derived mostly from primary fossil fuels or petroleum refinery products. Although carbon black is not considered to be a petrochemical, petrochemical feedstock is used in its production. Most of the carbon contained in raw materials used in production is stored in products, but during the conversion processes, some carbon is emitted in the form of $CO_2$ or $CH_4$.

During the reporting period, production of petrochemicals – methanol, ethylene and ethylene dichloride (which was used to produce vinyl chloride monomer) was present in Croatia, together with production of carbon black.

Methanol, included in the sub-category 2.B.8.a, was produced during the whole time series. Ethylene (2.B.8.b) was produced in the period 1990-2011, ethylene dichloride (2.B.8.c) in the period 1990-2001 and carbon black (2.B.8.f) in the period 1990-2009. There was no production of other petrochemicals in Croatia during the reporting period.

Carbon black was produced by the furnace black process in one plant. For other petrochemicals, only nationally aggregated statistical data are available.

#### 4.3.8.2. Methodological issues

Methodology

*Methanol (2.B.8.a)*

Data on type of feedstock and processes used in methanol production in Croatia are currently not obtainable. Only aggregated production quantities are available from national statistics.

Since default feedstock in the IPCC Guidelines is natural gas, and since methanol production is not included in the energy balance under the "non-energy use" category (see Annex 4), to avoid double-counting, emissions from this sub-category were reported as IE in this submission and are considered to be included in the Energy sector.

*Ethylene (2.B.8.b)*

- $CO_2$, $CH_4$: T1 (1990-2011)

As in methanol production, data on the type of feedstock and processes used are currently not available. Only nationally aggregated production quantities are available.

Therefore, Tier 1 method (2006 IPCC Guidelines) is used for both $CO_2$ and $CH_4$ emissions calculations, where national ethylene production was multiplied by default emission factors.

Upon investigating national energy statistics, it was concluded that fuels that are likely used in ethylene production, as described in the 2006 IPCC Guidelines (which identify naphtha as a default feedstock in default steam cracking process), are not reported in national energy statistics, i.e. these emissions are not included in the Energy sector, thus double counting is avoided.

*Ethylene dichloride (2.B.8.c)*

- $CO_2$: T1 (1990-2001)

As in the production of above-given chemicals, data on the type of feedstock and processes used are currently not available. Only nationally aggregated production quantities of ethylene dichloride are available.

Therefore, Tier 1 method (2006 IPCC Guidelines) is used for $CO_2$ emission calculations, where national ethylene dichloride production was multiplied by a default emission factor for non-combustion related emissions.

According to the 2006 IPCC Guidelines, it may be assumed that non-combustion $CH_4$ emissions from ethylene dichloride production are negligible.

It is assumed that combustion-related emissions are included in the Energy sector.

*Carbon black (2.B.8.f)*

- $CO_2$: T2 (1990-2009)

$CO_2$ emissions from carbon black production were calculated using the mass balance-based Tier 2 method specified by the 2006 IPCC Guidelines. Only primary feedstock (hydrocarbon feedstock) is included in emissions calculation in this sector. Natural gas was used as a secondary feedstock but since its consumption is included in the national energy balance, $CO_2$ generated from its use is accounted for in the Energy sector. Moreover, there were no secondary products from this process. Taking into account the aforesaid, emissions for this sub-category were calculated as follows:

$$E_{CO2} = [(FA \times FC) - (PP \times PC)] \times 44/12$$

Where:

| | |
|---|---|
| $E_{CO2}$ | - emissions of $CO_2$ [t] |
| FA | - annual consumption of feedstock for carbon black production [t] |
| FC | - carbon content of feedstock [t C/t feedstock] |
| PP | - annual production of carbon black [t] |

| | |
|---|---|
| PC | - carbon content of carbon black [t C/t product] |
| 44/12 | - ratio of molecular weights, $CO_2$ to carbon |

Emission factors

*Ethylene (2.B.8.b)*

- $CO_2$, $CH_4$: D (1990-2011)

Default emission factors (2006 IPCC Guidelines) were used for emissions calculations.

For $CO_2$, default EF for process feedstock use (for default steam cracking ethylene production process) of 1.73 tonnes $CO_2$/tonne ethylene produced was used. Adjustment factor for Western Europe (100%) was applied.

For $CH_4$, default EF of 3 kg $CH_4$/tonne ethylene produced was used.

*Ethylene dichloride (2.B.8.c)*

- $CO_2$: D (1990-2001)

Default emission factor (2006 IPCC Guidelines) of 0.0057 tonne $CO_2$/tonne product was used for emissions calculations (balanced process; non-combustion process vent emissions).

*Carbon black (2.B.8.f)*

- $CO_2$: PS (1990-2009)

The Tier 2 methodology is based on mass balance calculations and therefore there are no emission factors associated with the methodology.

Activity data

Activity data (production quantities) for petrochemicals were obtained from national statistics.

All input data for carbon black, including annual quantities of hydrocarbon feedstock used and carbon black produced, as well as data on carbon content of both feedstock and product, were submitted by the manufacturer to the Ministry of Economy and Sustainable Development, and then delivered to IPPU sector experts. Hydrocarbon feedstock used consisted of highly aromatic oils obtained by secondary processing of petroleum and coal tar.

Annual production of chemicals (Table 4.3-3) and emissions of $CO_2$ and $CH_4$ from Petrochemical and Carbon Black Production (Table 4.3-4) are given below.

Table 4.3-3: Annual production of chemicals

| Year | Carbon black (kt) | Ethylene (kt) | Ethylene dichloride (kt) | Methanol (kt) |
|---|---|---|---|---|
| 1990 | 30.6 | 72.6 | 72.7 | 0.016 |
| 1991 | 18.8 | 66.9 | 68.3 | 0.016 |
| 1992 | 13.5 | 68.3 | 92.1 | 0.016 |
| 1993 | 17.1 | 68.6 | 79.6 | 0.016 |
| 1994 | 16.9 | 65.3 | 97.5 | 0.016 |

| Year | Carbon black (kt) | Ethylene (kt) | Ethylene dichloride (kt) | Methanol (kt) |
|---|---|---|---|---|
| 1995 | 27.2 | 67.5 | 84.4 | 0.012 |
| 1996 | 26.7 | 64.8 | 48.6 | 0.009 |
| 1997 | 24.2 | 63.6 | 26.3 | 0.013 |
| 1998 | 22.2 | 60.1 | 31.3 | 0.013 |
| 1999 | 17.6 | 60.3 | 47.7 | 0.013 |
| 2000 | 20.3 | 38.9 | 71.4 | 0.008 |
| 2001 | 21.4 | 46.6 | 64.4 | 0.006 |
| 2002 | 19.4 | 43.6 | NO | 0.008 |
| 2003 | 21.4 | 41.3 | NO | 0.004 |
| 2004 | 20.3 | 49.9 | NO | 0.004 |
| 2005 | 18.4 | 50.3 | NO | 0.003 |
| 2006 | 26.3 | 48.8 | NO | 0.003 |
| 2007 | 23.7 | 45.4 | NO | 0.002 |
| 2008 | 16.9 | 43.0 | NO | 0.002 |
| 2009 | 4.0 | 38.8 | NO | 0.001 |
| 2010 | NO | 36.3 | NO | 0.001 |
| 2011 | NO | 23.3 | NO | 0.002 |
| 2012 | NO | NO | NO | 0.003 |
| 2013 | NO | NO | NO | 0.001 |
| 2014 | NO | NO | NO | 0.001 |
| 2015 | NO | NO | NO | 0.001 |
| 2016 | NO | NO | NO | 0.001 |
| 2017 | NO | NO | NO | 0.001 |
| 2018 | NO | NO | NO | 0.002 |
| 2019 | NO | NO | NO | 0.001 |
| 2020 | NO | NO | NO | 0.0001 |
| 2021 | NO | NO | NO | 0.0003 |
| 2022 | NO | NO | NO | 0.001 |

Table 4.3-4: Emissions of $CO_2$ and $CH_4$ from Petrochemical and Carbon Black Production

| Year | Carbon black (t) | | Ethylene (t) | | Ethylene dichloride (t) | |
|---|---|---|---|---|---|---|
| | $CO_2$ (kt) | $CH_4$ (kt) | $CO_2$ (kt) | $CH_4$ (kt) | $CO_2$ (kt) | $CH_4$ (kt) |
| 1990 | 66.4 | NA | 125.7 | 0.2 | 0.4 | NA |
| 1991 | 39.0 | NA | 115.7 | 0.2 | 0.4 | NA |
| 1992 | 26.1 | NA | 118.2 | 0.2 | 0.5 | NA |
| 1993 | 37.2 | NA | 118.7 | 0.2 | 0.5 | NA |
| 1994 | 34.8 | NA | 112.9 | 0.2 | 0.6 | NA |
| 1995 | 65.0 | NA | 116.9 | 0.2 | 0.5 | NA |
| 1996 | 59.9 | NA | 112.1 | 0.2 | 0.3 | NA |
| 1997 | 45.3 | NA | 109.9 | 0.2 | 0.1 | NA |
| 1998 | 46.8 | NA | 104.1 | 0.2 | 0.2 | NA |
| 1999 | 32.6 | NA | 104.3 | 0.2 | 0.3 | NA |
| 2000 | 33.2 | NA | 67.3 | 0.1 | 0.4 | NA |
| 2001 | 22.0 | NA | 80.7 | 0.1 | 0.4 | NA |
| 2002 | 35.3 | NA | 75.3 | 0.1 | NO | NA |

| Year | Carbon black (t) | | Ethylene (t) | | Ethylene dichloride (t) | |
|---|---|---|---|---|---|---|
| | $CO_2$ (kt) | $CH_4$ (kt) | $CO_2$ (kt) | $CH_4$ (kt) | $CO_2$ (kt) | $CH_4$ (kt) |
| 2003 | 41.8 | NA | 71.4 | 0.1 | NO | NA |
| 2004 | 38.0 | NA | 86.3 | 0.1 | NO | NA |
| 2005 | 34.4 | NA | 87.0 | 0.2 | NO | NA |
| 2006 | 51.6 | NA | 84.5 | 0.1 | NO | NA |
| 2007 | 48.4 | NA | 78.6 | 0.1 | NO | NA |
| 2008 | 31.7 | NA | 74.5 | 0.1 | NO | NA |
| 2009 | 6.8 | NA | 67.1 | 0.1 | NO | NA |
| 2010 | NO | NO | 62.7 | 0.1 | NO | NA |
| 2011 | NO | NO | 40.3 | 0.1 | NO | NA |
| 2012 | NO | NO | NO | NO | NO | NA |
| 2013 | NO | NO | NO | NO | NO | NA |
| 2014 | NO | NO | NO | NO | NO | NA |
| 2015 | NO | NO | NO | NO | NO | NA |
| 2016 | NO | NO | NO | NO | NO | NA |
| 2017 | NO | NO | NO | NO | NO | NA |
| 2018 | NO | NO | NO | NO | NO | NA |
| 2019 | NO | NO | NO | NO | NO | NA |
| 2020 | NO | NO | NO | NO | NO | NA |
| 2021 | NO | NO | NO | NO | NO | NA |
| 2022 | NO | NO | NO | NO | NO | NA |

Emissions of $SO_2$, CO, $NO_x$ and NMVOC were taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'. Tier 2 EMEP/EEA methodology and Tier 2 emission factors were used for calculations.

#### 4.3.8.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data for $CO_2$ and $CH_4$ emissions for all chemicals amounts to 7.5 % (default, 2006 IPCC Guidelines).

Uncertainty estimate associated with default emission factors for $CO_2$ and $CH_4$ emissions for ethylene amounts to 10 % (default). Uncertainty estimate associated with default emission factor for $CO_2$ emission for ethylene dichloride is in the range from -20% to +10 % (default).

Uncertainty estimate associated with default emission factors for $CO_2$ emission for carbon black amounts to 15 % (default).

Emissions from Petrochemical and Carbon Black Production have been calculated using the same method and data sets for every year in the time series.

#### 4.3.8.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

Since none of the production-specific parameters are known, there is a possibility of overestimation of $CO_2$ emissions for ethylene produced from petroleum refining processes or from petrochemical processes other than steam crackers, which could be included in national production statistics, resulting in overestimation of emissions from steam cracker derived ethylene.

#### 4.3.8.5. Category-specific recalculations

There were no category-specific recalculations.

#### 4.3.8.6. Category-specific planned improvements

This sub-sector has been identified as a key category and not all of the estimates within this sub-sector use a tier 2 or higher approach. Data for using higher tier for petrochemicals are currently not available. Majority of production was halted several years ago, which has consequently decreased the possibility to collect data required for higher tier methodology. Croatia has recently reviewed this sub-sector and incorporated additional sources using what is believed to be the best currently available data. This matter is included in the Data collection plan, and, depending on the available resources, further investigation will be made. At the moment, this issue is categorised as a long-term plan for improvement.

### 4.3.9. Fluorochemical production (2.B.9)

This category does not exist in Croatia.

## 4.4. Metal industry (CRF 2.C)

### 4.4.1. Iron and steel production (2.C.1)

#### 4.4.1.1. Category description

During the reporting period, iron and steel production in Croatia included the following:

- production in a so-called integrated facility, which included the production of pig iron in blast furnace and the production of steel in open-hearth furnace (OHF) – during 1990 and 1991;
- production of steel in electric arc furnaces (EAF) in two so-called secondary facilities, which use steel/iron scrap as basic raw materials – during the whole time series, with interruptions in production, described in more detail below; and
- production of cast iron in three foundries in the cupola and electric induction furnaces – since 1997.

*Production of iron and steel in an integrated facility*

The production of pig iron was carried out until the end of 1991 when it was shut down due to the inability of iron ore delivery during the war, as well as a reduction and subsequently a cessation of the production of steel in OHF in the same year. Production in OHF was stopped as a result of general economic stagnation and the increasing difficulty of placing products obtained through the outdated process on the market.

Emissions from lime produced for the needs of pig iron production are included in sub-sector 2.A.2.

It should be noted that sinter and pellets required for the production of iron were being imported and their production was not present in Croatia. Also, there was no production of direct reduced iron.

*Production of steel in secondary facilities*

One plant was producing steel during the entire reporting period, with the exception of 2016. The second plant was active in the period 1990-2008 and in 2013 and 2014. Both plants used EAFs during the entire period, in which liquid steel was produced and then processed to finished products by casting and rolling.

Since 2013, during the periods of operation, both plants were covered by the EU ETS. There was no production of steel in Croatia during 2016.

Steel production in the last active plant was discontinued in December 2015 due to the crisis in the European steel market, i.e. the lack of orders. Production was restarted in 2017 but the plant was operating at a much reduced rate. Following the initial phase of plant recommissioning and the achievement of the target level of product quality, there was an increase in production. In 2018, due to favourable market conditions and rising steel prices, production begins to recover, which is reflected in emissions trends.

*Production of cast iron*

Three foundries producing grey and ductile cast iron are covered by the EU ETS since 2013. To some extent, data from these foundries are available for the period 1997-2012 (see chapter below for more detailed explanation).

There was no production of cast iron in 2022.

#### 4.4.1.2. Methodological issues

<u>Methodology</u>

*Steel (2.C.1.a)*

- T2 (1990-2012)
- T3 (2013-onward)

Only $CO_2$ emissions from EAFs are included in this sub-category.

For the OHF process, which was stopped almost three decades ago, there are no plant-specific data available other than steel production quantities. An OHF is typically charged with molten iron and scrap and oxygen is injected into the furnace, but reduction of carbon in the iron and melting of the charge also occurs by firing fossil fuels across the surface of the raw material bath. Since according to the 2006 IPCC Guidelines, carbon in the iron may be ignored because it has been accounted for as a source of carbon for iron-making, and since all fuels used in the OHF process are accounted for in the national energy balance (in the Energy sector), emissions from OHF are not included in this category. However, activity data, i.e. steel production in OHF, are included in the IPPU sector in this category since they cannot be accounted for in the Energy sector.

For steel produced in EAFs, $CO_2$ emissions result from the use of fuels and raw materials including reducing agents. In the casting, rolling and further processing of steel, $CO_2$ emissions stem from fuel used in various processing steps. All emissions from fuel used in this category are allocated to the Energy sector. Furthermore, since all quantities of coke and anthracite are also accounted for in the national energy balance, they are not included in this category (they are included in the Energy sector).

Emissions of $CO_2$ from EAFs for the period 1990-2012 have been calculated using the Tier 2 method of 2006 IPCC Guidelines (mass balance approach and material-specific carbon contents).

Therefore:

$$E_{CO2} = \left[\sum_{a}(MI_a \text{ x } C_a) - \sum_{b}(MO_b \text{ x } C_b)\right] \text{ x } 44/12$$

Where:

$E_{CO2}$ - emissions of $CO_2$ to be reported in IPPU Sector [t]

$MI_a$ - quantity of furnace input material *a* [t]

$C_a$ - carbon content of each furnace input material [t C/t]

$MO_b$ - quantity of furnace output material *b* [t]

$C_b$ - carbon content of each furnace output material [t C/t]

44/12 - ratio of molecular weights, $CO_2$ to carbon

In this way, emission was calculated for each plant separately.

Since 2013, data on emissions and used calculation methodologies, which are verified by independent accredited verifiers, are taken from the annual emission report under the EU emission trading system. Steel manufacturers for their emission calculation use the methodology which is comparable to Tier 3 methodology from the 2006 IPCC Guidelines. For the purpose of reporting under the IPPU sector, these verified emissions had to be adjusted for the input materials like coke and anthracite, which are also accounted for in the national energy balance, i.e. they are already included in the Energy sector. This adjustment has resulted in differences in the process emissions reported under the IPPU sector in NIR and under the EU ETS.

*Pig iron (2.C.1.b)*

- OTH (1990-1991)

Complete data sets for all plant-specific inputs and outputs in pig iron production are not available. Only partial data on inputs are available from national statistics (data on coke and coal used in pig iron production), together with data on limestone and dolomite consumption collected from the former manufacturer. Since all quantities of both coke and coal are accounted for in the Energy sector, only the emission from limestone and dolomite use are currently included in this sub-category in the IPPU sector.

$CO_2$ emission is calculated using the methodology for the calculation of emissions from process use of carbonates (2006 IPCC Guidelines, Volume 3, Ch.2; Tier 3 method), i.e. by multiplying emission factor for each carbonate (expressed in tonnes of $CO_2$ released per tonne of carbonate) and annual consumption (mass) of each carbonate used. Since the fraction calcination achieved for particulate carbonates is not known, it is assumed that the fraction calcination is equal to 1.00.

*Cast iron (2.C.1.f)*

- OTH (1997-onward)

Since 2013, iron foundries are included in the EU ETS. Data on emissions and used calculation methodologies, which are verified by independent accredited verifiers, are taken from the annual emission report under the EU ETS. The foundries for their emission calculation use the same approach as in $CO_2$ emissions calculation form EAFs (carbon mass balance), comparable to the Tier 3 from the 2006 IPCC Guidelines. Since there is no specified methodology for cast iron production in the 2006 IPCC Guidelines, the $CO_2$ emissions calculation method for this source is categorised as “other” (OTH).

For the period prior to the inclusion into ETS, only partial plant-specific data are currently available. Thus, emissions for 1997-2012 were calculated by using annual cast iron production as surrogate data, which was multiplied by arithmetic mean value of emissions to production ratio from the years 2013-2019.

Emission factors

*Steel (2.C.1.a)*

- PS, D (1990-2012)
- PS (2013-onward)

For steel produced in EAFs, $CO_2$ emissions result from the use of steel and iron scrap, fuels, reducing agents like coke, EAF charge carbon, anthracite, etc. and carbon electrodes, i.e. from the furnace input material in the above-given equation. Output material consists of the steel produced, technological waste, slag, EAF dust and scale.

For the period 1990-2012, all data on consumption of input material and quantities of output material were collected by a survey of manufacturers, who submitted the requested data to the Ministry of Economy and Sustainable Development, and which were then delivered to IPPU sector experts.

Data on the carbon content of each material used/produced were not available for one plant, thus default values from the 2006 IPCC Guidelines were used. For the second plant, plant-specific data on carbon contents were only partially available. Consequently, the Tier 3 approach could not be applied.

Since activity data for the years 1990 and 1991 include steel produced in OHF, this is reflected in the IEFs for those years.

*Pig iron (2.C.1.b)*

- D (1990-1991)

For $CO_2$ emission calculation, default values (2006 IPCC Guidelines, Volume 3, Ch.2) of carbon dioxide contents of carbonate species were used (0.43971 t $CO_2$/t $CaCO_3$ and 0.47732 t $CO_2$/t $CaMg(CO_3)_2$).

*Cast iron (2.C.1.f)*

- PS (1997-onward)

Since 2013, EFs were derived from the detailed information on the carbon content of inputs and outputs of the casting process. Calculations of verified emissions for all foundries include all data in accordance with EU-ETS requirements.

Prior to 2013, IEFs are estimated based on data from the period 2013-2019, as described above under the Methodology section.

Activity data

*Steel (2.C.1.a)*

Annual steel production in OHF has been obtained by a survey of former manufacturer and cross-checked with national statistics.

For the period prior to ETS inclusion, all data included in calculations for steel production in EAFs have been obtained from manufacturers, with the exception on carbon content data for some of the raw materials, products and waste materials for which default values were used.

For one plant, none of the plant-specific carbon content data were available.

For the second plant, for input materials: carbon electrodes, EAF charge carbon, scrap iron, petroleum coke and anthracite, default values were used. For input materials: scrap steel, C wire and pig iron, as well as for all output materials: steel, technological waste, slag, EAF dust and scale, laboratory analysis data on carbon content are available (for all years). For all other raw materials used (e.g. alloys: Fe-Si-Mn, Fe-V, Fe-Cr, Fe-Mo etc., and other additives like fluorite), carbon content was given in the certificate from the raw material manufacturer (without information on how carbon content was estimated).

Since 2013, calculations of verified emissions for both plants include all data in accordance with EU ETS requirements and Tier 3 methodology from the 2006 IPCC Guidelines.

*Pig iron (2.C.1.b)*

Data on pig iron production as well as data on carbonates consumption were collected from the pig iron manufacturer. The production was halted almost three decades ago, which has consequently decreased the possibility to collect more detailed data. Croatia has recently reviewed this sub-category and incorporated additional sources using what is believed to be the best currently available data.

*Cast iron (2.C.1.f)*

Since 2013, detailed information on quantities and carbon contents of inputs and outputs of the casting process are available.

For the period 1997-2012, only data on production of cast iron were collected in full so far. This matter is currently being investigated, and, as more comprehensive data become available, they will be included in calculations.

Activity data and summarised emissions from iron and steel production are given in Table 4.4-1.

Table 4.4-1: Activity data and $CO_2$ emissions from iron and steel production

| Year | Steel production – in EAFs (kt) | Steel production – in OHF (kt) | Pig iron production (kt) | Cast iron production (kt) | Total emissions from steel and iron production (kt) |
|---|---|---|---|---|---|
| 1990 | 171.1 | 253.2 | 209.3 | NO | 43.8 |
| 1991 | 119.7 | 94.2 | 68.8 | NO | 23.2 |
| 1992 | 101.9 | NO | NO | NO | 12.4 |
| 1993 | 74.1 | NO | NO | NO | 9.0 |
| 1994 | 63.4 | NO | NO | NO | 8.3 |
| 1995 | 45.4 | NO | NO | NO | 6.4 |
| 1996 | 45.8 | NO | NO | NO | 5.4 |
| 1997 | 69.9 | NO | NO | 2.7 | 8.7 |
| 1998 | 103.2 | NO | NO | 3.6 | 13.2 |
| 1999 | 75.9 | NO | NO | 3.5 | 9.3 |
| 2000 | 69.6 | NO | NO | 1.1 | 8.7 |
| 2001 | 56.2 | NO | NO | 3.6 | 6.2 |
| 2002 | 32.8 | NO | NO | 5.4 | 4.4 |
| 2003 | 40.9 | NO | NO | 5.4 | 5.6 |
| 2004 | 86.1 | NO | NO | 5.6 | 13.7 |
| 2005 | 73.6 | NO | NO | 5.2 | 12.7 |
| 2006 | 80.5 | NO | NO | 5.9 | 13.3 |
| 2007 | 76.3 | NO | NO | 7.1 | 13.7 |
| 2008 | 138.9 | NO | NO | 7.6 | 23.4 |
| 2009 | 46.3 | NO | NO | 9.7 | 4.8 |
| 2010 | 103.4 | NO | NO | 11.1 | 14.7 |
| 2011 | 95.9 | NO | NO | 13.8 | 16.6 |
| 2012 | 1.0 | NO | NO | 26.0 | 1.4 |
| 2013 | 111.0 | NO | NO | 27.7 | 13.9 |
| 2014 | 146.5 | NO | NO | 28.2 | 10.1 |

| Year | Steel production – in EAFs (kt) | Steel production – in OHF (kt) | Pig iron production (kt) | Cast iron production (kt) | Total emissions from steel and iron production (kt) |
|---|---|---|---|---|---|
| 2015 | 121.5 | NO | NO | 27.1 | 9.3 |
| 2016 | NO | NO | NO | 23.6 | 1.1 |
| 2017 | 3.9 | NO | NO | 29.6 | 1.9 |
| 2018 | 135.8 | NO | NO | 29.5 | 9.0 |
| 2019 | 69.1 | NO | NO | 26.3 | 4.9 |
| 2020 | 45.3 | NO | NO | 24.8 | 4.9 |
| 2021 | 185.1 | NO | NO | NO | 14.3 |
| 2022 | 169.1 | NO | NO | NO | 13.4 |

Emissions of $NO_x$, CO, NMVOC and $SO_2$ were taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'. This category includes only process emissions.

#### 4.4.1.3. Uncertainties and time-series consistency

Uncertainty estimate for steel production associated with activity data amounts to 10 % for 1990 and 5 % for 2022. Uncertainty estimate associated with emission factors amounts to 10 % for 1990 and 5 % for 2022, according to values from the 2006 IPCC Guidelines.

For pig iron, uncertainty for activity data amounts to 2 % and 5 % for EF (1990).

Emissions have been calculated using the same method and data sets for the period 1990-2012 and verified ETS reports data since 2013. Fluctuations in IEFs in steel production are present due to different quantities of various input materials used over the years (e.g. jump in 2014 is caused by new materials like Fe-Mn HC and C wire being introduced as carbon donors).

#### 4.4.1.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.4.1.5. Category-specific recalculations

There were no category-specific recalculations.

#### 4.4.1.6. Category-specific planned improvements

There are no planned improvements for this category.

### 4.4.2. Ferroalloys production (2.C.2)

#### 4.4.2.1. Category description

Ferroalloys are alloys of iron and metals such as silicon, manganese or chromium. Similar to emissions from the production of iron and steel, $CO_2$ is emitted when metallurgical coke is oxidized during a high-temperature reaction with iron and the selected alloying element.

There were two factories producing ferroalloys in Croatia. One factory ceased its production in 1994, while the second factory stayed in operation until 2003.

Only nationally aggregated statistical data on production quantities are available.

#### 4.4.2.2. Methodological issues

Methodology

- T1 (1990-2003)

Emissions of $CO_2$ and $CH_4$ from ferroalloys production have been calculated using Tier 1 method (2006 IPCC Guidelines), i.e. by multiplying an annual production of each type of ferroalloys (ferromanganese, siliconmanganese and ferrochromium) by related emission factors.

Data needed for the Tier 2 approach are incomplete. As a result, Tier 1 methodology was used for the entire period.

Croatia recognizes the likelihood of double-counting of emissions from this category because the consumption of some of the reducing agents is included in the national energy balance, i.e. resulting emissions are already accounted for in the Energy sector. However, since data on amounts of these reducing agents consumed in ferroalloys production is lacking, it is not possible to subtract these emissions from IPPU sector (for more details see chapters 3.1.1. and 4.4.2.6).

Emission factors

- D (1990-2003)

Generic emission factors (default, 2006 IPCC Guidelines) of 1.3 t $CO_2$/t ferromanganese, 1.4 t $CO_2$/t siliconmanganese, 1.3 t $CO_2$/t ferrochromium and 1.2 t $CH_4$/t ferroalloys were used.

Activity data

Annual production of ferroalloys (see Table 4.4-2) was extracted from statistical reports published by the Central Bureau of Statistics. Ferroalloys production fluctuated over the years. It is mainly a result of discontinuous operations, caused by the war in Croatia.

Apart from data on production, only data on the consumption of reducing agents coke from coal and coal electrodes in ferroalloys production for 1990-1996 are available from national statistics. After this period, national classification of activities does not distinguish the use of these materials in ferroalloys production.

It should be noted that ferroalloys production was halted in 2003, which has subsequently decreased the possibility to further investigate this category and use higher tier approach.

Table 4.4-2: Ferroalloys production

| Year | Ferroalloys production (t) | | |
|---|---|---|---|
| | Ferromanganese | Silicon manganese | Ferrochromium |
| 1990 | 20,535 | 48,561 | 60,859 |
| 1991 | 13,053 | 38,365 | 72,845 |
| 1992 | 0 | 25,572 | 56,058 |
| 1993 | 0 | 8,577 | 28,028 |
| 1994 | 562 | 22,071 | 31,704 |
| 1995 | 0 | 0 | 26,081 |
| 1996 | 0 | 0 | 10,559 |
| 1997 | 47 | 416 | 24,231 |
| 1998 | 57 | 697 | 11,861 |
| 1999 | 64 | 271 | 13,807 |
| 2000 | 29 | 330 | 15,753 |
| 2001 | 43 | 297 | 361 |
| 2002 | 28 | 190 | 2 |
| 2003 | 62 | 660 | 2 |

Emissions of $CO_2$ and $CH_4$ from Ferroalloys production are presented in the Table 4.4-3.

Table 4.4-3: Emissions of $CO_2$ and $CH_4$ from Ferroalloys production

| Year | $CO_2$ emissions (kt) | | | $CH_4$ emissions (kt) |
|---|---|---|---|---|
| | Ferromanganese | Silicon manganese | Ferrochromium | Ferroalloys (total) |
| 1990 | 26.70 | 67.99 | 79.12 | 0.156 |
| 1991 | 16.97 | 53.71 | 94.70 | 0.149 |
| 1992 | 0.00 | 35.80 | 72.88 | 0.098 |
| 1993 | 0.00 | 12.01 | 36.44 | 0.044 |
| 1994 | 0.73 | 30.90 | 41.22 | 0.065 |
| 1995 | 0.00 | 0.00 | 33.91 | 0.031 |
| 1996 | 0.00 | 0.00 | 13.73 | 0.013 |
| 1997 | 0.06 | 0.58 | 31.50 | 0.030 |
| 1998 | 0.07 | 0.98 | 15.42 | 0.015 |
| 1999 | 0.08 | 0.38 | 17.95 | 0.017 |
| 2000 | 0.04 | 0.46 | 20.48 | 0.019 |
| 2001 | 0.06 | 0.42 | 0.47 | 0.001 |
| 2002 | 0.04 | 0.27 | 0.00 | 0.000 |
| 2003 | 0.08 | 0.92 | 0.00 | 0.001 |

### 4.4.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to 10 % and uncertainty estimate associated with default emission factors amounts to 25 %, according to values given in the 2006 IPCC Guidelines.

Emissions from Ferroalloys Production have been calculated using the same method and data sets for every year in the time series.

#### 4.4.2.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.4.2.5. Category-specific recalculations

There are no source-specific recalculations in this report.

#### 4.4.2.6. Category-specific planned improvements

All input data in this category were investigated to the extent it was currently possible. Ferroalloys production in Croatia was halted over 15 years ago, which makes it highly unlikely to collect more detailed activity data required for higher tier approach. Thus, it has been concluded that there is no realistic possibility for improvements in this category under the current circumstances.

However, the Annual data collection plan will continue to include this information, as it has hitherto been the case, and should additional data become available in the future, a further investigation of this category would be made.

### 4.4.3. Aluminium production (2.C.3)

#### 4.4.3.1. Category description

Primary aluminium is produced in two steps. First, bauxite ore is ground, purified and calcined to produce alumina ($Al_2O_3$). The alumina is then electrically reduced to aluminium by smelting in large pots. This process results in the emission of several greenhouse gases including $CO_2$, and two PFCs: $CF_4$ and $C_2F_6$.

Primary aluminium production in Croatia was halted in 1991.

Two types of technologies were applied in Croatia: prebaked anodes with side feed and prebake anodes with central feed. Total of 208 open furnaces with prebaked anodes and side feed (Alusuisse technology) were used (without computer-controlled process). In September 1990, 10 new closed furnaces were put in operation (Peciney technology), with central feed and computer-controlled process.

Apart from the abovementioned primary aluminium production, one plant manufactures aluminium castings by the pressure injection process. It does not deal with primary or secondary aluminium production. Therefore, there are no emissions of F-gases (PFC and HFC) or sulphur hexafluoride ($SF_6$) from this plant.

#### 4.4.3.2. Methodological issues

Methodology

- T1 (1990-1991)

The quantity of $CO_2$ released was estimated using the Tier 1 approach of the 2006 IPCC Guidelines (by multiplying annual primary aluminium production by a default emission factor).

PFCs emissions from Aluminium Production could represent a significant source of emissions due to high GWP values. Since only aluminium production statistics were available, emissions of $CF_4$ (PFC-14) and $C_2F_6$ (PFC-116) were estimated by multiplying annual primary aluminium production by default emission factors provided by the 2006 IPCC Guidelines. Regardless of the two different types of technologies applied in Croatia: prebaked anodes with side feed and prebaked anodes with central feed, emissions were not estimated separately for different technologies, since AD were provided in the aggregated form. Thus, only EFs for side worked prebaked anodes were taken into consideration.

Emissions of $SO_2$, CO, $NO_x$ and NMVOC have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'. Tier 2 EMEP/EEA methodology and Tier 2 emission factors were used for calculations.

Emission factors

- D (1990-1991)

The default emission factor of 1.6 tonnes $CO_2$ per tonne of aluminium for Prebake technologies is used (2006 IPCC Guidelines).

In addition, used emission factors equal 1.6 kg/t Al for $CF_4$ and 0.4 kg/t Al for $C_2F_6$, according to default values from 2006 IPCC Guidelines.

Activity data

Data on production processes and technologies were subsequently officially requested from the Croatian Chamber of Economy and obtained through direct communication with the former factory representative.

Activity data and emissions from this source are given in Table 4.4-4.

Table 4.4-4: Primary aluminium production and resulting emissions

| Year | Primary aluminium production (kt) | $CO_2$ emissions (kt) | $CF_4$ emissions (t) | $C_2F_6$ emissions (t) |
|---|---|---|---|---|
| 1990 | 74.2 | 118.8 | 118.8 | 29.7 |
| 1991 | 50.9 | 81.5 | 81.5 | 20.4 |

#### 4.4.3.3. Uncertainties and time-series consistency

Uncertainties related to the calculation of $CO_2$ emissions are primarily due to applied emission factor. A less uncertain method to calculate $CO_2$ emissions would be based upon the amount of reducing agent, i.e. amount of prebaked anodes used in the process but this information was not available. Nevertheless, it is very likely that use of the technology-specific emission factor, provided in the 2006 IPCC Guidelines, along with the correct production data produce accurate estimates.

Uncertainty estimate associated with activity data for $CO_2$ emissions amounts to 2 % and uncertainty estimate associated with default emission factor for $CO_2$ emissions amounts to 10 %, according to values given in the 2006 IPCC Guidelines.

Greater uncertainties are related to calculation of PFCs emissions because continuous emission monitoring was not carried out, and smelter-specific operating parameters were not available. Default emission factors were therefore applied to calculate PFCs emissions.

Uncertainty estimate associated with activity data for PFCs emissions amounts to 2 %, while the uncertainty of EFs (default, 2006 IPCC Guidelines) is in the range from -40% to +150%.

Emissions from Aluminium Production have been calculated using the same method and data sets for every year in the time series.

#### 4.4.3.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.4.3.5. Category-specific recalculations

There were no category-specific recalculations.

#### 4.4.3.6. Category-specific planned improvements

Primary aluminium production (electrolysis) was shut down almost 3 decades ago, mainly due to war activities, which makes it highly unlikely to collect more detailed activity data required for higher tier methodology. Thus, it has been concluded that there is no realistic possibility for improvements in this category under the given circumstances.

However, the Annual data collection plan will continue to include this information, as it has hitherto been the case, and should additional data become available in the future, a further investigation of this category would be made.

### 4.4.4. Magnesium production (2.C.4)

This category does not exist in Croatia.

### 4.4.5. Lead production (2.C.5)

This category does not exist in Croatia.

### 4.4.6. Zinc production (2.C.6)

This category does not exist in Croatia.

## 4.5. Non-energy products from fuels and solvent use (CRF 2.D)

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

#### 4.5.1.1. Category description

$CO_2$ emissions arising from the use of lubricants (oils and greases) in engines are considered to be non-combustion emissions and should be reported in the IPPU sector.

Consumption of lubricants was taken from the national energy balance. Consumption in 2-stroke engines is deducted from total lubricant use, which is included in the energy balance under the “non-energy use” category.

#### 4.5.1.2. Methodological issues

Methodology

- T1 (1990-2022)

Emissions of $CO_2$ from lubricant use have been calculated using Tier 1 method (2006 IPCC Guidelines), by multiplying total annual consumption of lubricants by a default emission factor.

There are no detailed data available on the quantities consumed per type of lubricant use. In addition, there are no country-specific EFs for 2.D.1 category. Therefore, higher tier could not be applied.

Emission factors

- D (1990-2022)

Emission factor is composed of a specific carbon content factor (CC) multiplied by the fraction of lubricants oxidized during use (ODU factor). A further multiplication by 44/12 (the mass ratio of $CO_2$/C) yields the emission factor (expressed as tonne $CO_2$/TJ).

Having only total consumption data for all lubricants, an overall (default) ODU factor of 0.2 was used, together with a default CC factor (20.0 t C/TJ on a Lower Heating Value basis).

In addition, a country-specific NCV of 33.5 TJ/Gg of lubricants, which was determined by the Energy Institute Hrvoje Požar[16], was used for calculations.

Activity data

Annual consumption of lubricants was extracted from the national energy balance, from which consumption in 2-stroke engines was deducted.

Annual consumption of lubricants in the scope of the 2.D.1 category and related emissions are given in Table 4.5-1.

Table 4.5-1: Consumption of lubricants and emissions of $CO_2$ from Lubricant use

| Year | Consumption of lubricants (kt) | $CO_2$ emissions from lubricants use (kt) |
|---|---|---|
| 1990 | 63.53 | 31.22 |
| 1991 | 51.83 | 25.47 |
| 1992 | 30.73 | 15.10 |
| 1993 | 30.23 | 14.85 |
| 1994 | 30.83 | 15.15 |
| 1995 | 31.43 | 15.44 |
| 1996 | 32.03 | 15.74 |
| 1997 | 32.73 | 16.08 |
| 1998 | 33.53 | 16.47 |
| 1999 | 33.32 | 16.37 |
| 2000 | 29.82 | 14.65 |
| 2001 | 30.92 | 15.19 |
| 2002 | 33.42 | 16.42 |

[16]The Energy Institute is in charge of national energy statistics, analysis of energy flows, data collection and development of national energy balance. As part of the emissions calculation improvement project conducted in 2020, the analysis of operations of the two Croatian refineries concluded that it is not possible to increase NCV for lubricants because such a correction would lead to a disturbed ratio of input and output energy in refineries in some years.

| Year | Consumption of lubricants (kt) | $CO_2$ emissions from lubricants use (kt) |
|---|---|---|
| 2003 | 28.82 | 14.16 |
| 2004 | 39.21 | 19.27 |
| 2005 | 35.21 | 17.30 |
| 2006 | 37.90 | 18.62 |
| 2007 | 44.88 | 22.05 |
| 2008 | 38.66 | 18.99 |
| 2009 | 37.06 | 18.21 |
| 2010 | 32.96 | 16.19 |
| 2011 | 33.02 | 16.23 |
| 2012 | 29.32 | 14.41 |
| 2013 | 28.33 | 13.92 |
| 2014 | 29.43 | 14.46 |
| 2015 | 31.83 | 15.64 |
| 2016 | 34.14 | 16.77 |
| 2017 | 33.54 | 16.48 |
| 2018 | 33.94 | 16.68 |
| 2019 | 35.15 | 17.27 |
| 2020 | 34.55 | 16.98 |
| 2021 | 35.05 | 17.22 |
| 2022 | 37.66 | 18.50 |

#### 4.5.1.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data for $CO_2$ emissions from the consumption of all types of lubricants amounts to 5 %, taking into account the presumed very low use of lubricants for 2-stroke engines. Uncertainty estimate associated with default $CO_2$ emission factors for all types of lubricants amounts to 50 %. Uncertainties have been estimated according to recommended default values from the 2006 IPCC Guidelines.

#### 4.5.1.4. Category-specific QA/QC and verification

Activities related to category-specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.5.1.5. Category-specific recalculations

There were no recalculations for this category.

#### 4.5.1.6. Category-specific planned improvements

There are no source-specific improvements planned for this category.

### 4.5.2. Paraffin wax use (2.D.2)

#### 4.5.2.1. Category description

Paraffin waxes are produced from crude oil and used in a number of applications such as the production of candles, paper coating, food production, etc. Emissions of $CO_2$ in this category primarily occur when the waxes or derivates of paraffins are combusted during their use.

Data on paraffin wax use were extracted from the national energy balance.

#### 4.5.2.2. Methodological issues

Methodology

- T1 (1990-2022)

Emissions of $CO_2$ have been calculated using Tier 1 method of the 2006 IPCC Guidelines, by multiplying total annual consumption of paraffin wax by related default emission factor and default ODU factor.

Emission factors

- D (1990-2022)

Default carbon content (CC) factor of paraffin wax (20.0 t C/TJ on a Lower Heating Value basis), default Oxidised During Use (ODU) factor (0.2) and mass ratio of $CO_2$/C (44/12) have been used for $CO_2$ emission calculation for the entire reporting period.

In addition, a country-specific NCV of 40.2 TJ/Gg was used, which was determined by the Energy Institute Hrvoje Požar.

Activity data

Annual consumption of paraffin wax was extracted from the national energy balance. Activity data and emissions of $CO_2$ from Paraffin Wax Use are given in Table 4.5-2.

Table 4.5-2: Consumption of paraffin wax and related $CO_2$ emissions

| Year | Consumption of paraffin wax (kt) | $CO_2$ emissions from paraffin wax use (kt) |
|---|---|---|
| 1990 | 17.60 | 10.37 |
| 1991 | 14.40 | 8.49 |
| 1992 | 8.50 | 5.01 |
| 1993 | 8.30 | 4.89 |
| 1994 | 8.60 | 5.07 |
| 1995 | 8.70 | 5.13 |
| 1996 | 8.90 | 5.25 |
| 1997 | 9.10 | 5.36 |
| 1998 | 9.20 | 5.42 |
| 1999 | 9.80 | 5.78 |
| 2000 | 10.50 | 6.19 |
| 2001 | 10.00 | 5.89 |
| 2002 | 9.80 | 5.78 |
| 2003 | 11.30 | 6.66 |
| 2004 | 10.80 | 6.37 |
| 2005 | 11.00 | 6.48 |
| 2006 | 11.10 | 6.54 |
| 2007 | 10.90 | 6.43 |
| 2008 | 9.50 | 5.60 |
| 2009 | 9.10 | 5.36 |

| Year | Consumption of paraffin wax (kt) | $CO_2$ emissions from paraffin wax use (kt) |
|---|---|---|
| 2010 | 7.90 | 4.66 |
| 2011 | 7.70 | 4.54 |
| 2012 | 6.20 | 3.65 |
| 2013 | 5.80 | 3.42 |
| 2014 | 7.00 | 4.13 |
| 2015 | 7.70 | 4.54 |
| 2016 | 7.90 | 4.66 |
| 2017 | 7.70 | 4.54 |
| 2018 | 6.40 | 3.77 |
| 2019 | 6.00 | 3.54 |
| 2020 | 5.60 | 2.75 |
| 2021 | 5.50 | 2.70 |
| 2022 | 6.90 | 3.39 |

#### 4.5.2.3. Uncertainties and time-series consistency

Uncertainty estimate for CRF 2.D.2 is in accordance with the 2006 IPCC Guidelines. The total uncertainty of the EF used equals 50 %, and the uncertainty of activity data is set to 5 %.

#### 4.5.2.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.5.2.5. Category-specific recalculations

There were no recalculations for this category.

#### 4.5.2.6. Category-specific planned improvements

There are no source-specific improvements planned for this category.

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

#### 4.5.3.1. Category description

This category includes the following sub-categories:

- Solvent use
- Road paving with asphalt
- Asphalt roofing
- Urea based catalytic converters

#### 4.5.3.2. Methodological issues

<u>Methodology</u>

*Solvent use*

- OTH (1990-2022)

Emissions of NMVOC were taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'.

The following sources are included in the NMVOC emissions estimations:

- Domestic solvent use including fungicides (NFR 2.D.3.a)[17]
- Coating applications (NFR 2.D.3.d)[18]
- Degreasing (NFR 2.D.3.e)[19]
- Dry cleaning (NFR 2.D.3.f)
- Chemical products (NFR 2.D.3.g)[20]
- Printing (NFR 2.D.3.h)
- Other solvent use (NFR 2.D.3.i)[21]

NMVOC emissions within the scope of the aforementioned CLRTAP submission have been calculated using Tier 1 (for coating applications, printing, and polyester and PVC processing within the Chemical products category) or Tier 2 (other source categories) methods, according to the EMEP/EEA methodology (EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2023).

$CO_2$ emissions from Solvent Use are calculated using a conversion factor, which contains a ratio C/NMVOC = 0.6 (2006 IPCC Guidelines, Volume 3, p. 5.17, default fossil carbon content fraction of NMVOC is 60 % by mass), and mass ratio of $CO_2$/C (44/12). Thus, the overall conversion factor of 2.2 was used for the whole time series.

*Road paving with asphalt and Asphalt roofing*

- OTH (1990-2022)

Emissions of NMVOC are taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'.

The approach for emission estimation for Asphalt roofing is based on the Tier 1, and for Road paving with asphalt Tier 2 method, according to the EMEP/EEA 2023 methodology.

Default fossil carbon content fraction of NMVOC from asphalt production and use for road paving varies between 40 to 50 % by mass (average value of 45 % is used) and is about 80 % for NMVOC from

[17] Croatian inventory stratifies the following solvent-containing products use: cosmetics and toiletries products, car care products, paint/varnish removers and solvents, sealants, filling agents, pesticides, and domestic use of pharmaceutical products.

[18] Refers to paints used within the industrial and domestic sectors.

[19] Degreasing is a process for cleaning products from water-insoluble substances as grease, fats, oils, waxes, carbon deposits, fluxes and tars. In most cases the process is applied to metal products, but also plastic, fiberglass, printed circuit boards and other products are treated by the same process.

[20] This source category includes activities: processing of polyester, PVC, polyurethane, polystyrene and rubber, manufacturing of pharmaceutical products, manufacturing of paints, inks, glues, adhesives, magnetic tapes, films and photographs, and asphalt blowing. Almost all activities still exist in Croatia, except for rubber manufacturing, polystyrene processing and asphalt blowing, which were shut down in 2006, 2011 and 2014, respectively.

[21] The following activities are present in Croatia: oil extraction, application of glues and adhesives, wood preservation, car dewaxing and concrete additive use. Glass wool and Mineral wool enduction, as well as underseal treatment and conservation of vehicles are not present in Croatia.

asphalt roofing (given in the 2006 IPCC Guidelines, as calculated from the NMVOC speciation provided in the EMEP/EEA Emission Inventory Guidebook). These default values, together with mass ratio of $CO_2/C$ (44/12), were used in $CO_2$ emissions calculations. Thus, conversion factors of 1.65 for road paving (0.45*44/12) and 2.93 (0.8*44/12) for asphalt roofing were used.

Detailed information on emissions trends for each category are available in the document 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'.

*Urea based catalytic converters*

- T1 (2000-2022)

This source category encompasses $CO_2$ emissions from the use of urea containing in diesel engines with SCR-catalysts in road transportation (Euro V/VI).

Emissions of $CO_2$ from urea-based catalytic converters were calculated by multiplying the amount of urea-based additive consumed for use in catalytic converters by mass fraction of urea in the urea-based additive (Equation 3.2.2, Volume 2 of the 2006 IPCC Guidelines). As this is based on the properties of the materials used, there are no tiers for this source, but for reporting purposes, the method used is categorised as "Tier 1".
Emissions from 1990 to 1999 do not occur because urea-based catalytic converters were introduced after 2000.

<u>Emission factors</u>

*Solvent use*

- D (1990-2022)

Default emission factors (EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2023), taking into account the implementation of abatement technology where applicable, were applied for source categories for NMVOC emissions.

$CO_2$ emissions from Solvent Use are calculated using a conversion factor as described under the Methodology section above.

*Road paving with asphalt and Asphalt roofing*

- D (1990-2022)

The recommended Tier 1/Tier 2 emission factors from the EMEP/EEA 2023 Guidebook were used for NMVOC emissions, taking into account the implementation of abatement technology where applicable.

$CO_2$ emissions are calculated using a conversion factor as described under the Methodology section above.

*Urea based catalytic converters*

- D (2000-2022)

The factor of 12/60 that captures the stoichiometric conversion from urea ($CO(NH_2)_2$) to carbon and factor of 44/12 that converts carbon to $CO_2$ were applied, according to the 2006 IPCC Guidelines, Volume 2, Ch. 3.

Also, the default value for purity (32.5 %) was included in the $CO_2$ emission calculation.

Activity data

For some of the source categories (domestic use of pharmaceutical products), NMVOC emissions estimate is based on population data. The activity data for other sources were extracted from statistical reports or were obtained from manufacturers.

Since the category Solvent use cannot be unified in terms of quantifying the activity data using the same unit, the 'Not Estimated' notation key was used in the reporting tables for this category.

Data on total diesel fuel consumed in road transportation, taken from the national energy balance, were used for emissions estimation for Urea Based Catalytic Converters.

The resulting emissions of $CO_2$ from this source category are presented in the Table 4.5-3.

Table 4.5-3: Emissions of $CO_2$ from Other source category

| Year | $CO_2$ emission from Solvent Use (kt) | $CO_2$ emission from Road paving (kt) | $CO_2$ emission from Asphalt roofing (kt) | $CO_2$ emission from Urea Based Catalytic Converters (kt) |
|---|---|---|---|---|
| 1990 | 139.9 | 0.015 | 0.009 | NO |
| 1991 | 89.1 | 0.011 | 0.006 | NO |
| 1992 | 53.7 | 0.003 | 0.005 | NO |
| 1993 | 50.3 | 0.002 | 0.005 | NO |
| 1994 | 52.9 | 0.019 | 0.005 | NO |
| 1995 | 92.4 | 0.020 | 0.006 | NO |
| 1996 | 83.8 | 0.025 | 0.007 | NO |
| 1997 | 59.6 | 0.038 | 0.002 | NO |
| 1998 | 57.9 | 0.037 | 0.004 | NO |
| 1999 | 52.3 | 0.040 | 0.005 | NO |
| 2000 | 53.3 | 0.036 | 0.009 | 2.7 |
| 2001 | 54.2 | 0.028 | 0.004 | 2.9 |
| 2002 | 65.8 | 0.054 | 0.004 | 3.3 |
| 2003 | 67.4 | 0.084 | 0.009 | 3.9 |
| 2004 | 79.9 | 0.099 | 0.009 | 4.2 |
| 2005 | 84.0 | 0.089 | 0.017 | 4.6 |
| 2006 | 93.8 | 0.082 | 0.028 | 5.0 |
| 2007 | 94.4 | 0.081 | 0.018 | 5.5 |
| 2008 | 97.1 | 0.106 | 0.010 | 5.3 |
| 2009 | 67.9 | 0.080 | 0.009 | 5.3 |
| 2010 | 63.6 | 0.054 | 0.007 | 5.2 |
| 2011 | 58.3 | 0.063 | 0.006 | 5.2 |
| 2012 | 55.5 | 0.062 | 0.004 | 5.1 |
| 2013 | 47.9 | 0.068 | 0.006 | 5.3 |
| 2014 | 42.7 | 0.057 | 0.005 | 5.3 |
| 2015 | 41.9 | 0.053 | 0.015 | 5.8 |
| 2016 | 45.4 | 0.054 | 0.007 | 6.1 |
| 2017 | 41.7 | 0.053 | 0.011 | 6.9 |
| 2018 | 51.7 | 0.063 | 0.006 | 6.6 |
| 2019 | 63.7 | 0.065 | 0.007 | 7.0 |
| 2020 | 59.5 | 0.058 | 0.007 | 6.3 |
| 2021 | 53.3 | 0.067 | 0.008 | 6.7 |
| 2022 | 43.8 | 0.064 | 0.008 | 7.3 |

#### 4.5.3.3. Uncertainties and time-series consistency

*Solvent use*

Uncertainty estimate associated with default emission factors for $CO_2$ emissions calculation amounts to 50 % (default 2006 IPCC Guidelines value).

*Road paving with asphalt and Asphalt roofing*

Uncertainty estimate associated with activity data (statistical data) for NMVOC emissions calculation amounts to 10 %. Uncertainty estimate associated with default emission factors for $CO_2$ emissions calculation amounts to 50 %. Default 2006 IPCC Guidelines values are taken into account.

*Urea based catalytic converters*

Uncertainty estimate associated with activity data for $CO_2$ emissions calculation amounts to 5 % (default, 2006 IPCC Guidelines). Uncertainty estimate associated with default emission factors for $CO_2$ emissions calculation amounts to 5 %, based on expert judgement.

#### 4.5.3.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates according to the 2006 IPCC Guidelines. Furthermore, documenting and archiving all input data and information relevant for the calculation of emissions is ensured.

#### 4.5.3.5. Category-specific recalculations

$CO_2$ emissions from Solvent use (Printing activity) were recalculated for the entire time series due to data harmonization with the IIR.

#### 4.5.3.6. Category-specific planned improvements

There are no planned category-specific improvements.

## 4.6. Electronics industry (CRF 2.E)

According to current understanding, this category does not exist in Croatia. Additional research is underway and any new information about this category will be included in the next report.

## 4.7. Product uses as substitutes for ODS (2.F)

Global warming potential values from the IPCC Fifth Assessment Report (AR5) have been used in this submission.

### 4.7.1. Refrigeration and air conditioning (2.F.1)

#### 4.7.1.1. Category description

The use of HFCs in refrigeration and air conditioning systems began in the early 1990s, shortly after the adoption of the Montreal Protocol. Refrigeration and air conditioning systems can be divided into six areas of application:

- commercial refrigeration,
- domestic refrigeration,
- industrial refrigeration and heat pumps,
- transport refrigeration,
- mobile air conditioning,
- stationary air conditioning including heat pumps.

PFCs have never been used in the refrigeration and air Conditioning sector in Croatia.

HFCs used in **commercial refrigeration** are HFC-134a and HFC-404A in smaller stand-alone refrigerators and freezers in stores and supermarkets and HFC-404A in larger capacity installations.

The Regulation (EU) No 517/2014 on fluorinated greenhouse gases (Annex III) prohibits the placing on the market of **domestic refrigeration** products filled with refrigerants with GWP > 150 since 2015. Prior to 2015, the refrigerant HFC-134a was mostly used in household refrigerators, while today only R-600a hydrocarbon is used. Domestic refrigerators with R-600a were on the market since 2000. First application was recorded in 1995. There was one manufacturer of household refrigerators and freezers in Croatia, however, for the last thirty years the appliances have not been produced in the country but only imported, adapted (but not filled) and sold domestically or exported. For this reason, all refrigerators are considered to be imported.

**Industrial refrigeration** in the food, petrochemical, pharmaceutical and other industries includes refrigerants HFC-404A, HFC-407F, HFC-417A, HFC-422D, HFC-507A and R-23.

For the **transport** of refrigerated goods, vans with a capacity of up to 3.5 t in most cases use HFC-134a, and to a lesser extent HFC-404A. Trucks with a capacity of over 3.5 t mostly use HFC-404A, and to a lesser extent HFC-134a, while in refrigeration units of semi-trailers of over 10 t only HFC-404A is used. There is only import and no production of commercial vehicles in Croatia.

**Mobile air conditioning** inside passenger cabins in vehicles is performed by air conditioning systems filled with HFC-134a. There is only import and no production of cars in Croatia.

**Stationary air conditioning** systems include smaller split, multisplit and VRF (variable refrigerant flow) systems, water chillers (with volumetric and turbo compressors) and heat pumps. HFCs used in these devices are HFC-410A, HFC-407C, R-134a and recently HFC-32 only for the so-called single split systems, and hydrocarbon R-290 in smaller heat pumps.

#### 4.7.1.2. Methodological issues

<u>Methodology</u>

*Commercial refrigeration (2.F.1.a)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of commercial refrigerators is assumed to be 15 years, in accordance with Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. The use of both HFCs for this purpose was first recorded in 1995.

*Domestic refrigeration (2.F.1.b)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of household refrigerators is 15 years according to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL.

*Industrial refrigeration (2.F.1.c)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of industrial refrigerators is assumed to be 25 years, in accordance to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. The use of HFC-404A and HFC-417A was first recorded in 1995, use of HFC-422D in 1998, HFC-407F in 2003, HFC-507A in 2007, and R-23 in 2015.

*Transport refrigeration (2.F.1.d)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of air conditioning systems is assumed to be 10 years (which is more than the value proposed in Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL). First use of HFCs for this purpose was recorded in 1995.

*Mobile air conditioning (2.F.1.e)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of air conditioning systems is assumed to be 12 years (data on the average age of vehicles provided by the Center for Vehicles of Croatia (CVH)). First use of HFCs for this purpose was recorded in 1996.

*Stationary air conditioning (2.F.1.f)*

- T2a (1995-2022)

Tier 2a methodology was applied. Equipment lifetime of air conditioning systems is assumed to be 15 years according to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. First use of HFC-407C for this purpose was recorded in 1995, of HFC-410A in 1999, of HFC-134a in water chillers with turbo compressors in 2001, and of R-32 in 2018.

Emission factors

*Commercial refrigeration (2.F.1.a)*

Product manufacturing factor of smaller stand-alone units was obtained from manufacturers and amounts to 0.5%. First fill emission factor of stable installations is 2%, according to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL.

Product life factor of a device is determined based on the forms that service technicians are obliged to fill out and annually submit to the Ministry of Economy and Sustainable Development. The average emission during the lifetime of stand-alone refrigeration units amounts to 10%, and of stable systems 25%.

Emission of HFCs during disposal is quite high. Even though the system of collection, recovery and disposal of HFCs exists since 2005, its efficiency is low (source: "Efficiency and sustainability of systems for collection, recovery and reuse of ODS and fluorinated greenhouse gases and analysis of the impact of Regulation (EU) 517/2014 on fluorinated greenhouse gases on the economy in the Republic of Croatia", FSB, 2016). Situation improved only after the adoption of the European Regulation 517/2014 on Fluorinated Greenhouse Gases and the shortage and increase in the price of HFCs. Therefore, average emission factors are assumed as follows:

- stand-alone units - 100% before 2015 and 50% after 2015,
- stable installations - 100% before 2005 (before the Regulation on ODS and Fluorinated Greenhouse Gases (OG 120/2005), which prescribes collection of fluorinated greenhouse gases upon final decommissioning), 50% from 2005 to 2015 and 30% after 2015.

*Domestic refrigeration (2.F.1.b)*

Product life factor is 0.2% according to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. Regulation on ODS and Fluorinated Greenhouse Gases (OG 120/2005) prescribes collection of fluorinated greenhouse gases during the final decommissioning. Until the establishment of the system of collection and disposal of household refrigerators (in 2012), HFCs were usually not collected. For this reason, until 2012, it is estimated that the emission from disposal is equal to 100%, and after that 50%, i.e., collection efficiency equals 0% and 50%, respectively.

*Industrial refrigeration (2.F.1.c)*

First fill emission factor of stable installations is 2% according to Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. Product life factor is determined based on the forms that service technicians are obliged to submit to the Ministry of Economy and Sustainable Development on an annual basis. The average emission during the lifetime of stable systems is 25%.

Emissions of HFCs during disposal in this category amount to 100% before 2005 (before Regulation OG 120/05), 50% from 2005 to 2015 and 30% after 2015.

*Transport refrigeration (2.F.1.d)*

As all vehicles are imported, there is no first fill emission factor. Product life factor is about 25%, but in consultation with service technicians, for safety reasons, the annual loss of 30% of the charge is assumed.

*Mobile air conditioning (2.F.1.e)*

As all vehicles are imported, there is no first fill emission factor. Product life factor is about 25%, but in consultation with service technicians, for safety reasons, the annual loss of 30% of the charge is assumed. Additionally, it is assumed that collection efficiency during vehicles disposal for the period 2006-2010 equals 50% to 90%, and for the period since 2011 it equals 90%.

*Stationary air conditioning (2.F.1.f)*

First fill emission factor is 2% according to the Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL. Product life factor of split, multisplit and heat pump is 15%. Data was obtained by analysing the service forms.

The average emission over the lifetime of VRF devices and chillers is 25%. Average disposal loss factors are as follows:

- split, multi split and heat pumps - 100% before 2015 and 50% after 2015,
- VRF and water chillers - 100% before 2005 (before Regulation OG 120/05), 50% from 2005 to 2015 and 30% after 2015.

<u>Activity data</u>

*Commercial refrigeration (2.F.1.a)*

The number of imported and exported stand-alone refrigerators was estimated based on data from PRODCOM statistics. The data contains imports and exports for two categories of devices:

- 28251333 - Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage, and
- 28251335 – Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage).

Data on imports and exports are included for the years 2003 to 2020 and are expressed in pieces. For the years before 2003, activity data were generated by linear extrapolation of data for the period 2003-2008. Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

The mass of HFCs in the stand-alone units was estimated based on an average charge of 1.5 kg.

In Croatia, there is also production of smaller stand-alone units. Data on HFC-134a and HFC-404A used in production of stand-alone equipment that was produced and that remained in Croatia was collected from manufacturers.

Data on stable installations of greater capacities were collected from the Ministry of Economy and Sustainable Development, which, in accordance with the Regulation on ODS and Fluorinated Greenhouse Gases, keeps a register (PNOS) of stationary equipment and devices filled with 3 or more kg of HFCs.

*Domestic refrigeration (2.F.1.b)*

The number of household refrigerators was estimated based on data from PRODCOM statistics. The data contain imports and exports for four categories of devices:

- 27511110 - Combined refrigerators-freezers, with separate external doors,
- 27511135 - Compression-type built-in refrigerators,
- 27511150 - Chest freezers of a capacity ≤ 800 litres,
- 27511170 - Upright freezers of a capacity ≤ 900 litres.

Data on imports and exports are included for the years 2003 to 2020 and are expressed in pieces. Data for 2021 and 2022 were obtained by linear extrapolation of the trend. For the years before 2003, activity data were generated based on data on the number of households provided by the Central Bureau of Statistics. It was assumed that each household has one refrigerator.

The mass of HFC-134a in household refrigerators was estimated based on an average charge of 50 grams. Household refrigerators are generally not refilled. When their cooling efficiency falls below a satisfactory value, refrigerators are replaced. The share of new refrigerators with R-600a was growing by 2% per year from 2000 to 2015, when the market share was estimated at 30% and 70% with HFC-134a.

*Industrial refrigeration (2.F.1.c)*

Activity data for this subcategory were collected, as in the case of the commercial refrigeration subcategory, from PNOS forms on stationary equipment and appliances filled with 3 or more kg. Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

*Transport refrigeration (2.F.1.d)*

The total number of refrigeration vehicles was obtained from the CVH. Data were obtained for the period 2007-2020. Data for 2021 and 2022 were obtained by linear extrapolation of the trend. Data for the period before 2007 were obtained by linear extrapolation of data for 2007-2019.

The ratio of HFC-134a to HFC-404a is as follows:

- 70/30% for the category of vehicles for the transport of goods of capacity of up to 3.5 t,
- 20/80% for the category of trucks with capacity over 3.5 t,
- 0/100% for the category of semi-trailers with capacity over 3.5 t.

*Mobile air conditioning (2.F.1.e)*

The total number of vehicles (cars, trucks, buses) is taken from the data of the Croatian National Statistics Office for the period 1996-2020. Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

The mass of the charge of one system is 0.7 kg and is in accordance with Table 7.9, Volume 3, Chapter 7, 2006 IPCC GL.

*Stationary air conditioning (2.F.1.f)*

There is no production of these devices in Croatia and they are solely being imported. Smaller split and multisplit air conditioners and heat pumps come precharged with refrigerant, while VRF systems as well as water chillers are filled after installation.

Activity data for this subcategory were collected from PNOS forms on stationary equipment and devices filled with 3 kg or more. Data for 2021 and 2022 were obtained by linear extrapolation of the trend. For devices smaller than 3 kg, which include split, multisplit and smaller heat pumps, there are no installation data. Information on these devices in Croatia were assessed based on the study "Efficiency and sustainability of systems for collection, recovery and reuse of ODS and fluorinated greenhouse gases and analysis of the impact of Regulation (EU) 517/2014 on fluorinated greenhouse gases on the economy in the Republic of Croatia", FSB, 2016, for 2015. For the period 1995 to 2008, data on imports and exports of split air conditioners from the HCFC Phase-out Management Plan (HPMP) of the Ministry of Environmental Protection and Physical Planning from 2009 were used. From the data it can be concluded that for the period before 2000 there was no import of smaller air conditioning systems and heat pumps filled with HFCs, i.e., only HCFC-22 was used. After 2005, due to the Regulation on ODS and Fluorinated Greenhouse Gases, which bans the import of HCFC-based products, the import of HFC-based devices began. Data for the period between those years were interpolated and after that period extrapolated using the GDP of the Republic of Croatia.

The increase in emissions due to disposal for the period after 2019 results from the fact that devices with R407C installed in 2005 were decommissioned in 2020. In 2005, a significant increase in commissioning of devices with R407C was recorded.

Total emissions of $CO_2$ equivalent from Refrigeration and Air Conditioning Equipment are given in the Table 4.7-1.

Table 4.7-1: Emissions from Refrigeration and Air Conditioning Equipment (t)

| Year | $CO_2$-eq (t) | | | | | |
|---|---|---|---|---|---|---|
| | 2.F.1.a | 2.F.1.b | 2.F.1.c | 2.F.1.d | 2.F.1.e | 2.F.1.f |
| 1995 | 1734 | 26 | 278 | 18644 | NO | 549 |
| 1996 | 3719 | 52 | 460 | 18442 | 456 | 1059 |
| 1997 | 6184 | 77 | 587 | 18240 | 1453 | 1635 |
| 1998 | 9325 | 103 | 927 | 18038 | 3080 | 2289 |
| 1999 | 13166 | 129 | 1221 | 17837 | 5393 | 3034 |
| 2000 | 17753 | 151 | 1573 | 17635 | 8310 | 3870 |
| 2001 | 23540 | 173 | 2102 | 17433 | 12034 | 4958 |
| 2002 | 34949 | 194 | 4808 | 17727 | 17228 | 5762 |
| 2003 | 43848 | 225 | 6273 | 18871 | 24002 | 6952 |
| 2004 | 51002 | 255 | 6816 | 20015 | 32426 | 8555 |
| 2005 | 60513 | 286 | 7865 | 34210 | 42596 | 30480 |
| 2006 | 70525 | 319 | 8931 | 35213 | 54639 | 58862 |
| 2007 | 85252 | 346 | 12319 | 35642 | 69115 | 98488 |
| 2008 | 96895 | 366 | 13718 | 37492 | 84990 | 136662 |
| 2009 | 115207 | 389 | 14988 | 37569 | 99959 | 178632 |
| 2010 | 134878 | 12946 | 16464 | 40526 | 113775 | 214502 |
| 2011 | 148195 | 12940 | 18694 | 40861 | 127420 | 250157 |
| 2012 | 170562 | 6666 | 25260 | 41442 | 138363 | 286571 |
| 2013 | 180449 | 6662 | 26466 | 43363 | 151168 | 323170 |
| 2014 | 198629 | 6658 | 33013 | 44772 | 168614 | 363278 |
| 2015 | 211390 | 5841 | 43956 | 47076 | 186639 | 410871 |
| 2016 | 257295 | 5707 | 54379 | 49461 | 210498 | 465117 |
| 2017 | 288586 | 5573 | 66906 | 50720 | 232590 | 544646 |
| 2018 | 292553 | 7949 | 70423 | 53867 | 266556 | 625722 |
| 2019 | 298079 | 7528 | 73730 | 54798 | 301887 | 696007 |
| 2020 | 303584 | 7853 | 74370 | 57320 | 335153 | 760778 |
| 2021 | 315105 | 8796 | 82302 | 59172 | 364919 | 834301 |
| 2022 | 317733 | 9445 | 84260 | 61283 | 400198 | 907703 |

#### 4.7.1.3. Uncertainties and time-series consistency

For commercial and industrial refrigeration and stationary air conditioning AD and EF uncertainty amounts to 50 %, based on expert judgement. For domestic refrigeration AD uncertainty is estimated to be 30 %, and EF uncertainty 25%. For transport refrigeration and mobile air conditioning AD and EF uncertainty amounts to 25 %.

#### 4.7.1.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan.

#### 4.7.1.5. Category-specific recalculations

In Domestic Refrigeration (2.F.1.b), for HFC-134a, errors were found and corrected in the calculation of emissions from stocks for the period 1995-2021.

In Mobile Air-Conditioning (2.F.1.e), for HFC-134a, errors were corrected in the calculation of emissions from disposal for the period 2007-2021 and emissions from stocks for the period 2020-2021.

#### 4.7.1.6. Category-specific planned improvements

Category-specific improvements are not planned.

### 4.7.2. Foam blowing agents (2.F.2); Fire protection (2.F.3); Aerosols (2.F.4); Solvents (2.F.5)

#### 4.7.2.1. Category description

*Foam blowing agents (2.F.2)*

Fluorinated hydrocarbons were used in the foam industry as foam suppression additives mainly as a substitute for CFC and HCFC gases. In Croatia, only a few companies produced rigid foams using HCFC-141b (from 1997 to 2008) and HCFC-142b (1991 to 1999), but due to legislation, the Regulation on ODS (120/2005) and harmonization with the legal framework of the European Union since 2008 (completion of the HCFC phase out Management Plan), they changed the technology using pentane-based natural gas.

There are two groups of foam, open cell or flexible foam and closed cell or rigid foam. For flexible foams, emission occurs immediately and/or shortly after production, while for rigid foams it occurs throughout the foam lifetime. The most common subcategory of flexible foams is polyurethane one component foam, which is most used for mattresses and furniture, and the most common rigid foams are polyurethane and extruded polystyrene foams (XPS) used in thermal insulation systems.

*Fire protection (2.F.3)*

In general, there are two types of fire protection equipment: stable, fixed installations and portable fire extinguishers. Until the early 1990s, halon systems were the second most widely used fire extinguishing agents after powder systems and apparatus. Today, instead of halons (1301 and 1211), which ceased to be used in accordance with the provisions of the Montreal Protocol, fire protection is carried out with apparatus and systems filled with HFCs. The following consumption was recorded in Croatia:

- HFC-125 and HFC-227ea in fixed systems,
- HFC-236fa in portable fire protection systems.

*Aerosols (2.F.4)*

Medical inhalers used in Croatia mostly use HFC-134a, but a few years ago a smaller quantity of HFC-227ea appeared on the market.

*Solvents (2.F.5)*

This category does not exist in Croatia.

### 4.7.2.2. Methodological issues

Methodology

*Foam blowing agents (2.F.2)*

- OTH (2003-2022 – closed-cell)
- T1a (2006-2010 – opened-cell)

Country specific method was used for the preparation of activity data, by reviewing PRODCOM database and statistics, as well as emission factors in accordance with the 2006 IPCC GL, which encourages presenting emissions from disposal and collection of HFCs at the end of their lifetime.

Emissions from disposal and destruction are not shown because the observed products have not yet reached the end of their life cycle.

For the period 2006-2010, quantity of HFC-152a was reported under the category of flexible foams - open cells based on the Tier 1a methodology, i.e., using data on imports and exports of HFC-152a.

*Fire protection (2.F.3)*

- T1 (1995-2022 – fixed systems)
- T2 (2003-2022 – portable systems)

Tier 1 (fixed systems) and Tier 2 (portable systems) approaches were used, according to equation 7.17, 2006 IPCC GL, Volume 3, Chapter 7, p. 61.

*Aerosols (2.F.4)*

- T1a (2003-2022)

The approach according to equation 7.6, 2006 IPCC GL, Volume 3, Chapter 7, p. 28 was used.

Emission factors

*Foam blowing agents (2.F.2)*

Emission factors according to table 7.6 Volume 3, Chapter 7, 2006 IPCC GL were used for XPS. Because the ratio of different types of PUR foams for this category is not known, general emission factor according to the table 7.5 was used.

Values of emission factors for rigid foams are:

- lifetime: 50 years XPS and 20 years PUR
- first year: 40 % XPS and 10 % PUR
- annual losses: 3% XPS and 4.5% PUR

For flexible foams, emission factor of 100% during production was used.

*Fire protection (2.F.3)*

Initial charge emission factor for fixed systems is estimated to be 2%. Stock and disposal emission factors are estimated to be 4% and 2%, according to 2006 IPCC GL and recommendations of the experts from the company that deals with filling, collecting and maintenance of fixed systems (Vatroservis d.o.o., Varaždin).

Emission factor of manufacturing portable fire extinguishers was obtained from the company PASTOR TVA d.d., and amounts to 1%. Product life factor of portable systems is also estimated at 4%. As portable fire extinguishers have a lifetime of 10 years, after that the substance is collected from the system, the tank is changed and refilled with the collected and added new substance. The manufacturer estimates that between 5 and 15% of the substance in the tank is lost during the renewal of the device (for transfer to a temporary container). For this reason, emission factor of 15% was used for the recovery/disposal.

*Aerosols (2.F.4)*

As the time between the purchase and the use is extremely short, and the inhaled gas is emitted into the atmosphere without any chemical changes, when calculating emissions, the emission factor is assumed to be 1, i.e., the emission level corresponds to 100% of use/purchase of inhalers.

Activity data

*Foam blowing agents (2.F.2)*

Activity data were generated using PRODCOM statistics database. These data include imports, exports and production for two categories of foam:

- 22214120 - Plates, sheet, film, foil and strip of cellular polymers of styrene (containing XPS),
- 22214150 - Plates, sheets, film, foil and strip of cellular polyurethanes (PUR).

Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

Data on imports, exports and production are included for the years from 2003 to 2022 and are expressed in kilograms. To calculate the mass of HFC used for foam blowing, it is necessary to know the portion of HFC gas within the foam product, the portion of HFC gas within the foam blowing mixture and the type of HFC gas, according to equation 7.7, Volume 3, Chapter 7, 2006 IPCC GL. The total emission for a given year was calculated using the default factors from Tables 7.5 and 7.6.

The following table shows the assumed values and references used in the calculation.

Table 4.7-2: Summary of values and references used in the calculation for the category 2.F.2

| Data | XPS | PUR | Reference |
|---|---|---|---|
| Domestic production in the given year [t] | PRODCOM statistics | | https://ec.europa.eu/eurostat/web/main/data/database |
| Import – export of foam in the given year [t] | | | |
| Foam blowing mixture / foam type [%] | 6 % | 8 % | Revised IPCC1996, page 2.59 (6-15 %) and IPCC/TEAP Study |
| HFC foam blowing mixture | 40 % and decreases to 20 % | 20 % and decreases to 10 % | DG Climate F-gases Reg.Review Study and IPCC/TEAP Study |

Within the PRODCOM category 22214120 polystyrene foams, only XPS is manufactured by HFC charge blowing. Estimation of the share of XPS foams within the category of polystyrene foams on the Croatian market is estimated at 10%, by the Croatia Green Building Council (CGBC). The use of HFC gases for foam blowing began mainly after 2003 as a replacement for ozone-depleting substances. Today, HFC gases are also being replaced by technologies with natural substances with low GWP, such as $CO_2$, hydrocarbons, etc.

According to the F-gases Regulation Review of DG Climate study, the ratio of HFCs among other foam-blowing gases is 40% for XPS foams and 20% for PUR foams for the period 2003-2011. Also, according to the same study, the first significant HFC consumption for foam production started in 2003 (the company BASF) and ended in 2011, while the IPCC/TEAP study suggests the end of consumption in 2015.

The share of the use of different HFC gases for foam production is based on historical data published by BASF:

- 90% HFC-134a and
- 10% HFC-227ea.

It should be noted that HFC-227ea gas is considered to be a zeotropic mixture of HFC-365mfc gases to which HFC-227ea is added to neutralize flammability in the following proportions:

- HFC-365mfc / HFC-227ea - 93/7% - for direct foam injection and
- HFC-365mfc / HFC-227ea - 87/13% - for fully formulated PU systems.

The share of flexible and rigid foams within the PUR foam category is also based on historical data from BASF:

- 90% rigid foam and
- 10% flexible foam.

The emissions calculation for flexible foam was made in accordance with expression 7.8 Volume 3, Chapter 7, 2006 IPCC GL.

In addition to the methodology given above, for the period 2006-2010, quantities of HFC-152a were reported in the category of open cell flexible foams based on the Tier 1a methodology, i.e., data on imports and exports of HFC-152a used for the production of flexible foams.

*Fire protection (2.F.3)*

Introduction to the market of HFCs in fixed and portable systems and their lifetime is as follows:

- HFC-125: introduction to the market in 2003, lifetime 20 years
- HFC-227ea: introduction to the market in 1995, lifetime 20 years
- HFC-236fa: introduction to the market in 2003, lifetime 10 years

Activity data for substances used in fixed fire extinguishing systems (HFC-125 and HFC-227ea) were collected for the period 2003-2020, partially from the Ministry of Economy and Sustainable Development and partially from importers of these substances.

Activity data related to portable fire extinguishers (HFC-236fa) were collected for the period 2003-2020 from the company that manufactures them. In addition to quantities of HFC-236fa imported during this period, quantities of devices sold on domestic and foreign markets were also collected. The company produces two types of fire extinguishers: Fe36 - 2 kg and Fe36 - 3 kg.

Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

*Aerosols (2.F.4)*

Medical inhalers are imported and they are not produced in Croatia. As it is a medical product, their placing on the market is strictly regulated. In Croatia, medical inhalers filled with HFC-134a were placed on the market in 2003, and those filled with HFC-227ea in 2016.

Activity data were collected for the years from 2007 to 2020, from the Agency for Medicinal Products and Medical Devices of Croatia (HALMED), for medical inhalers filled with HFC-134a and HFC-227ea.

Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

For the years prior to 2007, activity data (consumption) was estimated by extrapolation, using the GDP of the Republic of Croatia.

Emissions of HFCs used in 2.F.2, 2.F.3 and 2.F.4 are given in the Table 4.7-3.

Table 4.7-3: Emissions of HFCs used in 2.F.2, 2.F.3 and 2.F.4

| Year | $CO_2$-eq (t) | | |
|---|---|---|---|
| | 2.F.2 | 2.F.3 | 2.F.4 |
| 1995 | 1484 | 201 | NO |
| 1996 | 3129 | 129 | NO |
| 1997 | 4279 | 123 | NO |
| 1998 | 6102 | 119 | NO |
| 1999 | 8323 | 114 | NO |
| 2000 | 10951 | 109 | NO |
| 2001 | 12868 | 205 | NO |
| 2002 | 18893 | 165 | NO |
| 2003 | 15431 | 425 | 4740 |
| 2004 | 17180 | 546 | 5115 |
| 2005 | 18866 | 761 | 5503 |
| 2006 | 20337 | 1263 | 6000 |
| 2007 | 22458 | 2125 | 6569 |
| 2008 | 21483 | 2269 | 5335 |
| 2009 | 20551 | 2722 | 7611 |
| 2010 | 19659 | 3118 | 8781 |
| 2011 | 18807 | 3772 | 8424 |
| 2012 | 17992 | 4758 | 8419 |
| 2013 | 17097 | 5636 | 9028 |
| 2014 | 1484 | 5577 | 9349 |
| 2015 | 3129 | 6143 | 9897 |
| 2016 | 4279 | 5987 | 9906 |
| 2017 | 6102 | 5972 | 9791 |
| 2018 | 8323 | 5823 | 9858 |
| 2019 | 10951 | 5844 | 10075 |
| 2020 | 12868 | 5719 | 9464 |
| 2021 | 18893 | 5675 | 9638 |
| 2022 | 16267 | 5610 | 9555 |

### 4.7.2.3. Uncertainties and time-series consistency

For category 2.F.2, uncertainty of estimation of activity data is 50%, while uncertainty of estimation of emission factors is 25%, based on expert estimates.

For category 2.F.3, activity data uncertainty is 25% while emission factors uncertainty is 10%, because the highest values of the recommended range were used in the calculation.

For category 2.F.4, given that the pharmaceutical segment is highly regulated, solely for the purpose of estimating consumption for the period 2003 to 2007, activity data uncertainty is estimated at 10%. Uncertainty of emission factors was estimated at 0%.

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

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan.

#### 4.7.2.5. Category-specific recalculations

There were no recalculations.

#### 4.7.2.6. Category-specific planned improvements

Category-specific improvements are not planned.

## 4.8. Other product manufacture and use (CRF 2.G)

Global warming potential values from the IPCC Fifth Assessment Report (AR5) have been used in this submission.

### 4.8.1. Electrical equipment (2.G.1)

#### 4.8.1.1. Category description

$SF_6$ is used for spark prevention and insulation in high voltage (110-380 kV) and medium voltage (1-36 kV) gas circuit breakers – GBC and gas insulated switchgear and substations – GIS. This equipment was first used in Croatia in 1982. The equipment is manufactured in Croatia in several subsidiary companies of the company KONČAR – ELEKTROINDUSTRIJA d.d. It is exported and also partially imported. Equipment lifetime is between 30 and 40 years.

#### 4.8.1.2. Methodological issues

<u>Methodology</u>

- T2 (1990-2022)

In Croatia, $SF_6$ gas is not produced, but is fully imported for the needs of equipment production and system upgrades during service and maintenance.

Monitoring of imports, inputs, exports and outputs and placing on the market of $SF_6$ gas as well as stationary equipment containing it (commissioning, decommissioning) was for the first time prescribed by the Regulation on ODS and Fluorinated Greenhouse Gases (OG 92/2012) in 2012. Available data were obtained from the Ministry of Economy and Sustainable Development.

The Tier 2 methodology in accordance with the 2006 IPCC GL was applied:

$$\text{Total emission} = \text{Manufacturing Emissions} + \text{Equipment Installation Emissions} + \text{Equipment Use Emissions} + \text{Equipment Disposal Emissions}$$

Emission factors

According to manufacturers and operators, emission factor during filling in factory and first filling on site during installation ranges from 1% to 2% and is therefore estimated at 1.5%.

Emission factor for servicing and maintenance is 0.01 for high voltage circuit breakers and 0.005 for high voltage apparatus.

In Croatia, $SF_6$ gas is not destroyed but collected during the disposal of equipment. Data on equipment and nameplate mass of gas at disposal are documented in accordance with the abovementioned Regulation. According to the operator's data, emission factor at disposal was estimated at 2%.

Activity data

Activity data were collected from users, operators of $SF_6$ gas-filled equipment. Data on total amount of gas used to fill electrical equipment, data on gas leakage during use, data on equipment produced for national needs and exports, as well as estimates of emissions during production and disposal losses were collected for the whole time series.

Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

Data on imports and exports of equipment were collected from databases of the Croatian Customs Administration.

Emissions of $SF_6$ used in Electrical Equipment are presented in the Table 4.8-1.

Table 4.8-1: Emissions of $SF_6$ (kt $CO_2$-eq)

| Year | $SF_6$ (kt $CO_2$-eq) |
|---|---|
| 1990 | 11055 |
| 1991 | 10934 |
| 1992 | 11021 |
| 1993 | 11138 |
| 1994 | 11955 |
| 1995 | 12447 |
| 1996 | 12895 |
| 1997 | 12523 |
| 1998 | 13403 |
| 1999 | 13348 |
| 2000 | 12717 |
| 2001 | 12806 |
| 2002 | 13147 |
| 2003 | 13496 |
| 2004 | 13954 |
| 2005 | 14701 |
| 2006 | 14569 |
| 2007 | 14587 |
| 2008 | 13390 |
| 2009 | 9628 |

| Year | $SF_6$ (kt $CO_2$-eq) |
|---|---|
| 2010 | 10133 |
| 2011 | 10574 |
| 2012 | 11299 |
| 2013 | 7399 |
| 2014 | 7910 |
| 2015 | 5747 |
| 2016 | 6801 |
| 2017 | 7233 |
| 2018 | 6463 |
| 2019 | 8093 |
| 2020 | 9353 |
| 2021 | 9629 |
| 2022 | 9998 |

#### 4.8.1.3. Uncertainties and time-series consistency

Since data were obtained from industry, the uncertainty of activity data was estimated at 25%. Uncertainty of emission factors was estimated at 30%.

#### 4.8.1.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan.

#### 4.8.1.5. Category-specific recalculations

There were no recalculations.

#### 4.8.1.6. Category-specific planned improvements

Category-specific improvements are not planned.

### 4.8.2. $SF_6$ and PFCs from other product use (2.G.2)

This category does not exist in Croatia.

### 4.8.3. $N_2O$ from product uses (2.G.3)

#### 4.8.3.1. Category description

Nitrous oxide emissions can arise from a number of products, but the dominant influence is in two sub-sectors: in medicine for anaesthesia and in the food industry as propellant.

#### 4.8.3.2. Methodological issues

Methodology

For the purposes of emission estimate, methodology according to equation 8.24, 2006 IPCC GL, Volume 3, Chapter 8, p. 36 was applied.

Emission factors

For emission estimate, total emission of nitrous oxide in the reporting year is assumed, i.e. in both cases of application, emission factors are assumed to be 1.

Activity data

Historical activity data were collected from the local distributor of nitrous oxide, separately for medical needs and for the needs of the food industry, for the period 2009-2020, and also from the Ministry of Economy and Sustainable Development.

*Data on nitrous oxide consumption activities for medical purposes*

For the period 2000-2009, activity data are estimated by linear extrapolation using known data for the years 2009-2020, while for the period 1990-2000, consumption is fixed on the value from the year 2000. Moreover, with the aim of comparing supplier data, data on nitrous oxide consumption were collected from several of the largest hospitals in Croatia for the period 2017-2020. Consumption matches within ± 10%. In conversations with hospital pharmacies, it can be concluded that nitrous oxide consumption has been declining over the years with the intention of abandoning this method of anaesthesia altogether. Data for 2021 and 2022 were obtained by linear extrapolation of the trend.

*Data on activities of nitrous oxide consumption for food purposes*

From conversations with the heads of procurement departments of major food companies in Croatia, it is possible to conclude that nitrous oxide has not been used for food production for the last ten years Previously, it was procured exclusively from one producer, but data for the period prior to 2009 are not available. For this reason, the estimate of nitrous oxide consumption for the food industry is estimated only on the basis of data submitted by the Ministry of Economy and Sustainable Development for the period 2009-2017, while consumption for the period 2018-2022 is estimated by linear extrapolation.

Total $N_2O$ emissions from product uses are shown in Table 4.8-2.

Table 4.8-2: N2O emission from product uses

| Year | $N_2O$ (kt) |
|---|---|
| 1990 | 0.123 |
| 1991 | 0.123 |
| 1992 | 0.123 |
| 1993 | 0.123 |
| 1994 | 0.123 |
| 1995 | 0.123 |
| 1996 | 0.123 |
| 1997 | 0.123 |
| 1998 | 0.123 |
| 1999 | 0.123 |
| 2000 | 0.123 |
| 2001 | 0.120 |
| 2002 | 0.117 |
| 2003 | 0.113 |
| 2004 | 0.110 |
| 2005 | 0.107 |

| Year | $N_2O$ (kt) |
|---|---|
| 2006 | 0.103 |
| 2007 | 0.100 |
| 2008 | 0.097 |
| 2009 | 0.091 |
| 2010 | 0.090 |
| 2011 | 0.089 |
| 2012 | 0.081 |
| 2013 | 0.074 |
| 2014 | 0.067 |
| 2015 | 0.068 |
| 2016 | 0.065 |
| 2017 | 0.066 |
| 2018 | 0.062 |
| 2019 | 0.061 |
| 2020 | 0.067 |
| 2021 | 0.064 |
| 2022 | 0.064 |

#### 4.8.3.3. Uncertainties and time-series consistency

For estimation of $N_2O$ emissions from use of anaesthesia, uncertainty of activity data is 20%, and uncertainty of emission factors is 10%, based on expert estimates.

For emissions from use in food industry, uncertainty of activity data is 50% and the uncertainty of emission factors is 10%, based on expert estimates.

#### 4.8.3.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan.

#### 4.8.3.5. Category-specific recalculations

There were no recalculations.

#### 4.8.3.6. Category-specific planned improvements

Category-specific improvements are not planned.

## 4.9. Other (2.H)

This category includes the following sub-categories:

- Pulp and paper industry
- Food and beverages industry

### 4.9.1. Pulp and paper industry (2.H.1)

There are three types of processes for a production of pulp and paper that have existed or still exist in Croatia: Kraft (sulphate), acid sulphite and neutral sulphite semi-chemical process. Sulphate pulping was used until 1990 and acid sulphite pulping was used until 1994, while the neutral sulphite semi-chemical process still exists.

Emissions of $SO_2$, CO, $NO_x$, NMVOC and $NH_3$, as well as activity data, are taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution.

Emissions estimate is based on the Tier 2 of EMEP/EEA 2023 methodology; multiplication of annual products quantities by the appropriate emission factor. For all activities in this source category, default emission factors are used (EMEP/EEA 2023 Guidebook).

Detailed information on emissions trends for each source category are available in the above-mentioned emission inventory report.

### 4.9.2. Food and beverages industry (2.H.2)

The following activities are considered within the scope of this category: production of wine (white and unspecific colour wine), spirits, beer, bread, coffee roasting, meat, fish etc. frying/curing, sugar production, animal feed, margarine and solid fats and final cakes, biscuits and breakfast cereals production.

Emissions of NMVOC, as well as activity data, are taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022; Submission to the Convention on Long-range Transboundary Air Pollution'.

Emissions estimate is based on the Tier 2 of EMEP/EEA 2023 methodology; multiplication of annual products quantities by the appropriate emission factor. For all activities in this source category, default emission factors are used (EMEP/EEA 2023 Guidebook).

Detailed information on emissions trends for each source category are available in the above-mentioned emission inventory report.

# Chapter 5: Agriculture (CRF sector 3)

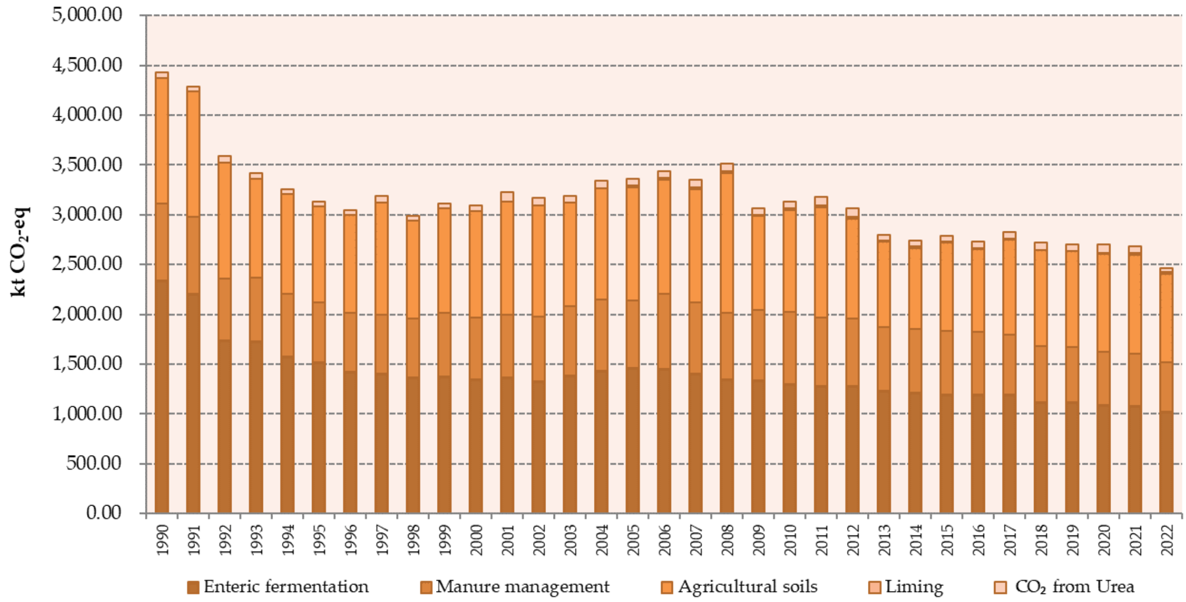
## 5.1. Overview of sector

The agricultural activities contribute directly to the emission of greenhouse gases through various processes. The following main sources have been identified to make a more complete break down in the emission calculation:

- Livestock: enteric fermentation ($CH_4$) and manure management ($CH_4$, $N_2O$)
- Agricultural soils ($N_2O$)
- Liming and urea application ($CO_2$)

The total emission in 2022 caused by agricultural activities was 2,467.91 kt $CO_2$-eq, which represents 10.1% of the total inventory emission. Methane ($CH_4$) and nitrous oxide ($N_2O$) are primary greenhouse gases discharged as a consequence of agricultural activities (Figure 5.1-1). Of all the ruminants, dairy cattle are the largest source of methane ($CH_4$) emission. The result of agricultural soil management, manure management and agricultural engineering are relatively high in the emission of nitrous oxide ($N_2O$). Emission generated by burning agricultural residues was not included in the calculation because this activity is prohibited by Croatian regulations. There are no ecosystems in the Republic of Croatia that could be considered natural savannas or rice fields; therefore, no greenhouse gas emissions exist for this sub-category.

Figure 5.1-1: Agriculture emission trend




Greenhouse gas emission decreased from 1990-1996 due to the war which highly influenced the animal population, crop production, consumption of mineral fertilizers and the overall agricultural practice in Croatia. In the post-war period, the sector began to revitalize and emission trend stabilized due to better national circumstances for agricultural production. Table 5.1-1 and Table 5.1-2 show the total emission from Agriculture by gases and by emission sources for the period 1990-2022.

Table 5.1-1: Emission of greenhouse gases from agriculture by gas

| Year | Methane emission kt $CH_4$ | | | Nitrous oxide emission kt $N_2O$ | | | Carbon dioxide emission kt $CO_2$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation | Manure management | Total | Manure management | Agricultural soils | Total | Liming | Urea | Total |
| **1990** | 83.43 | 17.57 | 101.00 | 1.073 | 4.76 | 5.84 | 0.00 | 50.02 | 50.02 |
| **1991** | 78.84 | 17.90 | 96.74 | 1.03 | 4.73 | 5.76 | 0.00 | 50.95 | 50.95 |
| **1992** | 62.24 | 14.32 | 76.56 | 0.81 | 4.39 | 5.20 | 0.00 | 65.51 | 65.51 |
| **1993** | 61.90 | 15.13 | 77.03 | 0.80 | 3.74 | 4.55 | 0.00 | 52.14 | 52.14 |
| **1994** | 56.31 | 15.31 | 71.62 | 0.77 | 3.76 | 4.53 | 0.00 | 47.57 | 47.57 |
| **1995** | 54.17 | 14.66 | 68.83 | 0.72 | 3.65 | 4.37 | 0.00 | 46.29 | 46.29 |
| **1996** | 51.01 | 14.66 | 65.68 | 0.68 | 3.69 | 4.37 | 0.00 | 52.44 | 52.44 |
| **1997** | 50.09 | 14.83 | 64.92 | 0.67 | 4.25 | 4.92 | 0.00 | 68.39 | 68.39 |
| **1998** | 48.86 | 14.97 | 63.84 | 0.64 | 3.71 | 4.35 | 0.00 | 44.25 | 44.25 |
| **1999** | 49.14 | 16.44 | 65.58 | 0.67 | 3.95 | 4.62 | 0.00 | 50.49 | 50.49 |
| **2000** | 48.20 | 16.01 | 64.22 | 0.64 | 4.02 | 4.66 | 0.00 | 60.87 | 60.87 |
| **2001** | 48.68 | 16.63 | 65.31 | 0.64 | 4.29 | 4.93 | 0.00 | 92.09 | 92.09 |
| **2002** | 47.58 | 17.12 | 64.71 | 0.63 | 4.20 | 4.83 | 0.00 | 80.76 | 80.76 |
| **2003** | 49.65 | 18.41 | 68.06 | 0.65 | 3.93 | 4.58 | 0.00 | 71.79 | 71.79 |
| **2004** | 51.12 | 19.60 | 70.71 | 0.66 | 4.21 | 4.86 | 0.00 | 75.94 | 75.94 |
| **2005** | 52.10 | 18.62 | 70.72 | 0.60 | 4.29 | 4.89 | 0.00 | 70.97 | 70.97 |
| **2006** | 52.02 | 20.94 | 72.96 | 0.63 | 4.33 | 4.95 | 17.48 | 63.19 | 80.67 |
| **2007** | 50.03 | 20.25 | 70.28 | 0.59 | 4.29 | 4.87 | 16.60 | 72.72 | 89.32 |
| **2008** | 48.13 | 18.68 | 66.81 | 0.54 | 5.30 | 5.84 | 20.78 | 75.83 | 96.60 |
| **2009** | 47.63 | 20.11 | 67.74 | 0.55 | 3.57 | 4.13 | 11.92 | 65.04 | 76.96 |
| **2010** | 46.56 | 20.73 | 67.29 | 0.53 | 3.85 | 4.39 | 21.46 | 66.58 | 88.04 |
| **2011** | 45.63 | 20.01 | 65.64 | 0.50 | 4.16 | 4.66 | 21.32 | 83.86 | 105.18 |
| **2012** | 45.84 | 19.54 | 65.38 | 0.49 | 3.77 | 4.26 | 14.38 | 86.85 | 101.23 |
| **2013** | 43.96 | 18.49 | 62.45 | 0.46 | 3.23 | 3.69 | 14.23 | 60.39 | 74.61 |
| **2014** | 43.33 | 18.52 | 61.85 | 0.47 | 3.06 | 3.53 | 19.99 | 49.47 | 69.47 |
| **2015** | 42.64 | 18.59 | 61.23 | 0.46 | 3.33 | 3.79 | 12.09 | 57.25 | 69.34 |
| **2016** | 42.70 | 18.01 | 60.70 | 0.46 | 3.15 | 3.60 | 11.20 | 64.96 | 76.17 |
| **2017** | 42.58 | 17.40 | 59.98 | 0.45 | 3.58 | 4.03 | 10.92 | 70.21 | 81.13 |
| **2018** | 39.94 | 16.20 | 56.14 | 0.42 | 3.63 | 4.05 | 4.62 | 67.62 | 72.24 |
| **2019** | 39.97 | 15.79 | 55.76 | 0.42 | 3.61 | 4.04 | 2.07 | 73.59 | 75.66 |
| **2020** | 38.97 | 15.13 | 54.09 | 0.42 | 3.70 | 4.12 | 6.89 | 88.29 | 95.18 |
| **2021** | 38.55 | 15.06 | 53.61 | 0.40 | 3.73 | 4.13 | 18.70 | 73.57 | 92.26 |
| **2022** | 36.46 | 13.97 | 50.43 | 0.39 | 3.36 | 3.76 | 18.70 | 42.01 | 60.71 |

Table 5.1-2: Emission of greenhouse gases from agriculture in $CO_2$-eq

| Year | Methane emission kt $CO_2$-eq | | | Nitrous oxide emission kt $CO_2$-eq | | | Carbon dioxide emission kt $CO_2$-eq | | | kt $CO_2$-eq |
|---|---|---|---|---|---|---|---|---|---|---|
| | Enteric fermentation | Manure management | Total | Manure management | Agricultural soils | Total | Liming | Urea | Total | TOTAL EMISSION |
| **1990** | 2336.03 | 491.91 | 2827.94 | 284.43 | 1261.96 | 1546.38 | 0.00 | 50.02 | 50.02 | **4424.34** |
| **1991** | 2207.56 | 501.14 | 2708.70 | 273.86 | 1253.04 | 1526.91 | 0.00 | 50.95 | 50.95 | **4286.56** |
| **1992** | 1742.71 | 400.88 | 2143.60 | 214.32 | 1163.31 | 1377.63 | 0.00 | 65.51 | 65.51 | **3586.74** |
| **1993** | 1733.21 | 423.71 | 2156.92 | 212.46 | 992.16 | 1204.62 | 0.00 | 52.14 | 52.14 | **3413.68** |
| **1994** | 1576.63 | 428.79 | 2005.42 | 204.08 | 996.08 | 1200.16 | 0.00 | 47.57 | 47.57 | **3253.16** |
| **1995** | 1516.84 | 410.38 | 1927.22 | 190.45 | 968.07 | 1158.53 | 0.00 | 46.29 | 46.29 | **3132.04** |
| **1996** | 1428.37 | 410.61 | 1838.98 | 180.35 | 977.51 | 1157.86 | 0.00 | 52.44 | 52.44 | **3049.29** |
| **1997** | 1402.54 | 415.34 | 1817.88 | 176.66 | 1125.92 | 1302.59 | 0.00 | 68.39 | 68.39 | **3188.85** |
| **1998** | 1368.17 | 419.28 | 1787.45 | 170.83 | 981.88 | 1152.71 | 0.00 | 44.25 | 44.25 | **2984.41** |
| **1999** | 1375.91 | 460.40 | 1836.31 | 178.69 | 1046.34 | 1225.03 | 0.00 | 50.49 | 50.49 | **3111.83** |
| **2000** | 1349.71 | 448.41 | 1798.12 | 169.57 | 1064.64 | 1234.21 | 0.00 | 60.87 | 60.87 | **3093.20** |
| **2001** | 1363.14 | 465.58 | 1828.72 | 169.36 | 1136.56 | 1305.92 | 0.00 | 92.09 | 92.09 | **3226.74** |
| **2002** | 1332.32 | 479.44 | 1811.77 | 167.79 | 1112.11 | 1279.90 | 0.00 | 80.76 | 80.76 | **3172.42** |
| **2003** | 1390.19 | 515.53 | 1905.72 | 171.77 | 1041.63 | 1213.41 | 0.00 | 71.79 | 71.79 | **3190.91** |
| **2004** | 1431.35 | 548.67 | 1980.02 | 173.65 | 1115.07 | 1288.72 | 0.00 | 75.94 | 75.94 | **3344.68** |
| **2005** | 1458.81 | 521.42 | 1980.23 | 160.19 | 1135.95 | 1296.14 | 0.00 | 70.97 | 70.97 | **3347.34** |
| **2006** | 1456.68 | 586.27 | 2042.96 | 165.86 | 1146.28 | 1312.15 | 17.48 | 63.19 | 80.67 | **3435.77** |
| **2007** | 1400.89 | 566.87 | 1967.76 | 155.48 | 1136.12 | 1291.60 | 16.60 | 72.72 | 89.32 | **3348.68** |
| **2008** | 1347.72 | 523.05 | 1870.77 | 143.47 | 1405.12 | 1548.59 | 20.78 | 75.83 | 96.60 | **3515.96** |
| **2009** | 1333.59 | 563.17 | 1896.76 | 146.82 | 946.85 | 1093.67 | 11.92 | 65.04 | 76.96 | **3067.39** |
| **2010** | 1303.76 | 580.40 | 1884.16 | 141.44 | 1021.41 | 1162.85 | 21.46 | 66.58 | 88.04 | **3135.04** |
| **2011** | 1277.73 | 560.25 | 1837.98 | 132.32 | 1101.49 | 1233.81 | 21.32 | 83.86 | 105.18 | **3176.97** |
| **2012** | 1283.43 | 547.14 | 1830.57 | 129.65 | 999.96 | 1129.60 | 14.38 | 86.85 | 101.23 | **3061.41** |
| **2013** | 1230.76 | 517.77 | 1748.53 | 121.34 | 856.40 | 977.74 | 14.23 | 60.39 | 74.61 | **2800.88** |
| **2014** | 1213.29 | 518.59 | 1731.88 | 123.46 | 811.37 | 934.83 | 19.99 | 49.47 | 69.47 | **2736.18** |
| **2015** | 1193.79 | 520.64 | 1714.43 | 121.10 | 882.33 | 1003.43 | 12.09 | 57.25 | 69.34 | **2787.20** |
| **2016** | 1195.55 | 504.15 | 1699.71 | 121.14 | 834.08 | 955.21 | 11.20 | 64.96 | 76.17 | **2731.08** |
| **2017** | 1192.32 | 487.16 | 1679.48 | 119.85 | 949.33 | 1069.18 | 10.92 | 70.21 | 81.13 | **2829.79** |
| **2018** | 1118.35 | 453.56 | 1571.91 | 111.49 | 961.04 | 1072.54 | 4.62 | 67.62 | 72.24 | **2716.69** |
| **2019** | 1119.03 | 442.20 | 1561.23 | 112.55 | 957.37 | 1069.92 | 2.07 | 73.59 | 75.66 | **2706.80** |
| **2020** | 1091.14 | 423.50 | 1514.65 | 111.26 | 979.63 | 1090.89 | 6.89 | 88.29 | 95.18 | **2700.72** |
| **2021** | 1079.31 | 421.70 | 1501.01 | 106.13 | 988.03 | 1094.16 | 18.70 | 73.57 | 92.26 | **2687.42** |
| **2022** | 1020.85 | 391.25 | 1412.11 | 103.38 | 891.71 | 995.09 | 18.70 | 42.01 | 60.71 | **2467.91** |

In Agriculture, five source categories represent key source category regardless of LULUCF (detailed in Table 5.1-3):

Table 5.1-3: Key categories in agriculture sector based on the level and trend assessment in 2022[22]

| IPCC Source Categories | Direct GHG | Criteria for Identification | | | |
|---|---|---|---|---|---|
| | | If Column C is Yes, Criteria for Identificatio | | | |
| AGRICULTURE SECTOR | | Excluding LULUCF | | Including LULUCF | |
| 3.A Enteric Fermentation | $CH_4$ | Yes | T1e T2e | L1i | T1i T2i |
| 3.B Manure Management | $CH_4$ | Yes | | L1i | T1i |
| 3.B Manure Management | $N_2O$ | Yes | T1e T2e | L2i | T1i T2i |
| 3.D.1 Direct $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | T2e | L1i L2i | T1i T2i |
| 3.D.2 Indirect $N_2O$ Emissions From Managed Soils | $N_2O$ | Yes | T2e | L1i L2i | T2i |

L1e - Level excluding LULUCF - Tier1 T1e - Trend excluding LULUCF - Tier1
L2e - Level excluding LULUCF - Tier2 T2e - Trend excluding LULUCF - Tier2
L1i - Level including LULUCF - Tier1 T1i - Trend including LULUCF - Tier1
L2i - Level including LULUCF - Tier2 T2i - Trend including LULUCF - Tier2

## 5.2. $CH_4$ emissions from enteric fermentation in domestic livestock (CRF 3.A.)

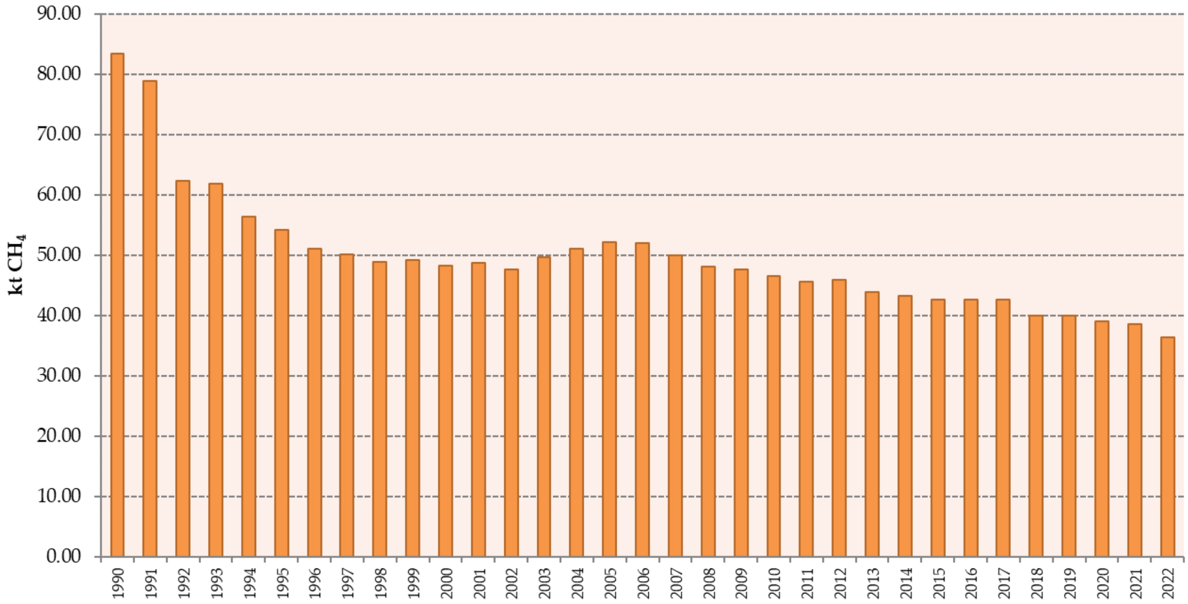
### 5.2.1. Category description

Methane is a direct product of animal metabolism generated during the digestion process. The greatest producers of methane are ruminants (cows, other cattle and sheep). The amount of methane produced and excreted depends on the animal digestive system and the amount and type of the animal feed. Estimates in the inventory include only emissions in farm animals. Buffalo, camels, and lamas do not occur in the Republic of Croatia. Emissions from wild animals and semi-domesticated game are not quantified and neither are emissions from humans or pet animals. Young cattle are the single major source of emissions with 37% of total $CH_4$ emission from Enteric fermentation in 2022, followed by dairy cattle with 28%. Cattle livestock in total is responsible for 79% of total $CH_4$ emission from Enteric fermentation.

Figure 5.2-1 shows the emission of methane from Enteric fermentation for the period from 1990-2022. The emission trend follows the trend of animal population which significantly decreased during the war period in the early 1990s (up to 1996). Following a minor increase of the animal population trend from 2002-2006, the trend is shows a steady decrease for each animal category (see Table 5.2-2).

[22] Data on key categories are taken from Annex 1 Key Categories.

Figure 5.2-1: $CH_4$ emission from Enteric fermentation




### 5.2.2. Methodological issues

<u>Cattle</u>

Starting with this year's inventory, a new country-specific approach was developed for the emission estimate from cattle, with the assistance of experts from the Faculty of Agriculture, University of Zagreb. Country specific values were developed for key years and then interpolated for the time periods between key years. A country-specific Tier 2/3 approach was used for dairy cows, according to a dynamic simulation model that describes the mechanism of the fermentation process in the gastro-intestinal tract. This model predicts the consequences of feeding on microbial fermentation and the accompanying production of $CH_4$ in the rumen and large intestine. The simulation model predicts GEi and $CH_4$ production in the rumen and large intestine from the consumption of the eaten meal and its nutritional characteristics (dry matter consumption, chemical composition, characteristics of digestion in the rumen). Subsequently, the model calculates Ym from the predicted $CH_4$ and GEi emissions. In addition, the model predicts Ym instead of the previous approach in which we assumed a constant Ym value, as is the case with the exclusive Tier 2 approach.

For other categories of cattle the Tier 2 approach was applied, and the gross energy intake of consumed food was calculated according to emission factors (EF) for Croatia. For this calculation, EFs were calculated using Ym and gross energy (GE; MJ/kg dry matter) feed intake (GEi; MJ/animal/day). The default IPCC value of 0.065 was used as Ym , except for the feeding of white meat calves that are mainly fed milk and/or milk replacer and therefore do not yet have a fully developed rumen.

Since the methodology for the categorization of cattle in the statistical data has changed over the years – from 8 categories for the period 1990-1999 to 11 categories for 2000-2022. Over time, it is expected that this CBS categorization will be uniform across the dataset.

Cattle classification used for emission calculation is as follows: Mature dairy – mature dairy cows; Mature non-dairy – mature females and males (other cows, heifers, bullocks, oxen); Young cattle – calves. Table 5.2-3 contains information on how CBS categories for cattle were reclassified into the appropriate IPCC categories. In addition, a separate category for "beef cattle" did not exist for 1990-1999, instead reported as "Cows". However "Cattle of 2 years and over, other cows" was considered to be the correct "beef cattle" category in the 2000-2022 period, amounting to an average of ~0,85% of all cattle numbers. This percentage value was used to extrapolate an estimated number of beef cattle for

1990-1999. The calculated beef cattle numbers were then subtracted from the “cows” AD, resulting in a final dairy cows number for 2000-2022.

Table 5.2-1: Cattle classification into main IPPC subcategories

| IPPC categories | CBS categories | |
|---|---|---|
| | 1990-1999 | 2000-2022 |
| Dairy cows | ▪ Cows* | ▪ Dairy cows |
| Mature non-dairy cattle | ▪ Bovine over 2 years<br>▪ Heifers in calf | ▪ Cattle of 2 years and over, heifers<br>▪ Cattle of 2 years and over, heifers for slaughter<br>▪ Cattle of 2 years and over, dairy cows |
| | ▪ *[Beef cattle]*** | ▪ Cattle of 2 years and over, other cows |
| | ▪ Breeding bulls | ▪ Cattle of 2 years and over, male |
| | ▪ Bullocks | |
| Young cattle | ▪ Calves under 3 months old<br>▪ Bovine from 3 months to 1 year | ▪ Young cattle under 1-year-old, for slaughter<br>▪ Young cattle under 1-year-old, female<br>▪ Young cattle under 1-year-old, male |
| | ▪ Bovine from 1 year to 2 years | ▪ Cattle between 1 and 2 years old, heifers<br>▪ Cattle between 1 and 2 years old, heifers for slaughter<br>▪ Cattle between 1 and 2 years old, male |

** Corrected using the “Beef Cattle” calculated category to get dairy cows numbers*

*** This category was created using the appropriate 2000-2022 category AD trend.*

Table 5.2-2. Maintenance coefficients used to estimate $CH_4$ emissions from enteric fermentation of cattle.

| IPCC categories | CBS animal categories | $Cf_i$ (MJ $d^{-1}$ $kg^{-1}$) |
|---|---|---|
| Dairy cows | ▪ Dairy cows | 0.386 |
| Mature non-dairy cattle | ▪ Cattle of 2 years and over, heifers | 0.322 |
| | ▪ Cattle of 2 years and over, heifers for slaughter | 0.322 |
| | ▪ Cattle of 2 years and over, other cows | 0.322 |
| | ▪ Cattle of 2 years and over, male | 0.322 |
| Young cattle | ▪ Young cattle under 1-year-old, for slaughter | 0.322 |
| | ▪ Young cattle under 1 year old, female | 0.322 |
| | ▪ Young cattle under 1 year old, male | 0.322 |
| | ▪ Cattle between 1 and 2 years old, heifers | 0.322 |
| | ▪ Cattle between 1 and 2 years old, heifers for slaughter | 0.322 |
| | ▪ Cattle between 1 and 2 years old, male | 0.370 |

## Intake of feed and meals for cattle, excluding dairy cows

Dry matter intake (DMi; kg dry matter/animal/day) was calculated using the Dutch WUM model. The consumption of different components in the meal (milk/milk by-products, grass, grass silage, corn silage, standard concentrates, protein-rich concentrates and wet by-products) is calculated annually by category of cattle based on national statistics on the quantities of these feeds that were traded or produced. These statistics on feed components cover part of the total energy requirements calculated annually according to a country-specific method for different categories of cattle. Subsequently, it is assumed that the rest of the energy needs for the recorded level of production is covered by the intake of grass from the pasture.

**Intake of feed and meals for dairy cows**

For dairy cows, a combination of Tier 2/3 approaches is applied to calculate country-specific emission factors, divided into the north-west and south-east regions of the Republic of Croatia. Since both regions have different meal compositions, the emissions are also different. The most important difference compared to the Tier 2 approach is that the simulation model predicts the emission factor from food intake and nutritional characteristics as model inputs, without using BEi or Ym values. Another important difference compared to the Tier 2 approach is that the simulation model takes into account several nutritional characteristics to predict the fermentation process in the rumen and colon, instead of using only the net energy value for milk production and maintenance as a nutritional characteristic. A final difference compared to the Tier 2 approach is that the simulation model calculates BEi from dry matter intake and meal composition instead of adopting BE values for DM of feed. EF, BEi and Ym of adult dairy cows are calculated annually. The Tier 3 approach does not take into account the effects of feed additives that should reduce $CH_4$ emissions.

Important input data for the simulation model are:

- Food intake/consumption levels, DM, were calculated according to the WUM model for the North-West and South-East regions, according to the same method as described I for cattle, excluding adult dairy cows.

- Chemical composition of DM in different feed components (grasses, grass silage, corn silage, low-protein concentrates, protein-rich concentrates and juicy by-products). They differ in the content of soluble carbohydrates (including sugars), starch, cell walls (hemicellulose, cellulose, lignin), crude proteins (including distinguishing the ammonia fraction), crude fats and crude ash. Data on composition come from information from the laboratory of the Institute for Animal Nutrition, University of Zagreb, Faculty of Agriculture, and adapted literature data, if there was no own data, in which voluminous feed, concentrates, and commercial feed mixtures were analyzed.

- Characteristics of intestinal degradability of starch, crude proteins and fibers.

The above data varies with annual changes in the proportion of individual feed ingredients (grasses, grass silage, corn silage, low-protein concentrates, protein-rich concentrates, wet by-products) and with changes in the chemical composition and intrinsic characteristics of the decomposition of these substances. The rate of passage of fermentable nutrients and the acidity of rumen and colon contents are also important model parameters that have a significant impact on predicted $CH_4$ production. However, this refers to internal model parameters that do not need to be provided as input to the model. Within the current method, a simulation model predicts fractional transit rate as a function of ST and acidity as a function of predicted volatile fatty acid concentration.

Methane conversion factor (Ym)

Based on the estimated values of the emission factor and BEi, the simulation model calculates the value of Ym. Ym is therefore not part of the assumptions made in the model representation, but is the model's predicted outcome in the same unit used for Ym with the other categories. From the predicted values of the emission factor and BE per year, Ym is calculated as follows:

Ym = EF × 55.65 / (GE x 365) (2.4)

Where:

Ym - Methane conversion factor (fraction of introduced BE converted into $CH_4$)

EF - Emission factor (kg $CH_4$ /animal/year) estimated by the BE simulation model – BE intake (MJ/animal/day) estimated by simulation model

It is assumed that 1 kg of $CH_4$ has a standard energy value of 55.65 MJ (IPCC, 2006), and a factor of 365 was used to calculate BEi on an annual basis..

If the results of the simulation model are not available in a certain year, a secondary (simplified) approach is used to calculate the emission factor, where Ym and BE/DM from three previous years will be used (as a reserve of options). The following equation is then used to calculate the emission factor:

EF = (DM × 365 × BE/DM (gross energy in DM; average from years n-1 to years n-3) × Y m (average year n-1 to year n-3)) / 55.65 (2.5)

Where:

EF - Emission factor (kg $CH_4$ /animal/year)

DM - Ingested dry matter intake (kg DM/animal/day)

BE - The value of gross energy input (MJ/animal/day)

Ym - Methane conversion factor (fraction of introduced BE converted into $CH_4$)

It is assumed that 1 kg of $CH_4$ has a standard energy content of 55.65 MJ (IPCC, 2006), and the factor 365 is used to calculate DM on an annual basis.

The emission factor is calculated more accurately using equation 2.5 because the estimates are based on the feeding characteristics of three consecutive previous years instead of using the characteristics of only one year. Ym depends on all the input data in the simulation model: 1) the level of feed intake, 2) the chemical composition of the ingested feed and 3) the characteristics of breakdown in the rumen.

More detailed information on cattle national specific values presented can be found in the study „*Expert basis for improvement of the calculation of greenhouse gas emissions from sector 3. Agriculture for the purposes of developement a national inventory of greenhouse gas emissions*“.

Other animal categories

The IPCC Tier 1 methodology has been used to calculate methane emission from enteric fermentation for other livestock categories except for poultry. Default emission factors for developed countries were used for the entire data series (Table 10.10 and 10.11, 2006 IPCC Guidelines). $CH_4$ emissions from enteric fermentation of poultry were not calculated since the estimation method for this animal category were not developed and no default EF for tier method was provided by the 2006 IPCC Guidelines.

For rabbits, emissions have been estimated by applying emission factor used in the Slovenian and Italian GHG inventories, i.e. 0.08 kg per animal per year (for all years in the time series).

Entire agricultural land area in Croatia is in “Cool” climate zone, with a median temperature of 10-11°C according to the literature (Z*aninović, M. et al*).

Activity data

The main three sources regarding the animal's population numbers are the Central Bureau of Statistics (CBS), Croatian Agricultural Agency (CAA) and FAO database. See Table 5.2-3 for detailed information. For animal categories where national data was not available, FAO data was considered an adequate replacement source. Activity data source for horses and mules and asses for the time period 2010-2022 uses values from the Ministry of Agriculture (MA) for increased accuracy of data. Data provided by Croatian Agricultural Agency (CAA) was used for he population numbers of horses and mules/asses for the missing years (1995-1999).

Activity data for rabbits and hares is available from CBS for the years: 2003, 2007, 2010, 2013, 2016 and 2020. For the rest of the time series the AD was interpolated (for the missing years in the middle of the time series), for 1990-2002 highest available AD (for 2003) was used. For 2017-2019 available 2016 AD was used. For the year 2022, 2020 AD was used. Further investigation into the availability and accuracy of source data for some of the key historical years - in particular the 1990-2002 period. Decision was thus made to go with the conservative approach of using the “last good number” for the 1990-2002 and revisit the AD extrapolation as more known datapoints become available.

Cattle, swine and poultry subcategorization into distinct cattle subcategories was provided by CBS.

Table 5.2-3: Sources of activity data regarding animal population

| Animal category | CBS | FAO | Croatian Agricultural Agency | Ministry of Agriculture | Extrapolation / interpolation |
|---|---|---|---|---|---|
| Cattle | 1990-2022 | | | | |
| Sheep | 1990-2022 | | | | |
| Goats | 1990-1991; 1999-2022 | 1992-1998 | | | |
| Horses | 1990-1994 | | 1995-1999 | 2010-2022 | |
| Mules/assess | 1990-1991 | 1992-1994 | 1995-1999 | 2010-2022 | |
| Swine | 1990-2022 | | | | |
| Poultry | 1990-2022 | | | | |
| Rabbits | 2003, 2007, 2010, 2013, 2016, 2020 | | | | 1990-2002[1], 2004-2006, 2008-2009, 2014-2015, 2017-2019[2], 2021,2022[3] |

[1] *used AD from year 2003* [2] *used AD from year 2016* [3] *used AD from year 2020*

Table 5.2-4: Number of animals produced annually in the period from 1990 – 2022

| Year | *Animal number / 1000 heads* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dairy cattle | Non-dairy | Sheep | Goats | Horses | Mules/asses | Swine | Total Poultry | Rabbits |
| **1990** | 463 | 361 | 751 | 172 | 39 | 17 | 1573 | 17102 | 463 |
| **1991** | 444 | 313 | 753 | 133 | 36 | 13 | 1621 | 16512 | 463 |
| **1992** | 360 | 230 | 539 | 114 | 26 | 13 | 1182 | 13142 | 463 |
| **1993** | 347 | 242 | 525 | 105 | 22 | 12 | 1262 | 12697 | 463 |
| **1994** | 326 | 193 | 444 | 108 | 21 | 7 | 1347 | 12503 | 463 |
| **1995** | 317 | 176 | 453 | 107 | 5 | 2 | 1175 | 12024 | 463 |

| Year | *Animal number / 1000 heads* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dairy cattle | Non-dairy | Sheep | Goats | Horses | Mules/asses | Swine | Total Poultry | Rabbits |
| **1996** | 294 | 168 | 427 | 105 | 5 | 2 | 1197 | 10993 | 463 |
| **1997** | 284 | 168 | 453 | 100 | 6 | 2 | 1176 | 10945 | 463 |
| **1998** | 274 | 169 | 427 | 84 | 7 | 2 | 1166 | 9959 | 463 |
| **1999** | 268 | 170 | 488 | 78 | 7 | 2 | 1362 | 10871 | 463 |
| **2000** | 262 | 164 | 529 | 79 | 10 | 3 | 1234 | 11256 | 463 |
| **2001** | 254 | 184 | 539 | 93 | 11 | 3 | 1234 | 11747 | 463 |
| **2002** | 247 | 170 | 580 | 97 | 14 | 3 | 1286 | 11665 | 463 |
| **2003** | 252 | 192 | 587 | 86 | 15 | 3 | 1347 | 11778 | 463 |
| **2004** | 226 | 240 | 722 | 126 | 17 | 3 | 1489 | 11185 | 395 |
| **2005** | 235 | 236 | 796 | 134 | 18 | 3 | 1205 | 10641 | 326 |
| **2006** | 233 | 250 | 680 | 103 | 19 | 3 | 1488 | 10088 | 257 |
| **2007** | 225 | 242 | 646 | 92 | 18 | 3 | 1348 | 10053 | 189 |
| **2008** | 213 | 241 | 643 | 84 | 20 | 4 | 1104 | 10015 | 200 |
| **2009** | 212 | 235 | 619 | 76 | 20 | 4 | 1250 | 10787 | 211 |
| **2010** | 207 | 238 | 629 | 75 | 19 | 2 | 1231 | 9469 | 222 |
| **2011** | 185 | 262 | 639 | 70 | 20 | 3 | 1233 | 9523 | 177 |
| **2012** | 181 | 271 | 679 | 72 | 20 | 3 | 1182 | 10160 | 132 |
| **2013** | 168 | 274 | 620 | 69 | 21 | 3 | 1111 | 9280 | 86 |
| **2014** | 159 | 281 | 605 | 61 | 21 | 2 | 1156 | 10268 | 86 |
| **2015** | 152 | 289 | 608 | 62 | 22 | 2 | 1167 | 10168 | 85 |
| **2016** | 147 | 298 | 619 | 76 | 23 | 3 | 1163 | 9835 | 84 |
| **2017** | 139 | 311 | 637 | 77 | 23 | 3 | 1121 | 10399 | 74 |
| **2018** | 136 | 278 | 636 | 80 | 24 | 4 | 1049 | 11413 | 65 |
| **2019** | 130 | 290 | 657 | 82 | 25 | 4 | 1022 | 12747 | 55 |
| **2020** | 110 | 313 | 662 | 86 | 26 | 5 | 1033 | 13057 | 45 |
| **2021** | 102 | 325 | 654 | 86 | 29 | 5 | 971 | 12096 | 45 |
| **2022** | 79 | 343 | 643 | 82 | 31 | 6 | 944 | 10917 | 45 |

The overall livestock population decreased significantly in the war period (1991-1995) compared to 1990. Dairy cattle maintained the decreasing trend over the entire period from 1990-2022, with a sharp drop in 2022.

### 5.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to minimal ±1% and maximum of ±36%, based on expert judgement. The expert judgement used for the uncertainty of the AD is based on the authority and information of the AD source (CBS source, FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty estimate associated with emission factors amounts to minimal ±15% and maximum of ±40%, based on expert judgements.

$CH_4$ emissions from Enteric Fermentation have been calculated using the same method and data sets for every year in the time series. Additional efforts are required in order to reconcile the probable inconsistency of AD for animal numbers trend, specifically the numbers of mules/asses and horses during the war period (1990-1995) and number of rabbits. CBS is the main data source for other animals with the exception of FAO data for goats. Trend analysis was performed for the goat's AD time series – FAO data was found to be inline and consistent with CBS data.

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

During the preparation of inventory submission, activity data regarding animal population for the entire time series were checked and revised if found necessary. Therefore, activities related to quality control were focused on completeness and consistency of emission estimates and also on the proper use of notation keys in the CRF tables. After a final draft of this chapter was prepared, an audit was carried out to check selected activities from Tier 1 General inventory level QC procedures which revealed that most of the activities were correctly carried out, during inventory preparation, despite the fact that formal QC procedures were not prepared.

### 5.2.5. Category-specific recalculations

Emissions were recalculated for the period 2016 – 2019 due to the correction of AD for swine.

Impact of recalculations on the total 3.A source emissions compared to the last submission is presented in Table 5.2-5.

Table 5.2-5: Emission difference of CRF 3.A. source due to the recalculations

| (CRF 3.A) | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| kt $CO_2$-eq | -1.271 | -1.319 | -1.316 | -1.365 |
| % | -0.11% | -0.11% | -0.12% | -0.12% |

### 5.2.6. Category-specific planned improvement

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Report the feeding situation for cattle in CRF table 3.A instead of reporting activity coefficients
- Continued improvements and investigation of activity data and additional annual population subcategorization for animal species that present a significant share in emissions. This applies particularly to improvement to swine subcategorization to prevent overestimation of emissions.
- Continued investigation of activity data (livestock population) with the purpose of gathering more detailed activity data, including sheep annual population subcategorization and rabbit population for historical years.
- Revisiting CBS data on NAPA activity data on swine and poultry categories using a more detailed model for accurate cross-analysis of available data, with the goal of getting a more accurate AAP value. Until such analysis is performed and a model developed, Croatia will use the CBS NAPA data for swine and poultry subcategories without conversion to AAP.

## 5.3. Manure management (CRF 3.B.)

Management of livestock manure produces both methane ($CH_4$) and nitrous oxide ($N_2O$) emissions. $CH_4$ produced during the storage and treatment of manure, and from manure deposited on pasture is estimated, and the main factors affecting $CH_4$ emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. This occurs most readily when large numbers of animals are managed in a confined area and where manure is disposed of in liquid-based systems.

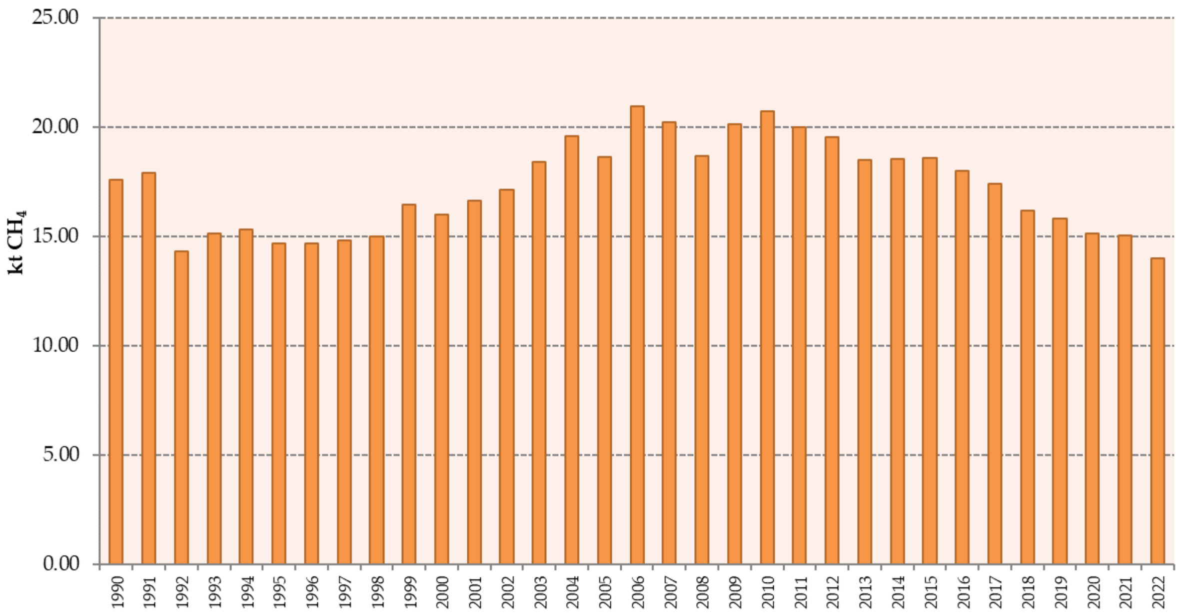
$N_2O$ is produced during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. The emission of $N_2O$ from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Direct $N_2O$ emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx.

### 5.3.1. Manure management – $CH_4$ emissions (CRF 3.B.1.)

#### 5.3.1.1. Category description

Methane is generated under the conditions of anaerobic decomposition of manure. Manure storing methods, in which anaerobic conditions prevail (liquid animal manure in septic pits), are favourable for anaerobic decomposition of organic substance and release of methane. Methane emission from Manure management for the period from 1990 to 2022 is presented in Figure 5.3-1. The emission trend depends on the animal population trend.

Figure 5.3-1: $CH_4$ emission from Manure management




#### 5.3.1.2. Methodological issues

Country-specific approach was developed with the assistance of experts from the Faculty of Agriculture, University of Zagreb for key years and then interpolated for the time periods between key years. More detailed information about this improvement can be found in the study „*Expert basis for improvement of the calculation of greenhouse gas emissions from sector 3. Agriculture for the purposes of developement a national inventory of greenhouse gas emissions*".

The 2006 IPCC methodology, Tier 2 method has been used to calculate methane emission from Manure Management for all animals except rabbits. The same activity data as in Enteric fermentation have been used in emission calculation, thus referring to Chapter 5.2.2 and Table 5.2-2 for additional information. Estimates have been calculated using default VS and $B_O$ rates for western Europe from the 2006 IPCC Guidelines (tables 10A-1 to 10A-9), combined with the national data for N-rate typical animal mass (TAM) for cattle and swine categories and default TAM from the 2006 IPCC Guidelines for all other animal categories; national data on manure management systems (MMS) ratios for all animals except rabbits (see Chapter 5.3.2.2 for detailed information on MMS).

For rabbits, Tier 1 method IPCC default emissions factor 0.08 kg/head/year was applied. It was considered that rabbits are not grazed and that only the solid manure system has been used.

Table 5.3-1: Manure management emission factors for each animal category for the year 2022

| | | | | | | MMS Distribution / MCF | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Typical Animal Mass (TAM), kg | VS | B0 | $CH_4$ emission, per head (FE) | | Anaerobic lagoon | Liquid system | Daily spread | Solid storage and dry lot | Pasture range and paddock | Digesters | Other |
| | | | | | **MCF** | 22 | 22 | 0 | 2 | 1 | 2 | 1,5 |
| **Mature dairy cattle** | 528.1 CS | 5.18 | 0.24 | 39.58 | | 5.20% | 51.00% | 0.00% | 30.83% | 1.83% | 10.00% | 0.83% |
| **Other mature cattle** | 179.28 CS | 2.68 | 0.17 | 11.28 | | 2.20% | 38.20% | 0.00% | 43.67% | 5.00% | 10.00% | 0.83% |
| **Growing cattle** | 554.22 CS | 2.72 | 0.18 | 11.92 | | 2.20% | 38.20% | 0.00% | 43.67% | 5.00% | 10.00% | 0.83% |
| **Sheep** | 48.5 | 0.40 | 0.19 | 0.22 | | 0.00% | 0.00% | 0.00% | 18.13% | 81.87% | 0.00% | 0.00% |
| **Market swine** | 64.5 | 0.31 | 0.46 | 6.34 | | 2.20% | 80.64% | 0.00% | 7.10% | 0.07% | 10.00% | 0.00% |
| **Breeding swine** | 194.5 | 0.46 | 0.45 | 8.60 | | 2.13% | 71.97% | 0.00% | 14.90% | 1.00% | 10.00% | 0.00% |
| **Goats** | 38.5 | 0.30 | 0.18 | 0.14 | | 0.00% | 0.00% | 0.00% | 5.33% | 94.67% | 0.00% | 0.00% |
| **Horses** | 377 | 2.13 | 0.30 | 2.03 | | 0.00% | 0.00% | 0.00% | 29.67% | 70.33% | 0.00% | 0.00% |
| **Mules and Asses** | 130 | 0.94 | 0.33 | 0.83 | | 0.00% | 0.00% | 0.00% | 10.00% | 90.00% | 0.00% | 0.00% |
| **Layers** | 1.8 | 0.02 | 0.39 | 0.07 | | 0.00% | 7.80% | 0.00% | 91.27% | 0.93% | 0.00% | 0.00% |
| **Broilers** | 1.8 | 0.01 | 0.36 | 0.02 | | 0.00% | 0.93% | 0.00% | 98.07% | 1.00% | 0.00% | 0.00% |
| **Turkeys** | 6.8 | 0.07 | 0.36 | 0.12 | | 0.00% | 0.00% | 0.00% | 98.07% | 1.93% | 0.00% | 0.00% |
| **Ducks** | 2.7 | 0.02 | 0.36 | 0.04 | | 0.00% | 0.93% | 0.00% | 93.07% | 5.00% | 0.00% | 1.00% |
| **Other** | 2.7 | 0.02 | 0.36 | 0.07 | | 0.00% | 10.00% | 0.00% | 80.00% | 5.00% | 0.00% | 5.00% |
| **Rabbits** | 1.6 | 0.10 | 0.32 | 0.08 | | 0.00% | 0.00% | 0.00% | 100.00 % | 0.00% | 0.00% | 0.00% |

CS - country specific

### 5.3.1.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to minimal ±1% and maximum of ±36%, based on expert judgement. The expert judgement used for the uncertainty of the AD is based on the authority and information of the AD source (CBS source, FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty estimate associated with emission factors amounts to minimal ±15% and maximum of ±40%, based on expert judgements.

#### 5.3.1.4. Category-specific QA/QC and verification

During the preparation of inventory submission, activity data regarding animal population for the entire time series were checked and revised if found necessary. Therefore, activities related to quality control were focused on completeness and consistency of emission estimates and also on the proper use of notation keys in the CRF tables. After a final draft of this chapter was prepared, an audit was carried out to check selected activities from Tier 1 General inventory level QC procedures which revealed that most of the activities were correctly carried out, during inventory preparation, despite the fact that formal QC procedures were not prepared.

#### 5.3.1.5. Category-specific recalculations

Emissions were recalculated:

- for the period 2016 – 2019 due to the correction of AD for swine.
- for the year 2021 due to the correction of AD for geese.

Impact of recalculations on the total 3.B.1 source emissions compared to the last submission is presented in Table 5.3-2.

Table 5.3-2: Emission difference of CRF 3.B.1 source due to the recalculations

| (CRF 3.B.1) | 2016 | 2017 | 2018 | 2019 | 2021 |
|---|---|---|---|---|---|
| **kt $CO_2$-eq** | -7.62 | -7.78 | -7.64 | -7.80 | 0.001 |
| **%** | -1.51% | -1.60% | -1.69% | -1.76% | 0.0002% |

#### 5.3.1.6. Category-specific planned improvement

Planned improvements assumed to be short-term goals (up to 1 year) are:

- Analysys and confirmation of MCFs values used for $CH_4$ emissions from MMS systems.

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Planned improvements for the Enteric Fermentation source (regarding AD) will also improve emissions calculation from Manure management sector. Please refer to chapter 5.2.6 for the planned improvements for Enteric Fermentation.

### 5.3.2. Manure management – $N_2O$ emissions (CRF 3.B.2.)

#### 5.3.2.1. Category description

There are two emission pathways of nitrous oxide ($N_2O$) as a result of manure management. Direct $N_2O$ emissions via combined nitrification and denitrification of nitrogen contained in the manure, dependant on storage and treatment types and methods. Emissions of nitrous oxide ($N_2O$) from all animal waste management systems are estimated. A considerable amount of nitrous oxide evolves during storage of animal waste and is attributed to livestock breeding. This includes emissions from anaerobic lagoons, liquid systems, solid storage, dry lot and other systems. Second pathway is indirect emission from volatile nitrogen losses that occur in the forms of ammonia and NOx, and losses through runoff and leaching into soils. Nitrous oxide ($N_2O$) emissions from Manure management for the period from 1990 to 2022 are presented in Figure 5.3-2.

Figure 5.3-2: $N_2O$ Emissions from Manure management


### 5.3.2.2. Methodological issues

**Direct $N_2O$ Emissions from Manure Management**

Activity data regarding livestock population are the same as for the calculation of $CH_4$ emission from Enteric fermentation and Manure management. The 2006 IPCC methodology (Tier 1) with some national specific data (presented in Table 5.3-1) has been used[23]. Emissions were calculated using equation 10.25 (2006 IPCC Guidelines). Default values for N excretion rates for all animal categories were used (Table 10.19 of 2006 IPCC Guidelines). Default TAM (typical animal values) were used for all livestock other than cattle. Country-specific data used was typical animal mass for cattle categories and percentages of all livestock categories managed in each manure management system (Table 5.3-1 for the last inventory year), except for rabbits for which a 100% solid storage was assumed.

Country-specific approach was developed with the assistance of experts from the Faculty of Agriculture, University of Zagreb for key years and then interpolated for the time periods between key years. More detailed information about this improvement can be found in the study „*Expert basis for improvement of the calculation of greenhouse gas emissions from sector 3. Agriculture for the purposes of developement a national inventory of greenhouse gas emissions*“.

**Indirect $N_2O$ Emissions from Manure Management**

Tier 1 methodology (Equation 10.26, 2006 IPCC Guidelines) has been used. Volatized N in forms of $NH_3$ and NOx was calculated for each manure management systems from all livestock categories, summing all N losses. Final $N_2O$ emissions were the estimated using Equation 10.27 (2006 IPCC guidelines), using default emission factors (Table 11.3, 2006 IPCC Guidelines).

For indirect $N_2O$ emissions associated with leaching and run-off IPCC Tier 2 approach was followed (Equation 10.28 of the 2006 IPCC Guidelines, volume 4, chapter 10). Parameters used are: total N excreted by livestock (kg head-1yr-1), the fraction of total annual nitrogen excretion for each livestock category managed in each manure management systems, $Frac_{leach}MS$ emission factor, which is the percent of managed manure nitrogen losses due to leaching and runoff during solid and liquid storage of manure (see Table 5.27) and emission factor 0.0075 kg $N_2O$-N per kg N leaching/runoff (IPCC, 2006).

[23] See Chapter 5.3.2.6 for details on planned improvement.

The requirements regarding handling application of organic manure, size and water tightness of animal manure stores with the goal of reducing impact on water bodies in sensitive areas were published in 1992 and later upgraded many times throught different laws and Good Practice Guidance and policies, up to current Decree on the protection of waters against pollution caused by nitrates from agricultural sources. For this reason, the selected value for Fracleach used in emission estimate is 1% (the lower bound from the typical range 1-20% as recommended by IPCC, 2006).

#### 5.3.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with livestock activity data amounts to minimal ±1% and maximum of ±36%, based on expert judgement. The expert judgement used for the uncertainty of the AD is based on the authority and information of the AD source (CBS source, FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty estimate associated with emission factors amounts to minimal ±15% and maximum of ±40%, based on expert judgements.

Uncertainty of emission factors is within the range -50% to +153%. Uncertainty of EF for indirect emissions is within the range ±400%.

#### 5.3.2.4. Category-specific QA/QC and verification

During the preparation of inventory submission, activity data regarding animal population for the entire time series were checked and revised if found necessary. Therefore, activities related to quality control were focused on completeness and consistency of emission estimates and also on the proper use of notation keys in the CRF tables. After a final draft of this chapter was prepared, an audit was carried out to check selected activities from Tier 1 General inventory level QC procedures which revealed that most of the activities were correctly carried out, during inventory preparation, despite the fact that formal QC procedures were not prepared.

#### 5.3.2.5. Category-specific recalculations

Emissions were recalculated:

- for the period 2016 – 2019 due to the correction of AD for swine,
- for the year 2021 due to the correction of AD for geese and the correction of national specific data (that were erroneously using 2020 values instead of 2021 values).

Impact of recalculations on the total 3.B.2 source emissions compared to the last submission is presented in Table 5.3-3.

Table 5.3-3: Emission difference of CRF 3.B.2 source due to the recalculations

| (CRF 3.B.2) | 2016 | 2017 | 2018 | 2019 | 2021 |
|---|---|---|---|---|---|
| **kt $CO_2$-eq** | -2.18 | -2.20 | -2.18 | -2.25 | -1.87 |
| **%** | -1.80% | -1.83% | -1.96% | -2.00% | -1.76% |

#### 5.3.2.6. Category-specific planned improvement

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Planned improvements for the Enteric Fermentation source (regarding AD) will also improve emissions calculation from Manure management sector. Please refer to chapter 5.2.6 for the planned improvements for Enteric Fermentation.

## 5.4. Rice cultivation (CRF 3.C.)

### 5.4.1. Category description

Anaerobic decomposition of organic material in flooded rice fields produces methane ($CH_4$) which escapes into the atmosphere by diffusive transport through the plants during the growing season. Rice cultivation does not occur in Croatia, so there is no possible emissions from this source.

## 5.5. Agricultural soils (CRF 3.D.)

A number of agricultural activities add nitrogen to soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of $N_2O$ emitted.

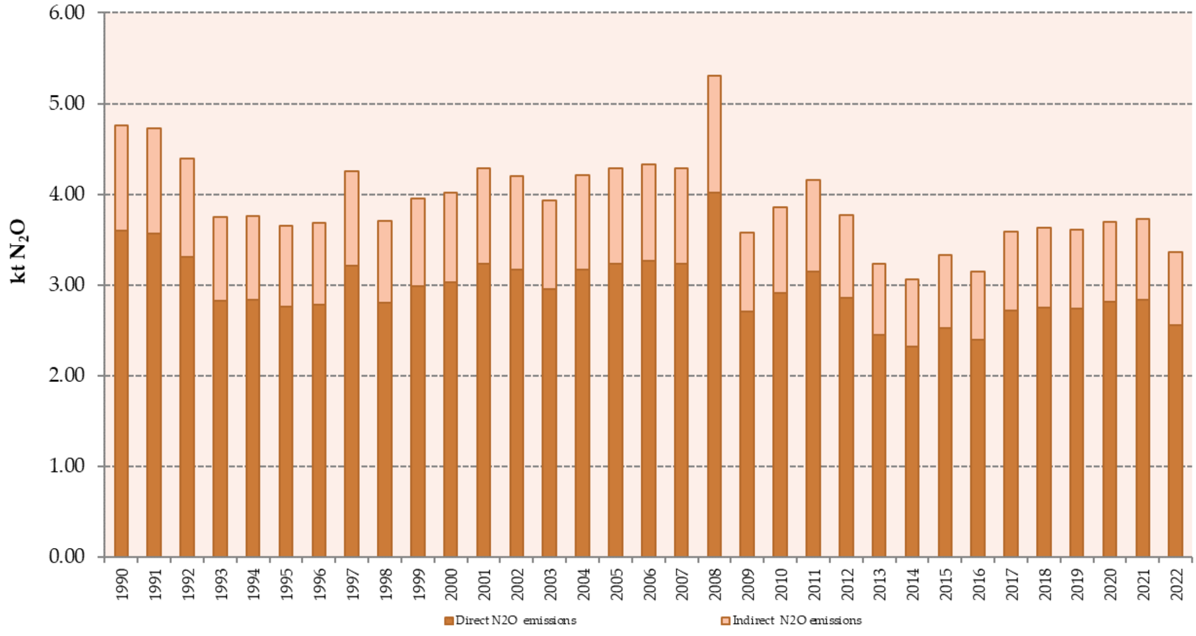
$CH_4$ emissions from 3.D source were not calculated since the estimation method for this source category were not developed and no default EF for tier method was provided by the 2006 IPCC Guidelines.

Usage of synthetic and organic fertilisers, deposited manure, crop residues, sewage sludge, mineralisation of N in soil organic matter due to management of organic soils, etc. Two sources of nitrous oxide emissions are distinguished:

- Direct $N_2O$ Emissions from Managed Soils (CRF 3.D.1.)
- Indirect $N_2O$ Emissions from Managed Soils (CRF 3.D.2.)

Direct $N_2O$ emissions are estimated separately from indirect emission, though both use the same set of activity data. Emissions of nitrous oxide ($N_2O$) from Agricultural soils for the period from 1990 to 2022 are presented in Figure 5.5-1. Emissions decreased after 1990 and during the war due to specific national circumstances and limited agricultural practice at that time. Afterwards, the emission trend is mostly influenced by the changes in the direct soil emissions. In 1997, 2001 and in particular 2008 direct soil emissions increased due to the increase in mineral fertilizer consumption and also due to the increase in crop production. In the period from 2004-2008, emission increased in comparison to 2003 due to increases in mineral fertilizer consumption, number of animals and crop production. Emissions for the years 2009 and 2010 decline sharply, mostly related to economic recession and a major decrease in the consumption of mineral fertilizers, while the year 2011 shows an increase again, due to increase in mineral fertilizer consumption. Data for the years 2012 - 2016 again show a decline in their consumption, with an all-time low in 2014. For the period 2017-2021, the consumption of mineral fertilizers is consistent with a slight upward trend, followed by a significant decrease in 2022.

Figure 5.5-1: Total $N_2O$ emissions from Agricultural soils




## 5.5.1. Direct $N_2O$ Emission from Managed Soils (CRF 3.D.1.)

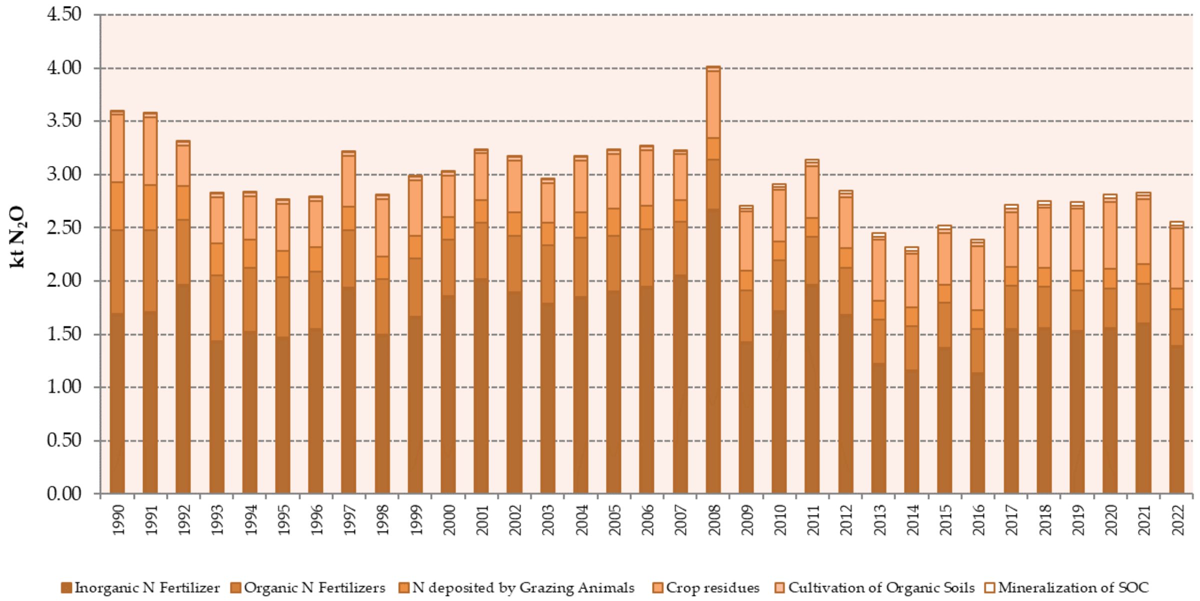
### 5.5.1.1. Category description

Direct $N_2O$ emissions from agricultural soils include the total amount of nitrogen applied to soils through human-induced N additions and/or change od practices. Specific N sources estimated are as follows:

- Inorganic N Fertilizers (3.D.1.1)
- Organic N Fertilizers (3.D.1.2)
- Animal Manure applied to Soils (3.D.1.2.a.)
- Sewage Sludge applied to Soils (3.D.1.2.b.)
- Urine and Dung deposited by Grazing Animals (3.D.1.3)
- Crop Residues (3.D.1.4)
- Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Content (3.D.1.5)
- Cultivation of Organic Soils (3.D.1.6)

Direct Emissions of $N_2O$ from Managed Soils for the period from 1990 to 2022 are shown in Figure 5.5-2.

Figure 5.5-2: Direct $N_2O$ emissions from Agricultural soils




### 5.5.1.2. Methodological issues

In order to calculate emission from Agricultural Soils, the IPCC methodology (Tier 1) has been used. Emission factors were taken from the 2006 IPCC Guidelines.

Inorganic N Fertilizers (3.D.1.1)

This estimate is based on the amount of N in mineral fertiliser that is annually consumed in the Republic of Croatia and on the “Mineral fertiliser consumption, in tonnes of nitrogen” dataset obtained from the CBS.

- Data on the consumption of mineral fertilisers that are produced and applied in Croatia were obtained from companies that produce synthetic fertilizers for the time period 1992-1999 since CBS has no data on N applied from mineral fertilizers before the time period before 2000 (Table 5.5-1). Data on mineral fertilizers produced and applied in Croatia in 1990 and 1991 have been estimated by extrapolation method using the pattern from 1992 to 1999.
- “Mineral fertiliser consumption, NUTS 0, in tonnes of nutrient” CBS dataset is available starting from the year 2000 (Table 5.5-2), with peak consumption in 2008.
- Minor discrepancies comparing the AD 2006-2016 on the consumption of mineral fertilisers and CBS datased were identified, contributed to slight differenced in the methodological approach. CBS data is considered to be national official data (submitted to Eurostat).

Figure 5.5-3: N from mineral fertilizers applied to soils

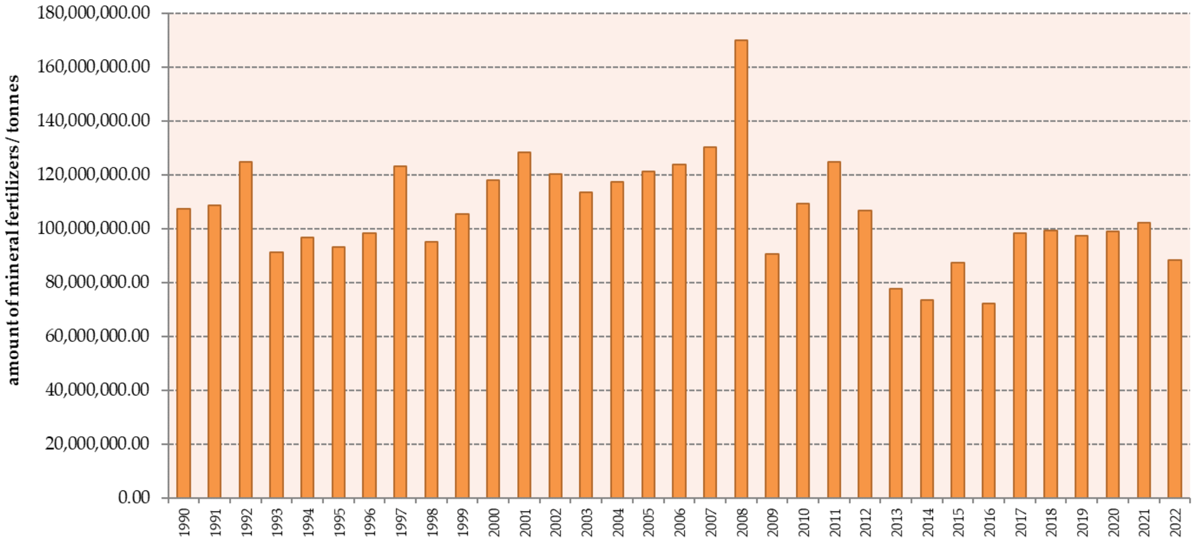



Table 5.5-1: Nitrogen from applied inorganic fertilizers in the period 1990-1999

| Year | Nitrogen applied / tonnes | | | | | |
|---|---|---|---|---|---|---|
| | Urea | Calcium ammonium nitrate | NPK | Ammonium nitrate | Urea ammonium nitrate | TOTAL |
| **1990** | 31,376.02 | 39,030.12 | 36,285.99 | 721.27 | NO | 107,413.40 |
| **1991** | 31,957.26 | 38,643.46 | 37,441.72 | 672.22 | NO | 108,714.66 |
| **1992** | 41,093.64 | 43,521.03 | 39,921.42 | 282.41 | NO | 124,818.50 |
| **1993** | 32,705.54 | 27,743.58 | 29,856.30 | 1,053.58 | NO | 91,358.99 |
| **1994** | 29,839.28 | 36,707.85 | 29,814.55 | 549.07 | NO | 96,910.74 |
| **1995** | 29,038.88 | 35,701.02 | 28,395.91 | 279.73 | NO | 93,415.53 |
| **1996** | 32,894.14 | 34,644.78 | 30,768.66 | 81.74 | NO | 98,389.32 |
| **1997** | 42,897.76 | 43,609.05 | 35,924.21 | 920.92 | NO | 123,351.94 |
| **1998** | 27,755.94 | 38,790.63 | 28,358.87 | 341.03 | NO | 95,246.47 |
| **1999** | 31,669.16 | 34,221.42 | 39,495.69 | 235.17 | NO | 105,621.44 |

Table 5.5-2: Nitrogen from applied inorganic fertilizers in the period 2000-2022

| Year | Nitrogen applied / tonnes |
|---|---|
| **2000** | 118,005 |
| **2001** | 128,343 |
| **2002** | 120,469 |
| **2003** | 113,621 |
| **2004** | 117,579 |
| **2005** | 121,309 |
| **2006** | 123,874 |
| **2007** | 130,448 |
| **2008** | 170,152 |
| **2009** | 90,793 |
| **2010** | 109,345 |
| **2011** | 125,015 |
| **2012** | 106,884 |
| **2013** | 77,920 |
| **2014** | 73,680 |

| Year | Nitrogen applied / tonnes |
|---|---|
| **2015** | 87,428 |
| **2016** | 72,320 |
| **2017** | 98,412 |
| **2018** | 99,420 |
| **2019** | 97,520 |
| **2020** | 98,964 |
| **2021** | 102,190 |
| **2022** | 88,431 |

Over the years, the consumption of mineral fertilizers fluctuates depending on the prices of the agricultural products. The consumption refers to the amounts produced and sold within the country and imported amounts. Regarding the domestic production for domestic consumption, low consumption in 1993 is recorded due to the war which obstructed the agricultural practice around the country while in 2009 it was caused by the drastic decrease of prices related to agricultural products. Only calcium ammonium nitrate (KAN) stayed at the same level (being the cheapest fertilizer). The consumption trend of this type of mineral fertilizer is decreasing in the period from 1992-2009 although from 2000 onwards is almost stationary. As for urea, its consumption increased from 1998-2008, then started fluctuating but on an overall higher level. NPK has the highest decreasing trend in the period from 2000-2004 which is a reflection of the economic position of agricultural producers. Recent drop of NPK usage is in correlation with the overall state of economic recession. The consumption of mineral fertilizers peaked in 2008 (which correlates with high maize production that year) and was characterized by high prices of agricultural products. The imported amounts were the highest in 2004 because at that time the fertilizer prices decreased in the region while the lowest imported amounts were recorded for 2008. The sharp decrease in 2022 is due to lowered agricultural production.

Organic N Fertilizers (3.D.1.2)

Estimated amounts of organic N inputs applied to soils other than grazing animals was calculated using Equation 11.3 from 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Applied animal manure and sewage sludge were accounted for.

*Animal Manure applied to Soils (3.D.1.2.a.)*

The estimate is based on the amount of N in solid and liquid manure/slurry which is annually used for crop fertilization, calculated using the Equation 11.4 from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. In the Republic of Croatia, manure is not used as fuel, feed or for construction, so adjustment of the annual amount of animal manure in regards to these fractions was not necessary.

*Sewage Sludge applied to Soils (3.D.1.2.b.)*

Sufficient activity data was provided for the period 2005-2022, while for the period 1990-2004 data was not provided or could not be estimated. Current AD set is limited to data provided by privately-owned companies to the MESD. Data source is the yearly publication "Wastewater purification sludge management for the sludge used in agriculture", MESD which contains AD (tonnes applied) and average composition of the sludge and that the report on the sludge used is required for all producers/users of the aforementioned sludge according to the „Ordinance for wastewater purification sludge management for the sludge used in agriculture“ set in the Official Gazette of the Republic of Croatia. The resulting sludge is the result of their production process, thus there is no driver that can be used to obtain relevant data prior to the initial year of operation. Spreading of discharge on agricultural land is not a practice in

Croatia. Release of septic tanks is controlled by Croatian legislative regulations („Municipal management law“, Official Gazette of the Republic of Croatia 26/03, 82/04, 178/04, 38/09, 79/09, 49/11, 144/12) - authorized municipal and transport companies collect and release the content from domestic septic tanks into the public sewage system at permitted locations.

Table 5.5-3: Amount of sludge and nitrogen percentage applied

| Year | Amount of sludge applied (tons dry matter) | Average nitrogen percentage (N % in dry matter mass) |
|---|---|---|
| **2005** | 3 | 3.89% |
| **2006** | 6 | 3.89% |
| **2007** | 7 | 3.89% |
| **2008** | 16 | 3.89% |
| **2009** | 459 | 3.89% |
| **2010** | 434 | 3.89% |
| **2011** | 683 | 3.89% |
| **2012** | 956 | 3.89% |
| **2013** | 1567 | 3.89% |
| **2014** | 920 | 3.89% |
| **2015** | 1321 | 3.89% |
| **2016** | 1555 | 3.89% |
| **2017** | 1290 | 3.89% |
| **2018** | 1711 | 3.89% |
| **2019** | 624 | 3.89% |
| **2020** | 629 | 3.89% |
| **2021** | 698 | 3.89% |
| **2022** | 872 | 3.89% |

*Other Organic Fertilizers Applied to Soils (3.D.1.2.c.)*

Activity data for this category is not available for now. It is assumed that emissions from this subsector are negligibly small. Total $N_2O$ emission from the entire Waste sector contributes to the total emissions with 0.4% and only a small percent can be applied to soils. Therefore, it is concluded that emissions are below national threshold of significance.

During the initial ESD 2021 review, it was requested to provide an example emission estimate in this NIR for one year using the IPCC default emission factors and assuming (with overestimation) that all waste composted was applied to soils. Example for the year 2019 follows:

The sectoral chapter for waste category 5.B.1 (composting) explains that AD and emission factors ($CH_4$ and $N_2O$) expressed on a dry weight basis have been included in CRF table and NIR report. Data on different types of composted waste were obtained in wet weight. Due to the lack of information on the moisture content of composted waste, estimation of dry waste is performed according to the recommendation from 2006 IPCC Guidelines, Chapter 4.1.3, Table 4.1: "*The emission factor for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.*" In the table 7.3-1, total composted waste for 2019 is given as dry matter and equals to 19,844 tonnes. Converted back to fresh matter (wet waste), this amounts to total of 49,610 tonnes waste (the obtained AD).

$$WetWaste_{COMP} = 19{,}844\ (tonnes\ dry\ waste) \div\ 40\%\ = 49{,}610\ tonnes$$

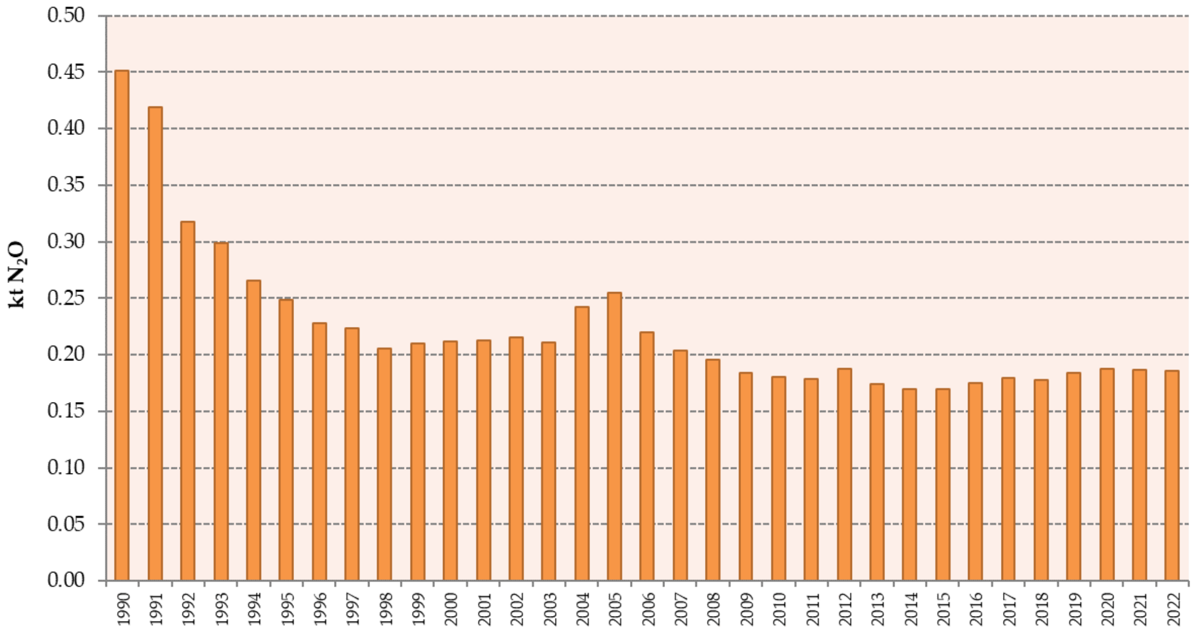
Using the default value of 0.0068 for N content of fresh matter (wet waste) in municipal waste (table 3.4 from EMEP/EEA air pollutant emission inventory guidebook 2019), default $EF_1$ (table 11.1 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories) and adjusted to $N_2O$ from $N_2O$-N this amounts to 0.0053 kt $N_2O$ (see the equations below), which is under the threshold of significance:

$$N_{COMP} = WetWaste_{COMP}(t) \times 0.0068 \times 10^3 = 337{,}348\ kg\ N$$
$$N2O_{COMP} = N_{COMP}\ (kg) \times EF_1 \times 10^{-6} \times 44 \div 28 = 0.0053\ kt\ N_2O$$

Urine and Dung deposited by Grazing Animals (3.D.1.3)

Annual amount of N input deposited on pasture, range and paddock soils by grazing animals. Equation 11.5 from 2006 IPCC Guidelines for National Greenhouse Gas Inventories was used for the estimation calculation. Data on N deposited was obtained from the Direct $N_2O$ emission from Manure Management (see Chapter 5.3.2.2 for details) using country-specific data on nitrogen excretion rates for each livestock species. Emissions of $N_2O$ follow the trend of livestock number and are being shown in Figure 5.5-4.

Figure 5.5-4: $N_2O$ emissions due to urine and dung deposited by grazing animals




Crop Residues (3.D.1.4)

Tier 1 method using Equation 11.6 from 2006 IPCC Guidelines for National Greenhouse Gas Inventories was used in calculation of nitrous oxide emission from crop residues. The estimate is based on the amount of crop residues including N-fixing crops returned to soils annually. The data on crop production were obtained from the Central Bureau of Statistics, FAO database and for certain years by extrapolation (see Table 5.5-4). National data (provided by Croatian CBS) are considered to be the most accurate source and was always used when available. For crops where national data was not available, FAO data was used. Where only a part of the national dataset was missing for a specific crop, trend of FAO data was found to be in line with the national data trends and was used for the missing years rather than interpolation. Extrapolation was used only where no national or FAO data was available. As for additional uses of crop residues, in Croatia alfalfa and clover are used as fodder. Field burning of crop residues is prohibited by law; therefore fraction of crop residue burnt is set as NO. Activity data related to crop production and harvest data is presented in Table 5.5-5.

Table 5.5-4: Data sources regarding crop production

| | Crop yield | | | Crop area | | |
|---|---|---|---|---|---|---|
| **Crop** | **CBS** | **FAO** | **Extrapolation*** | **CBS** | **FAO** | **Extrapolation*** |
| Soyabeans | 1990-2022 | | | 1990-2022 | | |
| Beans, dry | 1990-2022 | | | 1990-2022 | | |
| Cow peas, dry | 2008-2022 | 1992-2007 | 1990-1991 | 1998-1999<br>2008-2022 | 1992-1997<br>2000-2007 | 1990-1991 |
| Lentils | 1990-1991, 2020-2022 | 1992-2019 | | 1990-1998, 2020-2022 | 1999-2019 | |
| Peas, dry | 1990-2022 | | | 1990-2022 | | |
| Vetches | 1990-1997, 2020-2022 | 1998-2019 | | 1990-1997, 2020-2022 | 1998-2019 | |
| Clover | 1990-2022 | | | 1990-2022 | | |
| Alfalfa | 1990-2022 | | | 1990-2022 | | |
| Wheat | 1990-2022 | | | 1990-2022 | | |
| Maize | 1990-2022 | | | 1990-2022 | | |
| Potatoes | 1990-2022 | | | 1990-2022 | | |
| Sugar beets | 1990-2022 | | | 1990-2022 | | |
| Tobacco | 1990-2022 | | | 1990-2022 | | |
| Sunflowers | 1990-2022 | | | 1990-2022 | | |
| Rapeseed | 1990-2022 | | | 1990-2022 | | |
| Tomatoes | 1990-2022 | | | 1990-2022 | | |
| Barley | 1990-2022 | | | 1990-2022 | | |
| Oats | 1990-2022 | | | 1990-2022 | | |
| Cabbages and other brassicas | 1990-2022 | | | 1990-2022 | | |
| Garlic** | 1990-2022 | | | 1990-2022 | | |
| Onions** | 1990-2022 | | | 1990-2022 | | |
| Rye | 2014-2022 | 1992-2013 | 1990-1991 | 2014-2022 | 1992-2013 | 1990-1991 |
| Sorghum*** | 1990-1997, 2020-2022 | 1998-2019 | | 1990-1997, 2020-2022 | 1998-2019 | |
| Watermelons | 1990-2022 | | | 1990-2022 | | |

**Extrapolation was based on data for the period of 5 consecutive years.*

***CBS provides aggregated data for garlic & onions.*
*FAO data was used to calculate yearly ratios of garlic and onions in the total, aggregated number.*

****CBS did not obtain sorghum production data from 1997 to 2012*

Table 5.5-5: Production and harvest data for crops in the period from 1990 – 2022

| Year | Production of crops / tonnes/ ha | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat | | Maize | | Potatoes | | Sugar beets | | Tobacco | | Sunflowers | | Rapeseed | | Tomatoes | |
| | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha |
| 1990 | 1.602.435 | 318.955 | 1.951.066 | 503.342 | 610.236 | 77.016 | 1.205.928 | 29.872 | 12.394 | 10.105 | 52.995 | 20.971 | 33.200 | 12.647 | 54.742 | 5.801 |
| 1991 | 1.495.625 | 324.460 | 2.388.555 | 488.178 | 658.687 | 78.510 | 1.244.439 | 28.568 | 10.460 | 9.300 | 46.455 | 18.773 | 22.816 | 9.004 | 48.601 | 5.703 |
| 1992 | 658.019 | 168.865 | 1.358.084 | 370.205 | 480.079 | 60.758 | 525.105 | 16.537 | 11.651 | 8.377 | 40.414 | 18.153 | 24.183 | 11.743 | 35.262 | 4.318 |
| 1993 | 886.921 | 211.845 | 1.672.593 | 373.166 | 507.898 | 64.754 | 537.196 | 14.717 | 9.585 | 7.635 | 42.724 | 17.564 | 28.665 | 13.010 | 39.771 | 4.784 |
| 1994 | 750.330 | 198.381 | 1.686.992 | 370.517 | 563.285 | 66.356 | 591.819 | 16.043 | 8.613 | 6.659 | 26.547 | 17.871 | 28.341 | 13.889 | 46.276 | 4.959 |
| 1995 | 876.507 | 227.044 | 1.735.854 | 354.059 | 692.216 | 66.458 | 690.707 | 18.804 | 8.548 | 6.798 | 37.066 | 19.385 | 24.472 | 10.982 | 46.958 | 4.778 |
| 1996 | 741.235 | 200.852 | 1.885.515 | 360.824 | 666.020 | 65.537 | 906.246 | 20.896 | 11.272 | 7.735 | 28.526 | 18.849 | 11.661 | 7.651 | 49.019 | 4.901 |
| 1997 | 833.508 | 208.377 | 2.183.144 | 370.986 | 620.032 | 63.189 | 931.186 | 22.919 | 11.339 | 7.274 | 36.138 | 16.946 | 11.181 | 5.356 | 48.085 | 5.141 |
| 1998 | 1.020.045 | 241.734 | 1.982.545 | 377.536 | 664.753 | 64.931 | 1.233.322 | 29.287 | 12.133 | 7.445 | 62.206 | 28.642 | 21.967 | 8.949 | 62.003 | 5.765 |
| 1999 | 558.217 | 169.280 | 2.135.452 | 383.925 | 728.646 | 66.374 | 1.113.969 | 27.847 | 10.051 | 6.490 | 72.374 | 41.996 | 32.581 | 16.234 | 70.816 | 6.408 |
| 2000 | 865.260 | 182.333 | 1.190.238 | 292.431 | 198.243 | 17.237 | 482.211 | 20.985 | 9.714 | 5.678 | 53.956 | 25.715 | 29.436 | 12.886 | 15.530 | 477 |
| 2001 | 811.674 | 184.274 | 1.733.003 | 305.867 | 242.709 | 17.435 | 964.880 | 23.757 | 10.502 | 5.500 | 42.985 | 25.336 | 22.456 | 10.319 | 16.721 | 499 |
| 2002 | 822.650 | 179.153 | 1.956.418 | 306.805 | 266.055 | 17.222 | 1.183.445 | 25.149 | 10.905 | 5.489 | 62.965 | 26.835 | 25.585 | 13.041 | 15.437 | 472 |
| 2003 | 506.212 | 157.175 | 1.279.617 | 304.722 | 164.051 | 16.919 | 677.569 | 27.327 | 9.680 | 5.748 | 69.253 | 28.211 | 28.596 | 15.524 | 12.320 | 481 |
| 2004 | 801.424 | 162.634 | 1.931.627 | 306.347 | 247.057 | 16.043 | 1.260.444 | 26.503 | 10.293 | 5.394 | 68.973 | 28.328 | 31.392 | 14.282 | 15.191 | 461 |
| 2005 | 601.748 | 146.253 | 2.206.729 | 318.973 | 273.409 | 18.903 | 1.337.750 | 29.370 | 9.579 | 5.131 | 78.006 | 49.769 | 41.275 | 20.149 | 18.731 | 659 |
| 2006 | 804.601 | 175.551 | 1.934.517 | 296.195 | 274.529 | 16.759 | 1.559.737 | 31.881 | 10.851 | 4.940 | 81.614 | 35.308 | 19.996 | 8.413 | 16.507 | 461 |
| 2007 | 812.347 | 175.045 | 1.424.599 | 288.549 | 296.302 | 17.355 | 1.582.606 | 34.316 | 12.639 | 6.005 | 54.303 | 20.615 | 39.330 | 13.069 | 30.779 | 920 |
| 2008 | 858.333 | 156.536 | 2.504.940 | 314.062 | 255.554 | 15.000 | 1.269.536 | 22.000 | 12.866 | 5.897 | 119.872 | 38.631 | 62.942 | 22.372 | 17.327 | 689 |
| 2009 | 936.076 | 180.376 | 2.182.521 | 296.910 | 270.251 | 14.000 | 1.217.041 | 23.066 | 13.348 | 6.062 | 82.098 | 27.366 | 80.424 | 28.723 | 22.082 | 690 |
| 2010 | 681.017 | 168.507 | 2.067.815 | 296.768 | 178.611 | 10.950 | 1.249.151 | 23.832 | 8.491 | 4.119 | 61.789 | 26.412 | 33.047 | 16.339 | 22.279 | 499 |
| 2011 | 782.499 | 149.797 | 1.733.664 | 305.130 | 167.524 | 10.881 | 1.168.015 | 21.723 | 10.643 | 5.905 | 84.960 | 30.041 | 49.483 | 17.536 | 23.585 | 595 |
| 2012 | 999.681 | 186.949 | 1.297.590 | 299.161 | 151.278 | 10.232 | 919.230 | 23.502 | 11.787 | 5.958 | 90.019 | 33.534 | 26.406 | 9.893 | 18.438 | 448 |
| 2013 | 998.940 | 204.506 | 1.874.372 | 288.365 | 162.501 | 10.234 | 1.050.715 | 20.245 | 9.834 | 5.172 | 130.576 | 40.805 | 47.827 | 17.972 | 26.026 | 583 |
| 2014 | 648.917 | 156.139 | 2.046.966 | 252.567 | 160.847 | 10.310 | 1.392.000 | 21.900 | 9.164 | 5.196 | 99.489 | 34.869 | 71.228 | 23.122 | 19.374 | 319 |
| 2015 | 758.638 | 140.986 | 1.709.152 | 263.970 | 171.179 | 10.047 | 756.509 | 13.883 | 10.132 | 4.752 | 94.075 | 34.494 | 56.783 | 21.977 | 36.273 | 423 |
| 2016 | 960.081 | 168.029 | 2.154.470 | 252.072 | 193.962 | 9.866 | 1.169.622 | 15.493 | 8.977 | 4.413 | 110.566 | 40.254 | 112.990 | 36.778 | 24.571 | 370 |
| 2017 | 682.322 | 116.151 | 1.559.638 | 247.119 | 156.089 | 9.833 | 1.295.459 | 19.533 | 9.413 | 4.563 | 115.880 | 37.152 | 135.810 | 48.616 | 32.456 | 451 |
| 2018 | 738.363 | 135.708 | 2.147.275 | 235.352 | 182.261 | 9.272 | 776.491 | 14.066 | 7.561 | 3.834 | 110.790 | 37.128 | 155.842 | 55.032 | 22.642 | 491 |
| 2019 | 789.950 | 141.602 | 2.298.316 | 255.887 | 173.149 | 9.387 | 708.575 | 11.583 | 7.878 | 3.940 | 106.555 | 35.982 | 103.900 | 41.361 | 22.018 | 321 |
| 2020 | 849.656 | 145.053 | 2.430.598 | 288.398 | 174.279 | 9.325 | 774.331 | 10.458 | 7.084 | 3.420 | 120.016 | 39.001 | 119.667 | 41.661 | 33.369 | 404 |
| 2021 | 961.940 | 143.535 | 2.242.119 | 287.976 | 127.826 | 8.786 | 707.000 | 10.066 | 7.384 | 3.488 | 124.363 | 40.969 | 73.423 | 30.281 | 18.785 | 292 |
| 2022 | 947,615 | 157,864 | 1,641,893 | 268,054 | 103,400 | 7,368 | 572,186 | 8,889 | 6,303 | 3,036 | 152,894 | 51,112 | 58,067 | 22,402 | 25,843 | 348 |

Table 5.5-5: Production and harvest data for crops in the period from 1990 – 2022 (cont.)

| Year | Production of crops / tonnes/ ha | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barley | | Oats | | Cabbages and other | | Garlic | | Onions | | Rye | | Sorghum | | Watermelons | |
| | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha |
| 1990 | 196,554 | 51,565 | 62,287 | 25,495 | 122,045 | 10,174 | 12,214 | 3,647 | 39,925 | 7,000 | 15,840 | 3,053 | 17 | 176 | 20,938 | 1,898 |
| 1991 | 185,695 | 51,643 | 53,851 | 23,425 | 116,540 | 10,445 | 11,095 | 3,546 | 37,864 | 7,100 | 14,069 | 2,974 | 1,401 | 146 | 17,941 | 2,119 |
| 1992 | 106,811 | 32,873 | 45,262 | 17,582 | 68,422 | 7,745 | 6,744 | 2,304 | 28,717 | 5,082 | 6,069 | 2,252 | 17 | 140 | 8,062 | 682 |
| 1993 | 125,671 | 36,605 | 41,074 | 17,204 | 79,828 | 8,559 | 7,345 | 2,439 | 31,081 | 5,417 | 6,273 | 2,453 | 31 | 147 | 8,014 | 767 |
| 1994 | 107,810 | 36,225 | 42,425 | 18,493 | 95,791 | 8,788 | 9,346 | 2,543 | 40,896 | 5,955 | 7,146 | 2,963 | 23 | 136 | 16,045 | 1,141 |
| 1995 | 103,281 | 32,518 | 38,237 | 15,763 | 116,879 | 8,858 | 9,384 | 2,419 | 43,010 | 5,842 | 5,051 | 1,930 | 18 | 133 | 21,384 | 1,382 |
| 1996 | 88,091 | 31,034 | 39,529 | 16,290 | 122,635 | 8,767 | 8,820 | 2,474 | 39,421 | 5,852 | 5,517 | 2,043 | 18 | 12 | 26,901 | 1,867 |
| 1997 | 108,496 | 33,759 | 46,796 | 18,142 | 134,323 | 9,011 | 9,002 | 2,460 | 43,776 | 6,033 | 5,009 | 1,959 | 12 | 128 | 25,450 | 1,847 |
| 1998 | 143,510 | 42,737 | 56,110 | 21,669 | 129,674 | 9,247 | 10,624 | 2,651 | 51,662 | 6,565 | 5,530 | 2,146 | 546 | 130 | 60,243 | 2,599 |
| 1999 | 124,890 | 44,517 | 56,823 | 24,124 | 144,018 | 9,701 | 10,277 | 2,670 | 55,633 | 6,797 | 6,246 | 2,446 | 569 | 139 | 53,437 | 2,890 |
| 2000 | 179,652 | 55,511 | 61,604 | 26,042 | 27,351 | 1,390 | 1,468 | 187 | 8,145 | 656 | 7,236 | 2,738 | 565 | 141 | 24,044 | 929 |
| 2001 | 192,067 | 61,267 | 71,632 | 26,103 | 25,777 | 1,230 | 2,034 | 210 | 11,929 | 764 | 10,796 | 2,981 | 572 | 153 | 24,044 | 971 |
| 2002 | 206,478 | 61,165 | 74,187 | 24,484 | 29,770 | 1,397 | 1,889 | 193 | 11,298 | 699 | 9,207 | 3,244 | 554 | 150 | 26,417 | 1,038 |
| 2003 | 160,203 | 65,001 | 53,025 | 25,300 | 27,368 | 1,281 | 1,572 | 193 | 9,276 | 690 | 5,967 | 2,960 | 697 | 180 | 15,183 | 933 |
| 2004 | 237,603 | 67,538 | 73,462 | 23,457 | 26,310 | 1,225 | 1,864 | 360 | 11,309 | 448 | 8,994 | 2,869 | 624 | 189 | 22,411 | 865 |
| 2005 | 162,530 | 50,341 | 49,470 | 21,185 | 40,525 | 1,826 | 2,379 | 596 | 14,033 | 484 | 4,737 | 1,848 | 600 | 200 | 27,191 | 923 |
| 2006 | 215,262 | 59,159 | 66,630 | 24,914 | 42,193 | 1,628 | 2,770 | 619 | 16,392 | 432 | 5,487 | 2,008 | 800 | 300 | 25,593 | 966 |
| 2007 | 225,265 | 59,000 | 56,150 | 27,967 | 32,477 | 1,856 | 3,390 | 786 | 20,084 | 391 | 4,364 | 1,731 | 1,200 | 400 | 26,017 | 1,171 |
| 2008 | 279,106 | 65,536 | 65,328 | 19,873 | 43,492 | 3,084 | 3,725 | 958 | 22,349 | 477 | 4,079 | 1,367 | 760 | 217 | 33,643 | 1,393 |
| 2009 | 243,609 | 59,584 | 62,297 | 20,901 | 59,208 | 3,123 | 3,680 | 708 | 21,879 | 352 | 2,860 | 998 | 1,130 | 455 | 42,280 | 1,556 |
| 2010 | 172,359 | 52,524 | 48,190 | 19,280 | 33,839 | 1,571 | 3,198 | 600 | 19,594 | 239 | 2,507 | 1,035 | 1,000 | 390 | 21,679 | 849 |
| 2011 | 193,961 | 48,318 | 77,223 | 25,344 | 34,963 | 1,806 | 2,728 | 687 | 19,569 | 562 | 2,949 | 871 | 1,280 | 400 | 19,902 | 727 |
| 2012 | 235,778 | 56,905 | 94,542 | 28,514 | 21,106 | 1,187 | 3,287 | 543 | 19,646 | 301 | 2,426 | 846 | 1,372 | 384 | 20,226 | 685 |
| 2013 | 201,339 | 53,796 | 60,178 | 21,656 | 35,033 | 1,723 | 3,621 | 768 | 20,478 | 612 | 2,955 | 1,019 | 989 | 197 | 30,327 | 818 |
| 2014 | 175,592 | 46,160 | 56,555 | 21,146 | 24,703 | 850 | 4,272 | 548 | 24,160 | 436 | 2,800 | 1,373 | 0 | 0 | 25,598 | 791 |
| 2015 | 193,451 | 43,700 | 71,743 | 23,462 | 38,413 | 1,484 | 4,634 | 234 | 26,204 | 940 | 3,356 | 1,093 | 136 | 34 | 15,771 | 608 |
| 2016 | 263,165 | 56,483 | 80,414 | 26,572 | 37,315 | 1,492 | 1,297 | 245 | 25,093 | 906 | 4,646 | 1,285 | 206 | 58 | 19,908 | 682 |
| 2017 | 260,426 | 53,950 | 68,333 | 23,139 | 34,872 | 1,994 | 1,172 | 235 | 15,048 | 800 | 2,566 | 774 | 114 | 36 | 19,707 | 683 |
| 2018 | 227,520 | 50,988 | 44,827 | 15,885 | 38,766 | 1,816 | 1,733 | 405 | 21,098 | 800 | 4,100 | 1,292 | 152 | 46 | 27,737 | 968 |
| 2019 | 275,397 | 53,662 | 57,585 | 18,499 | 34,280 | 1,668 | 2,883 | 412 | 18,266 | 789 | 4,100 | 1,292 | 152 | 46 | 20,297 | 665 |
| 2020 | 321,776 | 66,329 | 321,776 | 19,397 | 38,533 | 1,565 | 1,972 | 266 | 16,351 | 607 | 4,367 | 1,058 | 244 | 80 | 15,594 | 530 |
| 2021 | 306,209 | 56,478 | 306,209 | 17,063 | 31,380 | 1,347 | 2,870 | 265 | 16,174 | 649 | 2,082 | 511 | 121 | 42 | 21,476 | 720 |
| 2022 | 318,202 | 63,067 | 318,202 | 15,925 | 28,484 | 1,370 | 973 | 215 | 12,484 | 594 | 2,865 | 820 | 36 | 24 | 23,819 | 1,002 |

Table 5.5-5: Production and harvest data for crops in the period from 1990 – 2022 (cont.)

| Year | Production of crops / tonnes/ ha | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soybeans | | Beans, dry | | Cowpeas, dry | | Lentils | | Peas, dry | | Vetches | | Clover | | Alfalfa | |
| | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha | tonnes | ha |
| 1990 | 55,461 | 27,260 | 18,437 | 8,132 | 1,790 | 153 | 202 | 115 | 1,000 | 3,402 | 3,457 | 1,148 | 225,466 | 54,785 | 252,563 | 56,801 |
| 1991 | 56,365 | 22,840 | 21,949 | 8,921 | 1,521 | 149 | 164 | 114 | 987 | 3,174 | 3,190 | 1,052 | 226,546 | 52,902 | 251,486 | 57,323 |
| 1992 | 46,129 | 26,220 | 15,961 | 5,980 | 895 | 186 | 205 | 92 | 812 | 2,597 | 2,125 | 871 | 129,747 | 35,665 | 142,613 | 36,769 |
| 1993 | 49,456 | 21,424 | 17,588 | 6,514 | 1,651 | 270 | 155 | 78 | 339 | 2,738 | 2,160 | 706 | 136,012 | 36,733 | 137,225 | 36,554 |
| 1994 | 44,127 | 20,435 | 20,596 | 6,958 | 441 | 120 | 167 | 86 | 400 | 2,899 | 2,509 | 741 | 155,087 | 36,595 | 162,457 | 37,519 |
| 1995 | 34,319 | 15,018 | 21,844 | 6,733 | 400 | 100 | 92 | 78 | 853 | 2,915 | 2,210 | 674 | 143,910 | 35,047 | 158,557 | 37,350 |
| 1996 | 35,896 | 16,423 | 20,221 | 6,975 | 669 | 166 | 123 | 89 | 611 | 2,787 | 2,386 | 690 | 165,973 | 36,632 | 188,462 | 40,464 |
| 1997 | 39,469 | 16,030 | 20,527 | 7,521 | 683 | 171 | 135 | 89 | 577 | 3,041 | 1,921 | 637 | 157,559 | 35,640 | 179,669 | 39,428 |
| 1998 | 77,458 | 34,015 | 21,003 | 5,946 | 670 | 234 | 143 | 90 | 746 | 562 | 2,396 | 757 | 158,516 | 36,396 | 201,778 | 41,759 |
| 1999 | 115,853 | 46,336 | 22,291 | 6,581 | 400 | 501 | 129 | 81 | 824 | 660 | 2,400 | 720 | 167,266 | 36,424 | 223,387 | 42,939 |
| 2000 | 65,299 | 47,484 | 2,657 | 7,470 | 591 | 153 | 124 | 78 | 913 | 555 | 2,400 | 720 | 100,179 | 21,198 | 85,575 | 17,238 |
| 2001 | 91,841 | 41,621 | 4,421 | 7,149 | 400 | 100 | 130 | 83 | 1,930 | 778 | 2,300 | 700 | 115,709 | 20,621 | 98,305 | 18,162 |
| 2002 | 129,470 | 47,897 | 5,163 | 7,104 | 400 | 100 | 117 | 75 | 2,082 | 872 | 2,268 | 716 | 131,103 | 20,470 | 107,815 | 17,279 |
| 2003 | 82,591 | 49,860 | 4,967 | 6,826 | 400 | 100 | 113 | 72 | 1,155 | 889 | 2,295 | 725 | 51,890 | 20,604 | 72,056 | 17,186 |
| 2004 | 97,923 | 36,979 | 4,459 | 6,137 | 400 | 100 | 110 | 71 | 1,859 | 813 | 2,299 | 728 | 124,813 | 19,921 | 103,555 | 16,712 |
| 2005 | 119,602 | 48,211 | 6,041 | 6,477 | 647 | 174 | 113 | 72 | 893 | 447 | 2,340 | 744 | 125,460 | 19,779 | 147,272 | 25,411 |
| 2006 | 174,214 | 62,810 | 4,058 | 6,367 | 400 | 100 | 140 | 100 | 715 | 326 | 2,400 | 750 | 121,411 | 19,134 | 162,694 | 26,282 |
| 2007 | 90,637 | 46,506 | 2,503 | 4,451 | 400 | 100 | 100 | 64 | 670 | 374 | 2,300 | 700 | 111,675 | 20,948 | 137,291 | 23,959 |
| 2008 | 107,558 | 35,789 | 3,263 | 2,147 | 1,149 | 371 | 41 | 41 | 870 | 351 | 2,071 | 672 | 176,089 | 24,683 | 196,244 | 25,265 |
| 2009 | 115,159 | 44,292 | 2,460 | 1,947 | 1,468 | 656 | 74 | 41 | 955 | 372 | 2,000 | 658 | 147,763 | 23,347 | 174,274 | 26,544 |
| 2010 | 153,580 | 56,456 | 1,641 | 1,276 | 1,197 | 577 | 29 | 16 | 340 | 221 | 2,098 | 700 | 119,969 | 20,472 | 177,652 | 27,207 |
| 2011 | 147,271 | 58,896 | 1,059 | 1,232 | 1,939 | 614 | 82 | 56 | 696 | 252 | 1,700 | 700 | 105,075 | 21,176 | 153,240 | 25,126 |
| 2012 | 96,718 | 54,109 | 472 | 788 | 1,863 | 798 | 22 | 11 | 404 | 139 | 0 | 0 | 83,817 | 20,270 | 124,055 | 24,803 |
| 2013 | 111,316 | 47,156 | 1,480 | 1,097 | 1,378 | 721 | 80 | 44 | 189 | 154 | 0 | - | 82,844 | 16,783 | 177,857 | 25,694 |
| 2014 | 131,424 | 47,104 | 1,329 | 1,483 | 1,413 | 678 | 83 | 29 | 579 | 219 | 0 | - | 70,873 | 10,497 | 128,702 | 22,116 |
| 2015 | 196,431 | 88,867 | 1,156 | 1,475 | 1,346 | 600 | 60 | 27 | 194 | 94 | 0 | - | 82,992 | 9,549 | 112,876 | 18,386 |
| 2016 | 244,075 | 78,614 | 1,461 | 1,574 | 3,985 | 1543 | 50 | 25 | 246 | 71 | DATA NOT AVAILABLE | - | 67,853 | 9,920 | 191,540 | 23,559 |
| 2017 | 207,765 | 85,133 | 1,340 | 1,539 | 2,347 | 938 | 46 | 22 | 142 | 71 | DATA NOT AVAILABLE | - | 24,861 | 5,326 | 187,917 | 26,057 |
| 2018 | 245,188 | 77,087 | 1,737 | 1,403 | 2,223 | 915 | 52 | 25 | 314 | 147 | DATA NOT AVAILABLE | - | 67,946 | 10,223 | 186,490 | 24,248 |
| 2019 | 244,279 | 78,334 | 1,381 | 1,113 | 2,870 | 1181 | 52 | 25 | 499 | 143 | DATA NOT AVAILABLE | - | 50,833 | 8,437 | 193,318 | 29,006 |
| 2020 | 266,014 | 86,185 | 1,325 | 984 | 1,629 | 602 | 0 | 0 | 170 | 130 | 0 | 0 | 60,049 | 9,332 | 201,460 | 26,337 |
| 2021 | 227,872 | 86,259 | 1,061 | 1,195 | 2,331 | 792 | 0 | 0 | 319 | 68 | 0 | 0 | 46,986 | 8,425 | 179,680 | 28,128 |
| 2022 | 194,771 | 90,669 | 814 | 930 | 1,163 | 598 | 0 | 0 | 279 | 76 | 0 | 0 | 35,849 | 6,793 | 181,89 | 27,14 |

By comparing all trends, the highest fluctuations can be noticed in regard to dry cowpeas, dry peas and soybeans. Production of dry cowpeas and dry peas is obtained from several different sources which resulted in the aforementioned trend fluctuation. Years 2000 and 2003 were very hot and dry which had a negative effect on soybeans production along with the changes in the seed market. Related fluctuations between 2006 and 2007 are caused by changes in harvested area and yield per hectare. Soybeans production increased from 2014 onwards, with a peak production figures in 2016. Higher fluctuations in trend have also been noticed for sunflower, tomato and rapeseed. The latter is primarily caused by changes in harvested area and in some cases changes in yield per hectare. Highest production year for maize was in 2008, which also correlates with the mineral fertilizer consumption trend.

Default crop specific factors were used from Table 11.2 of 2006 IPCC Guidelines for the emission calculation, except for dry matter fraction where a combination of sources were used, as presented in the Table 5.5-6. Slovenian, Portuguese and Hungarian NIRs were selected as a source for the dry matter fraction values due to the similarities and comparability of growing conditions for the selected crops for which national dry matter fraction data (*Znaor, D*) are not available. Dry matter fraction needed to be incorporated so that adjustments for moisture contents could be made.

Table 5.5-6: Dry matter fraction for crops

| Crop | dry matter fraction |
|---|---|
| Soybeans | 0.86 |
| Beans, dry | 0.895 |
| Cowpeas, dry | 0.85 |
| Lentils | 0.85 |
| Peas, dry | 0.87 |
| Vetches | 0.85 |
| Clover | 0.85 |
| Alfalfa | 0.85 |
| Wheat | 0.86 |
| Maize | 0.86 |
| Potatoes | 0.30 |
| Sugar beets | 0.25 |
| Tobacco | 0.89 |
| Sunflowers | 0.92 |
| Rapeseed | 0.90 |
| Tomatoes | 0.063 |
| Barley | 0.86 |
| Oats | 0.92 |
| Cabbages and other brassicas | 0.135 |
| Garlic | 0.354 |
| Onions, dry | 0.142 |
| Rye | 0.900 |
| Sorghum | 0.910 |
| Watermelons and melons | 0.850 |

GPG default values

Expert judgement (Faculty of Agriculture)

Values from Slovenian NIR

Values from Portuguese NIR

Values from Hungarian NIR

Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Content (3.D.1.5)

For the estimation of $N_2O$ direct emissions from managed soils concerning loss of soil organic matter resulting from change of land use or management of mineral soils, equation 11.8 from 2006 IPCC Guidelines was applied:

$$F_{SOM} = \sum_{LU} \left[ \left( \Delta C_{Mineral,LU} * \frac{1}{R} \right) * 1000 \right]$$

Where:

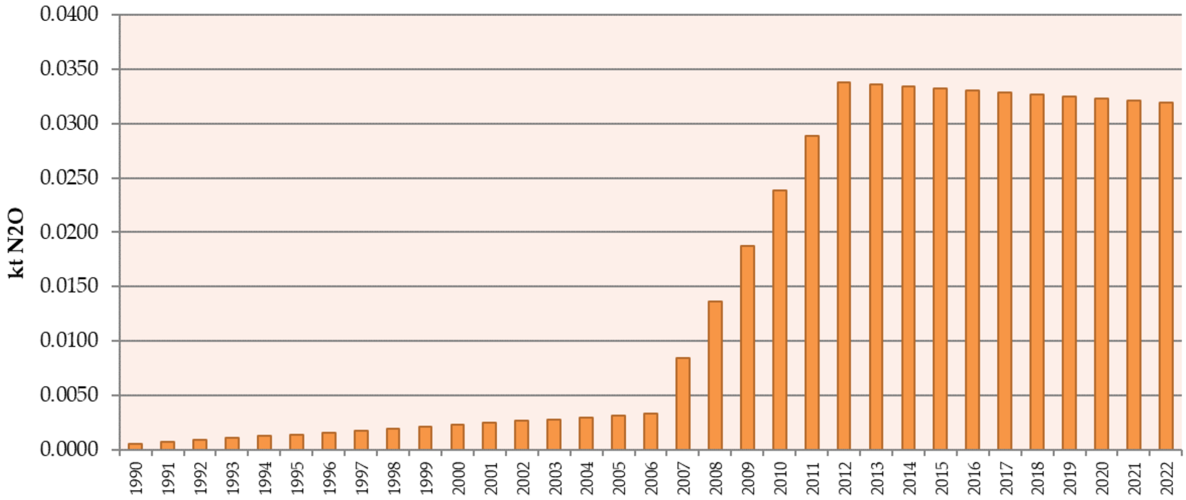
FSOM = the net annual amount of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, [kg, N]

ΔCMineral, LU = average annual loss of soil carbon for each land-use type (LU), [tonnes C]

R = C : N ratio of the soil organic matter

This equation was applied in case of management changes in cropland remaining cropland, for conversion from perennial cropland to annual cropland. All others Direct $N_2O$ emissions due to land-use changes and loss/gain of soil organic matter are reported under LULUCF chapter i.e. CRF Table 4(III).

Figure 5.5-5: $N_2O$ Emissions due to Loss/Gain of Soil Organic Content




Cultivation of Organic Soils (3.D.1.6)

Cultivation of soils with high content of organic material causes the release of a long term bounded N. Activity data regarding the area of histosols in the Republic of Croatia have been obtained from the Ministry of Economy and Sustainable Development, based on information available from ARKOD (Croatian Land Parcel Identification System – LPIS). Resulting in total histosol area amounts to 2685.49 ha. According to expert judgment by Ministry of Economy and Sustainable Development, this value is accurate on a national level and can be used for each year in the entire period.

#### 5.5.1.3. Uncertainties and time-series consistency

Uncertainty estimates are based on expert judgement and IPCC values on default EF. Uncertainty of activity data is 30% for mineral fertilizers, ±10% for animal manure, N-fixing crops and crop residues while for histosols it is ±20%. The expert judgement used for the uncertainty of the AD is based on the authority of the AD source (lower uncertainty for high authority CBS source, higher for FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty of emission factors is within the default range of -70% to +200% for mineral fertilizers, animal manure, mineralization/immobilization associated with loss/gain of soil organic matter, N-fixing crops and crop residues, , while for histosols is up to ±500% (using default EF IPCC values). Direct $N_2O$ emissions from agricultural soils have been calculated using the same method and data sets for every year in the time series.

Data on the production of crops were obtained from the Central Bureau of Statistics and FAO database. Croatian CBS is considered to be the most accurate data source and CBS AD was always used when available. For crops where national data was not available, FAO data was considered an adequate replacement source following trend analysis. Where only a part of the national dataset was missing for a specific crop, trend of FAO data was found to be in line with the national data trends, with no outliers.

For mineral fertilizers, data on the consumption of mineral fertilisers that are produced and applied in Croatia were obtained from companies that produces synthetic fertilizers for the time period 1992-2022 and compared with the available 2000-2022 data from CBS and found to be inline.

#### 5.5.1.4. Category-specific QA/QC and verification

During the preparation of inventory submission, activity data for the entire time series were checked and revised if found necessary, including the FAO data. National Inventory Reports of countries with similar climate and soil conditions were consulted and checked for values on dry matter fraction, residue/crop ratio and N fraction for non-N-fixing crops. Therefore, activities related to quality control were focused on completeness and consistency of emission estimates. After a final draft of this chapter was prepared, an audit was carried out to check selected activities from Tier 1 General inventory level QC procedures which revealed that most of the activities were correctly carried out, during inventory preparation, despite the fact that formal QC procedures were not prepared.

#### 5.5.1.5. Category-specific recalculations

Animal Manure applied to Soils (3.D.1.2.a)

Emissions were recalculated for the entire 2016-2019 period and year 2021 due to corrections of estimate in for 3B source. See Chapter 5.3.2.5 for details. Impact of all aforementioned recalculations of the total 3.D.1 source emissions is presented in table 5.5-7.

Table 5.5-7: Emission difference of CRF 3.D.1 source due to the recalculations

| (CRF 3.D.1) | 2016 | 2017 | 2018 | 2019 | 2021 |
|---|---|---|---|---|---|
| kt $CO_2$-eq | -2.03 | -2.05 | -2.05 | -2.13 | -0.76 |
| % | -0.32% | -0.29% | -0.28% | -0.29% | -0.10% |

#### 5.5.1.6. Category-specific planned improvement

Planned improvements assumed to be mid-term or long-term goals (over 1 year):

- Continued improvements and investigation of activity data (mineral fertilizer, crop production, sewage sludge) with the purpose of a more detailed explanation of the activity data trends and further verification of source data.
- Improving emission calculation from agricultural soils due to mineral fertilizers.

### 5.5.2. Indirect $N_2O$ Emissions from Managed Soils (CRF 3.D.2.)

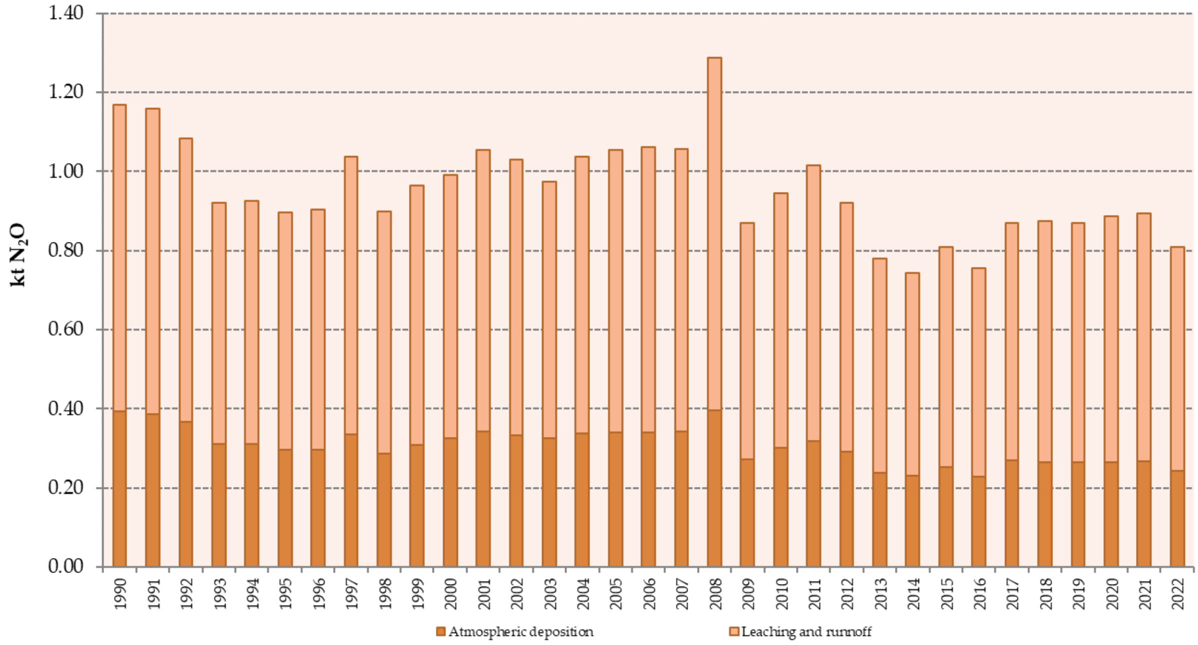
#### 5.5.2.1. Category description

Calculations of indirect $N_2O$ emission from nitrogen used in agriculture are based on two pathways. These are:

- volatilization and subsequent atmospheric deposition of $NH_3$
- leaching and runoff of the nitrogen that is applied to or deposited on soils

Volatilisation of N as $NH_3$ and oxides of N (NOx), and the deposition of these gases and their products $NH_4^+$ and $NO_3^-$ onto soils and the surface of lakes and other waters. Leaching and runoff from land of N from synthetic and organic fertiliser additions, crop residues, mineralisation of N associated with loss of soil C in mineral and drained/managed organic soils through land-use change or management practices, and urine and dung deposition from grazing animals. Some of the inorganic N in or on the soil, mainly in the $NO_3^-$ form, may bypass biological retention mechanisms in the soil/vegetation system by transport in overland water flow (runoff) and/or flow-through soil macropores or pipe drains. Indirect emissions of $N_2O$ from managed soils for the period from 1990 to 2022 are shown in Figure 5.5-6.

Figure 5.5-6: Indirect $N_2O$ emissions from Managed Soils




#### 5.5.2.2. Methodological issues

<u>Atmospheric deposition due to volatilization</u>

$N_2O$ emissions from atmospheric deposition of N volatilised from managed soil were estimated using Tier 1 methodology, using Equation 11.9 from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, using default emission factors and fractions.

<u>Nitrogen leaching and run-off</u>

$N_2O$ emissions resulting from nitrogen from fertilizers and other agricultural inputs that is lost through leaching and run-off were estimated using Tier 1 methodology, using Equation 11.10 from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, using default emission factors and fractions.

#### 5.5.2.3. Uncertainty and time-series consistency

The uncertainty of the calculation is conditioned by the use of emission factors recommended by the methodology and the input data unreliability. According to the bibliography, the uncertainty of the recommended emission factors is high. Uncertainty estimate associated with activity data amounts to a maximum of ±30 % (see Chapters 5.3.2.3 and 5.5.1.3, Uncertainties and time-series consistency for $N_2O$ emissions from Manure Management and Direct $N_2O$ Emissions from Agricultural Soils). Uncertainty estimate associated with emission factors amounts to 400 %, according to information on default factors uncertainty range provided in the IPCC Guidelines. Indirect $N_2O$ emissions have been calculated using the same method and data sets for every year in the time series.

#### 5.5.2.4. Category-specific QA/QC and verification

There is no category-specific information, QA/QC for this category is shared and presented in Chapters 5.3.2.4 and 5.5.1.4. ($N_2O$ emissions from Manure Management and Direct $N_2O$ Emissions from Agricultural Soils, respectively).

#### 5.5.2.5. Category-specific recalculations

Emissions were recalculated for the 2016-2019 period and year 2021 due to AD changes and improvements made in source: Manure Management – $N_2O$ Emissions (CRF 3.B.2). See Chapter 5.3.2.5 for recalculation explanations. Impact of all recalculations of the total 3.D.2 source emissions compared to the last submission is presented in Table 5.5-8.

Table 5.5-8: Emission difference of CRF 3.D.2 source due to the recalculations

| (CRF 3.D.2) | 2016 | 2017 | 2018 | 2019 | 2021 |
|---|---|---|---|---|---|
| kt $CO_2$-eq | -0.84 | -0.86 | -0.85 | -0.89 | -0.30 |
| % | -0.42% | -0.37% | -0.37% | -0.38% | -0.13% |

#### 5.5.2.6. Category-specific planned improvement

Planned improvements in this category are shared with the planned improvements for the $N_2O$ Emissions from Manure Management (Chapter 5.3.1) and Direct emission from agricultural soils (Chapter 5.5.1).

## 5.6. Prescribed burning of savannas (CRF 3.E.)

### 5.6.1. Category description

The term savannah refers to tropical and subtropical vegetation formations with predominantly continuous grass cover with an occasional tree or shrub interruption of the grass matrix. Large scale burning takes place primarily in the humid savannas since dry savannas lack sufficient grass cover to sustain fire. Savannas are intentionally burned during the dry season for agricultural purposes, mostly to encourage new grass growth for animal grazing. There are no ecosystems in the Republic of Croatia that could be considered natural savannas and no intentional burning of savannas occurs; no greenhouse gas emissions exist for this sub-category.

## 5.7. Field burning of agricultural residues (CRF 3.F.)

### 5.7.1. Category description

Burning of agricultural wastes (e.g., woody crop and cereal residues, crop processing residues) in the fields is common practice in developing countries and is present in some developed countries.

This activity is strictly prohibited by Croatian legislative regulations („Ordnance on good agricultural and environmental conditions“, Official Gazette of the Republic of Croatia 89/11, 65/13); the emission generated by burning agricultural residues was not included in the calculation.

## 5.8. Liming (CRF 3.G.)

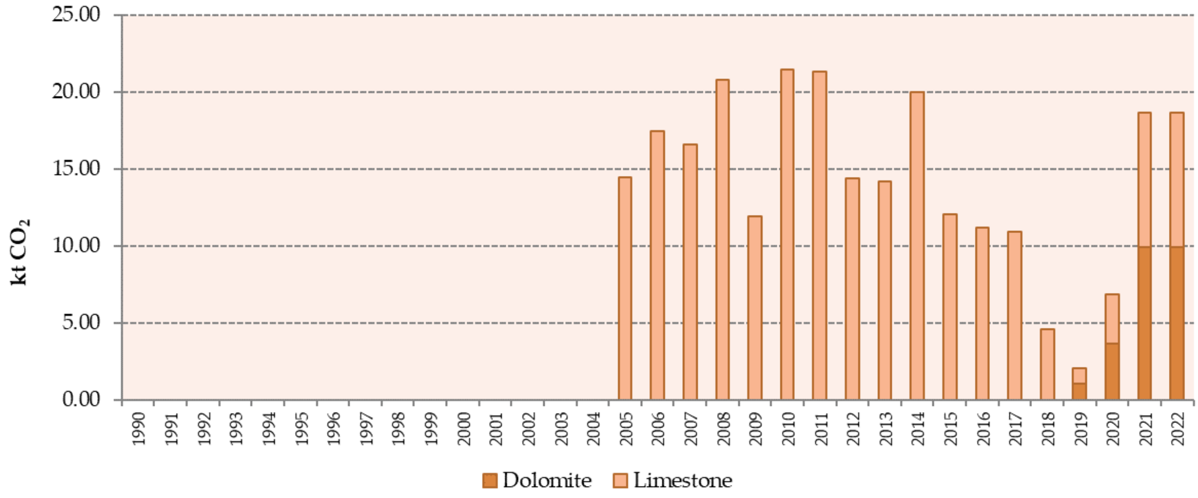
### 5.8.1. Category description

The application of carbocalk on agricultural soils was estimated for NIR 2014 for the first time. Data that are collected come from the sugar factories in Croatia in which carbocalk has been produced as only byproduct during the technological process of sugar production until 2019. Based on the new available information, carbocalk coming from sugar factories was only kind of lime applied on agricultural lands in Croatia until 2019. According to the information from fields, all carbocalk that has been produced in one year has been applied on agricultural lands in the same year. Due to the fact that sugar factories in Croatia are placed in areas with acidic soils (in cities Osijek, Virovitica and Zupanja), and the fact that all produced carbocalk is given for a free to local farmers, all quantities of lime produced are applied on soils. This has been practice in Croatia since 2005 in case of one sugar factory, and in case of another sugar factory since 2010 ( and it is connected with improvements in sugar production introduced by sugar factories). Before that, carbocalk produced in sugar factories was discharged into a water sewerage system which remained the standard practice in case of one factory.

These practices changed in recent years where one sugar factory is not active anymore and all lime produced in another factory has been sold outside of Croatia. Only the lime produced in third sugar factory and applied on agricultural soils in Croatia has been reported here. According to the new input data, until 2018 only limestone was used for sugar purification purposes. The new input data for 2019 and 2020 indicated the calcium magnesium carbonate has been also used for sugar purification purposes since 2019. For this year reporting the emissions due to carbocalk application as well as emissions due to the application of calcium magnesium carbonate in 2019 and 2020 were also estimated and presented in corresponding CRF tables. In case of calcium magnesium carbonate in period 1990-2018 NO is reported in CRF tables. In addition, previously reported emissions due to carbocalk application on soils in 2019 were corrected in line with the new activity data for this type of lime. No further investigation on this issue has been foreseen.

$CO_2$ emissions from liming for the period from 1990 to 2022 are presented in Figure 5.8-1.

Figure 5.8-1: Direct $CO_2$ emissions from Liming




### 5.8.2. Methodological issues

Estimation due to liming was performed using the 2006 IPCC Guidelines equation 11.12 and default emission factors.

### 5.8.3. Uncertainties and time-series consistency

The uncertainty of the calculation is conditioned by the use of emission factors recommended by the methodology and the input data unreliability. According to the bibliography, the uncertainty of the recommended emission factors is high.

### 5.8.4. Category-specific QA/QC and verification

There is no category-specific QA/QC information for liming. It has been included in the overall QA/QC system of the Croatian GHG inventory.

### 5.8.5. Category-specific recalculations

No recalculations were performed.

### 5.8.6. Category-specific planned improvement

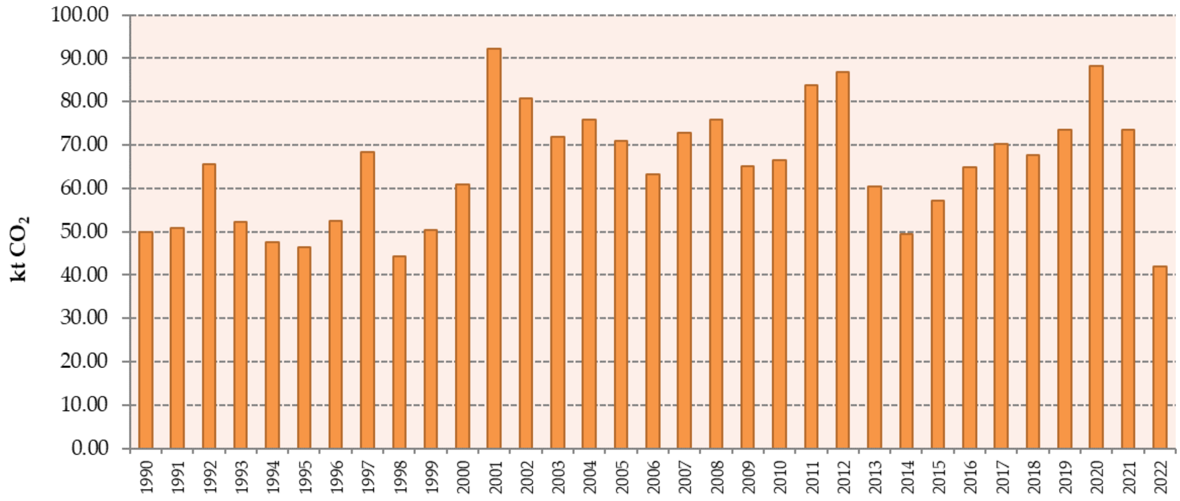
There is no improvement plan for this category.

## 5.9. Urea application (CRF 3.H.)

### 5.9.1. Category description

In addition to direct $N_2O$ emissions from managed soils, adding urea during fertilization results in conversion of $(CO(NH_2)_2)$ into ammonium ($NH_4^+$), hydroxyl ion ($OH^-$), and bicarbonate ($HCO_3^-$), in the presence of water and urease enzymes. Similar to the soil reaction following the addition of lime, bicarbonate that is formed evolves into $CO_2$ and water. This source category is included because the $CO_2$ removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector). Emission of $CO_2$ from urea application for the period from 1990 to 2022 is shown in Figure 5.9-1.

Figure 5.9-1: Direct $CO_2$ emissions from Urea Application




### 5.9.2. Methodological issues

$CO_2$ emissions resulting from nitrogen from fertilizers and other agricultural inputs that is lost through leaching and run-off were estimated using Tier 1 methodology, using Equation 11.13 from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, using default emission factors.

Activity data for applied urea was obtained from companies that produce synthetic fertilizers like urea and urea ammonium nitrate solutions. Entire proportion of urea and urea ammonium nitrate solutions was assumed to be urea for conversion of $CO_2$-C emissions to $CO_2$, according to Good Practice Guidance provided by 2006 IPCC Guidelines.

Table 5.9-1: Ammount of urea applied to soils

| Year | Urea applied / tonnes | Year | Urea applied / tonnes |
|---|---|---|---|
| **1990** | 68,209 | **2007** | 99,165 |
| **1991** | 69,472 | **2008** | 103,398 |
| **1992** | 89,334 | **2009** | 88,691 |
| **1993** | 71,099 | **2010** | 90,789 |
| **1994** | 64,868 | **2011** | 114,348 |
| **1995** | 63,128 | **2012** | 118,436 |
| **1996** | 71,509 | **2013** | 82,348 |
| **1997** | 93,256 | **2014** | 67,463 |
| **1998** | 60,339 | **2015** | 78,065 |
| **1999** | 68,846 | **2016** | 88,588 |
| **2000** | 82,999 | **2017** | 95,742 |
| **2001** | 125,584 | **2018** | 92,212 |
| **2002** | 110,121 | **2019** | 100,352 |
| **2003** | 97,899 | **2020** | 120,395 |
| **2004** | 103,555 | **2021** | 100,316 |
| **2005** | 96,782 | **2022** | 57,290 |
| **2006** | 86,167 | | |

### 5.9.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to a maximum of ±30 % (see Chapters 5.3.2.3 and 5.5.1.3, Uncertainties and time-series consistency for $N_2O$ emissions from Manure Management and Direct $N_2O$ Emissions from Agricultural Soils). Uncertainty estimate associated with emission factors amounts to -50 %, according to information on default factors uncertainty range provided in the IPCC Guidelines. Emissions have been calculated using the same method and data sets for every year in the time series.

### 5.9.4. Category-specific QA/QC and verification

There is no category-specific information, QA/QC for this category is shared and presented in Chapter 5.5.1.4 (Direct $N_2O$ Emissions from Agricultural Soils).

### 5.9.5. Category-specific recalculations

Emissions were recalculated for the year 2021 due to correction of invalidly entered AD value.

Impact of recalculations on the total 3.H source emissions compared to the last submission is presented in Table 5.9-2.

Table 5.9-2: Emission difference of CRF 3.H.2 source due to the recalculations

| (CRF 3.H.2) | 2021 |
|---|---|
| **kt $CO_2$-eq** | -10.6 |
| **%** | -14.4% |

### 5.9.6. Category-specific planned improvement

In addition to planned improvement shared with Direct $N_2O$ emissions from Agricultural Soils (see Chapter 5.5.1.6)., planned improvement which are assumed to be long-term goals (over 1 year) is development of proportion estimates of urea in applied urea solutions AD.

# Chapter 6: Land use, land-use change and forestry (CRF sector 4)

## 6.1.Overview of LULUCF sector

The land use categories relevant for the greenhouse gas (GHG) reporting are:

- Forest land (FL),
- Cropland (CL),
- Grassland (GL),
- Wetlands (WL),
- Settlements (SL),
- Other land (OL).

According to the 2006 IPCC Guidelines, emissions and removals are reported in subcategory land remaining in the same category and land converted to another land use category. All land use changes (LUC) are traced down and reported for a transition period of 20 years and reported in the respective categories afterwards, also. In compliance with the Guidelines, emissions/removals in the categories Wetlands remaining Wetlands, Settlements remaining Settlements and Other land remaining Other land are not estimated.

In LULUCF sector Forest land remaining Forest land, Cropland remaining Cropland and Land converted to Settlements categories are key category according to Trend Tier 1 and Tier 2 assessment and according to Tier 1 and Tier 2 Level assessment. Details are presented in Table 6.1-1.

Table 6.1-1: Key category analysis for LULUCF sector based on the level and trend assessment for 2022

| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, 2024) | | | | | |
|---|---|---|---|---|---|
| IPCC Source Categories | GHG | Key | If Column C is Yes, Criteria for Identification | | Com. |
| 4(III).Direct $N_2O$ emissions from N mineralization/immobilization | $N_2O$ | Yes | L1i | T1i T2i | |
| 4(V) Biomass Burning | $CO_2$ | Yes | L1i L2i | T1i T2i | |
| 4.A.1 Forest land remaining Forest land | $CO_2$ | Yes | L1i L2i | T1i T2i | |
| 4.A.2 Land converted to Forest Land | $CO_2$ | Yes | L1i L2i | T1i T2i | |
| 4.B.1 Cropland remaining Cropland | $CO_2$ | Yes | L1i L2i | T2i | |
| 4.B.2 Land converted to Cropland | $CO_2$ | Yes | L2i | T2i | |
| 4.C.2 Land converted to Grassland | $CO_2$ | Yes | L1i L2i | T1i T2i | |
| 4.D.2 Land converted to Wetlands | $CO_2$ | Yes | | T2i | |
| 4.E.2 Land converted to Settlements | $CO_2$ | Yes | L1i L2i | T1i T2i | |
| 4.G Harvested Wood Products | $CO_2$ | Yes | L1i L2i | T1i T2i | |

L1i - Level including LULUCF - Tier1 T1i - Trend including LULUCF - Tier1
L2i - Level including LULUCF - Tier2 T2i - Trend including LULUCF - Tier2

The completeness of the estimated emissions/removals is presented in Table 6.1-2.

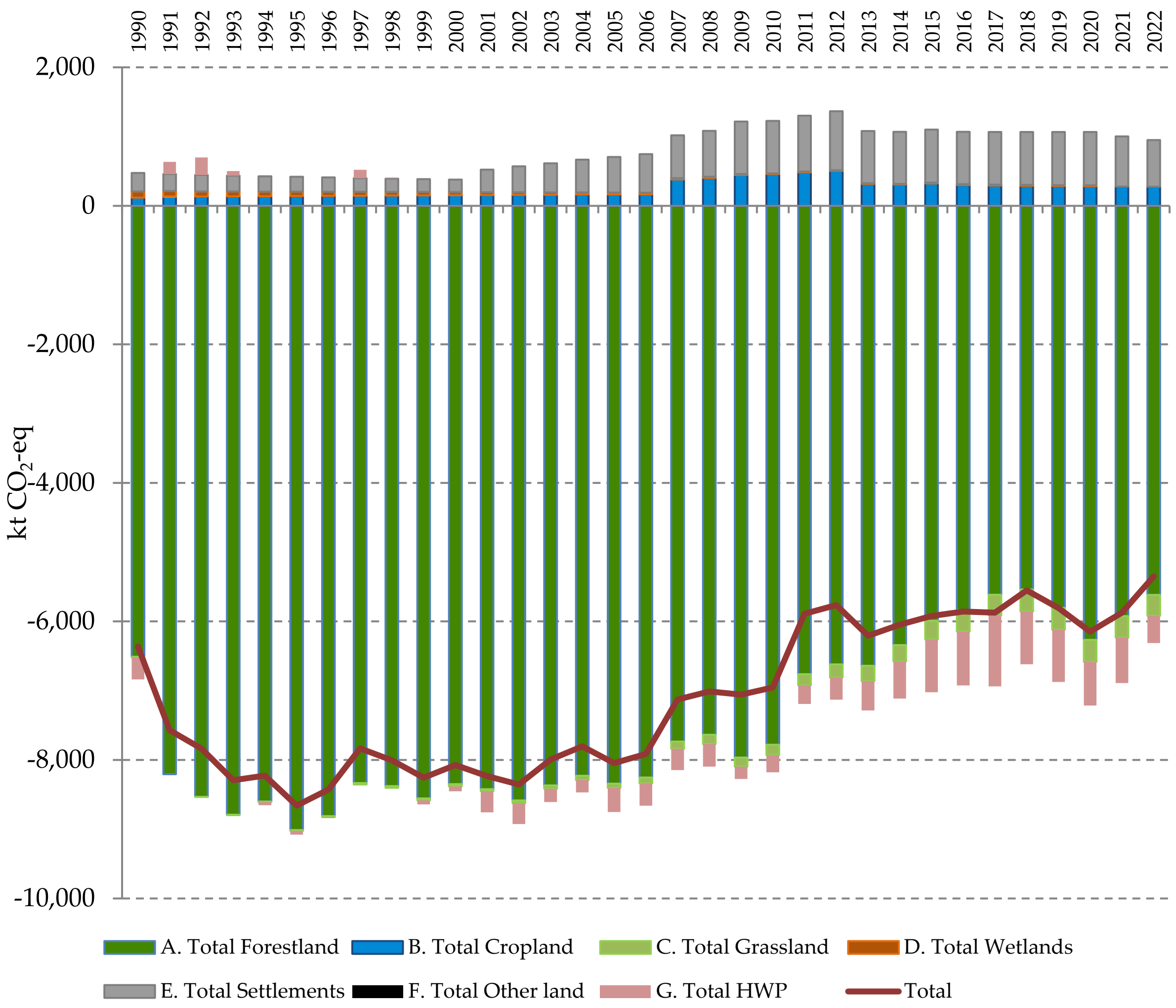
Table 6.1-2: Reported LULUCF categories - status of emission estimates

| LAND USE CATEGORIES | Net $CO_2$ emissions/removals | $CH_4$ | $N_2O$ |
|---|---|---|---|
| A. Forest land | x | x | x |
| 1. Forest land remaining Forest land | x | x | x |
| 2. Land converted to Forest land | x | x | x |
| B. Cropland | x | NO | x |
| 1. Cropland remaining Cropland | x | x | x |
| 2. Land converted to Cropland | x | NO | x |
| C. Grassland | x | NO | NO |
| 1. Grassland remaining Grassland | x | x | x |
| 2. Land converted to Grassland | x | NO | x |
| D. Wetlands | x | NO | NO |
| 1. Wetlands remaining Wetlands | NE | NO | NO |
| 2. Land converted to Wetlands | x | NO | x |
| E. Settlements | x | NO | NO |
| 1. Settlements remaining Settlements | NE | NO | NO |
| 2. Land converted to Settlements | x | NO | x |
| F. Other land | x | NO | NO |
| 1. Other land remaining Other land | NE | NO | NO |
| 2. Land converted to Other land | NO | NO | NO |

### 6.1.1. Emission trends

On the report of the previous figures and Figure 6.1-1, the conclusion is that LULUCF sector in Croatia presents a sink of greenhouse gases. Two land use categories, namely Forest land and Grassland, are categories with $CO_2$ removals, while every other category represents an emission source.

Figure 6.1-1: Emissions (+) / removals (-) trend for LULUCF sector land categories + HWP (1990-2022)




## 6.1.2. Methodology

Data on the total area of forest for the separate years, as well as the relative share of the coniferous and deciduous and the forests out of yield (maquies and shrub) were obtained from the Croatian Forest Ltd. company which was pursuant to the relevant legislation[24] for many years obliged to manage all forests in Croatia. Consequently, this company disposes with all forestry related data regardless the ownership type and current administrative organization of the sector. In order to comply with requirements, set in Saturday paper in 2012 regarding the traceability and identification of lands that are subject of forest activities, Croatia developed and implemented project "*Improving Croatian reporting in Land use, Land use change and Forestry (LULUCF) sector in the First commitment period of the Kyoto Protocol*" (abbreviated LULUCF 1). Special surveys were executed during the project and areas belonging to the categories of Forest land remaining Forest land and areas converted to/from Forest land were identified. Detailed description of the conducted work is presented in Chapter 6.4.2.2. Surveys conducted in Forest land category are performed for all type of forests (coniferous, deciduous, out of yield forests (maquies and shrub)) regardless the ownership type. The project was initiated by Ministry of Environmental and Nature Protection (MENP) through joint cooperation with relevant institutions.

[24] Forest Act (Official Gazette No. 68/18, 115/18, 98/19, 32/20, 145/20, 101/23, 36/24).

Information on areas of the wetlands, grassland, and settlements for the single years (1980, 1990, 2000, 2006, 2012 and 2018) were obtained from the Corine Land Cover (CLC) database. When presenting areas of Settlement, correction factor has to be defined and applied since these areas were observed smaller than areas in other countries. Information on areas of the cropland was extracted from the national Statistical Yearbooks and from the CLC database. For the purpose of this report the Croatian Bureau of Statistics (CBS) data from the time series 1960-2000 were used. A deviation in the CBS data series 1992-1997 was adjusted with linear interpolation. Changes in the CBS data collection approach and significant data deviation in the period after year 2000 were corrected using the data from CLC database.

By expert judgment certain land use changes were considered not to occur in Croatia:

- Wetlands, Settlements or Other land converted to Cropland or Grassland
- Wetlands converted to Settlements

The area of Other land is reported in accordance with the IPCC methodology. It was interpreted as the difference of the area of all other categories and the whole area of Croatia. Conducted survey under the LULUCF 1 project concluded that there is no conversion from Other land to forest land, as Croatia reported in previous reports before this survey.

After the total area of each category of land was determined, the LUC to and from each categories were defined. The major problem in presenting the land use changes was the limited amount of information on the land use changes between specific categories. The exact data on land use changes on yearly bases were available only for conversion from/to forest land and were collected through the LULUCF 1 project. Organized survey had determined the former land use types on the identified new forest areas and classified according to the ownership.

2006 IPCC Guidelines Approach 1 was applied for representing the areas of LUC in other categories of land by using information from available statistics and assumptions based on recognized pattern on land use changes. Then, the remaining area was calculated as the difference between the total area of a land use category and the land use changes to each category. Detailed descriptions of the methodology of area information are given in corresponding chapters of the report.

Table 6.1-3 presents the total area of the respective land uses and land-use changes between categories for the base and the inventoried year as well as the net changes for the period.

Table 6.1-3: Land use and LUC areas (kha) in Croatia for the years 1990-2022

| Area in kha | 1990 | 2022 | 1990 - 2022 |
|---|---|---|---|
| **4.A Forest land - Total** | 2356.83 | 2418.41 | 61.58 |
| 4.A1 Forest land remaining Forest land | 2353.29 | 2354.83 | 1.54 |
| 4.A1.a Forest land remaining forest land - coniferous | 211.56 | 215.89 | 4.34 |
| 4.A1.b Forest land remaining Forest land - deciduous | 1630.72 | 1630.56 | -0.16 |
| 4.A1.c Forest land remaining Forest land - out of yield | 511.01 | 508.38 | -2.64 |
| 4.A2. LUC in Forest land | 3.54 | 63.58 | 60.04 |
| 4.A2.1.a Annual cropland in Forest land | 0.00 | 2.16 | 2.16 |
| 4.A2.1.b Perennial cropland in Forest land | 0.00 | 0.21 | 0.21 |
| 4.A2.2. Grassland in Forest land | 3.54 | 61.21 | 57.67 |
| 4.A2.3. Wetlands in Forest land | 0.00 | 0.00 | 0.00 |
| 4.A2.4. Settlement in Forest land | 0.00 | 0.00 | 0.00 |
| 4.A2.5. Other land in Forest land | 0.00 | 0.00 | 0.00 |
| **4.B Cropland - Total** | 1625.38 | 1522.09 | -103.28 |
| Cropland annual | 1480.70 | 1400.62 | -80.08 |

| Area in kha | 1990 | 2022 | 1990 - 2022 |
|---|---|---|---|
| Cropland perennial | 144.68 | 121.47 | -23.20 |
| 4.B1 Cropland remaining Cropland - Total | 1618.43 | 1482.00 | -136.42 |
| 4.B1.a Annual cropland remaining Annual cropland | 1473.76 | 1345.90 | -127.87 |
| 4.B1.b Perennial cropland remaining Perennial cropland | 143.34 | 104.51 | -38.83 |
| 4.B1.c LUC Perennial cropland in Annual cropland | 0.43 | 24.45 | 24.02 |
| 4.B1.d LUC Annual cropland in Perennial cropland | 0.89 | 7.15 | 6.26 |
| 4.B2 LUC in cropland | 6.95 | 40.09 | 33.14 |
| 4.B2.1a Forest land in Annual cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.1b Forest land in Perennial cropland | 0.00 | 1.59 | 1.59 |
| 4.B2.2a Grassland in Annual cropland | 6.50 | 30.27 | 23.77 |
| 4.B2.2b Grassland in Perennial cropland | 0.45 | 8.23 | 7.78 |
| 4.B2.3a Wetlands in Annual cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.3b Wetlands in Perennial cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.4a Settlements in Annual cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.4b Settlements in Perennial cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.5a Other land in Annual cropland | 0.00 | 0.00 | 0.00 |
| 4.B2.5b Other land in Perennial cropland | 0.00 | 0.00 | 0.00 |
| **4.C Grassland - Total** | 1201.06 | 1153.22 | -47.84 |
| 4.C1. Grassland remaining Grassland | 1198.62 | 1072.99 | -125.63 |
| 4.C2. LUC in grassland | 2.44 | 80.23 | 77.79 |
| 4.C2.1 Forest land in Grassland | 0.00 | 0.00 | 0.00 |
| 4.C2.2a Annual cropland in Grassland | 2.33 | 71.21 | 68.87 |
| 4.C2.2b Perennial cropland in Grassland | 0.11 | 9.03 | 8.92 |
| 4.C2.3 Wetlands in Grassland | 0.00 | 0.00 | 0.00 |
| 4.C2.4 Settlements in Grassland | 0.00 | 0.00 | 0.00 |
| 4.C2.5 Other land in Grassland | 0.00 | 0.00 | 0.00 |
| **4.D Wetlands - Total** | 73.86 | 75.43 | 1.57 |
| 4.D1. Wetlands remaining Wetlands | 66.87 | 74.34 | 7.46 |
| 4.D2. LUC in Wetlands | 6.98 | 1.09 | -5.89 |
| 4.D2.1 Forest land in Wetlands | 0.00 | 0.00 | 0.00 |
| 4.D2.2a Annual cropland in Wetlands | 6.36 | 0.99 | -5.36 |
| 4.D2.2b Perennial cropland in Wetlands | 0.63 | 0.10 | -0.53 |
| 4.D2.3 Grassland in Wetlands | 0.00 | 0.00 | 0.00 |
| 4.D2.4 Settlements in Wetlands | 0.00 | 0.00 | 0.00 |
| 4.D2.5 Other land in Wetlands | 0.00 | 0.00 | 0.00 |
| **4.E Settlements - Total** | 200.65 | 288.88 | 88.23 |
| 4.E1 Settlements remaining Settlements | 174.32 | 218.00 | 43.67 |
| 4.E2 LUC in Settlements | 26.33 | 70.88 | 44.56 |
| 4.E2.1 Forest land in Settlements | 0.23 | 2.42 | 2.20 |
| 4.E2.2a Annual cropland in Settlements | 15.44 | 40.49 | 25.06 |
| 4.E2.2b Perennial cropland in Settlements | 1.53 | 4.00 | 2.48 |
| 4.E2.3 Grassland in Settlements | 9.14 | 23.96 | 14.83 |
| 4.E2.4 Wetlands in Settlements | 0.00 | 0.00 | 0.00 |
| 4.E2.5 Other land in Settlements | 0.00 | 0.00 | 0.00 |
| **4.F Other land - Total** | 201.63 | 201.37 | -0.26 |

| Area in kha | 1990 | 2022 | 1990 - 2022 |
|---|---|---|---|
| 4.F1 Other land remaining Other land | 201.63 | 201.37 | -0.26 |
| 4.F2 LUC in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.1 Forest land in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.2a Annual cropland in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.2b Perennial cropland in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.3 Grassland in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.4 Wetlands in Other land | 0.00 | 0.00 | 0.00 |
| 4.F2.5 Settlements in Other land | 0.00 | 0.00 | 0.00 |
| **Total area - Croatia** | **5659.40** | **5659.40** | 0.00 |

## 6.2. Land-use definitions and the classification systems used and their correspondence to the Land use, land-use change and forestry categories

### 6.2.1. Forest land (4.A)

Definitions applied within this inventory regarding the Forest land are consistent with the 2006 IPCC Guidelines and UNFCCC reporting requirements.

The Forest land is composed of *the Forest land remaining Forest land* (Fl-Fl)and *Land converted to Forest land* (L-Fl). The Forest land remaining Forest land is forest land with tree cover (national frame) but with forest defined as the land spanning more than 0,1 hectares with trees higher than 2 meters and canopy cover more than 10 percent, or trees able to reach these thresholds in situ (KP definition). Based on this definition, the forest stands that fall within these thresholds are high forests, plantations, cultures, coppice, maquies and shrub. Therefore, the Forest land remaining Forest land is forest land covered with high forests, plantations, cultures, coppice, maquies and shrub.

According to the Ordinance[25] total forest land in Croatia is divided in two main categories and several subcategories, as follows:

I. Forest land with tree cover

II. Land under forest management (forest land without tree cover):

- Productive forest land without tree cover (e.g. clearings, grasslands)
- Non-productive forest land without tree cover (e.g. fire lanes, landings)
- Barren wooded land (e.g., forest roads wider than 3 meters, quarries)

Therefore, within the national frames, there exists forest land without tree cover in Croatia under forest management plans, which represents grassland according to the IPCC definition. The latter indicates for example that afforestation does not necessarily mean land conversion for Croatia in the administrative national frame. Following the IPCC definitions of land use categories, land under the forest management plans on which afforestation is performed in Croatia, falls under the Grassland category. Hence, this afforestation land (though always “forest land” in the Croatian administrative understanding) represents a LUC land from Grassland to Forest land according to IPCC and is reported as such. The Croatian reporting of lands and LUCs follows the IPCC definitions. Other land category had been used previously to present land under the forest management (without tree cover). Since 2012 report and before LULUCF 1 project was executed, this has been changed and this land was reported under the Grassland category.

[25] Ordinance on Forest Management (OG 97/18, 101/18, 31/20, 99/21).

### 6.2.2. Cropland (4.B)

Based on the 2006 IPCC Guidelines definition of the Cropland category the area under the following classification of the CBS nomenclature was included in this report:

- Arable Land and Gardens,
- Nurseries,
- Osier Willows,
- Orchards,
- Olive groves,
- Vineyards.

After the year 2000 the area under the CBS nomenclature was revised and data were adjusted according to the below presented CLC nomenclature:

- Non-irrigated arable land,
- Permanently irrigated arable land,
- Vineyards,
- Fruit trees and berry plantations,
- Olive groves ,
- Annual crops associated with permanent crops (Complex cultivation patterns).

### 6.2.3. Grassland (4.C)

Following the IPCC definition of the grassland category, the next classes of the CLC database nomenclature are included in this report:

- Pastures,
- Land principally occupied by agriculture, with significant areas of natural vegetation,
- Natural grasslands,
- Moors and heathland ,
- Sclerophyllous vegetation.

### 6.2.4. Wetlands (4.D)

Two levels of the first classes under the CLC nomenclature (Wetlands and Water Bodies) were examined and classes presented below were included into the wetland area:

- Inland marshes,
- Salt marshes,
- Salines,
- Intertidal flats,
- Water courses,
- Water bodies,
- Coastal lagoons.

### 6.2.5. Settlement (4.E)

Based on the LULUCF definition of the settlement category the following classes of the CLC database nomenclature were included in this report:

- Continuous and discontinuous urban fabric area,
- Industrial or commercial units,
- Road and rail networks and associated land,
- Port areas,
- Airports,
- Mineral extraction sites,
- Dump sites,
- Construction sites,
- Green urban areas,
- Sport and leisure facilities.

## 6.3. Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

### 6.3.1. Forest land (4.A)

For the purposes of this reporting, data forwarded from the Croatian Forest Ltd. and collected through the surveys under the LULUCF 1 project were used for presenting the forest land areas.

The Forest Act[26] regulates the activities in forestry sector in Croatia. The forest management plans determine conditions for harmonious usage of forests and forest land and procedures in that area, necessary scope regarding the cultivation and forest protection, possible utilization degree and conditions for wildlife management. The forest management plans are as follows:

- General Forest Management Area Plan for the Republic of Croatia (General FMAPs),
- Forest Management Plan for management units,
- Programmes for management of management units on karst,
- Programmes for management of private forests,
- Programmes for forest renewal and protection in specially endangered area,
- Programmes for management of forest with special purpose,
- Annual forest management plans,
- Annual operative plans.

The Ministry of Agriculture supervises the decision-making process of management plans as well as their renewal and revision.

The FMAP, among others, appoints activities which will be performed in the forests for the next 10 years but also, to some extent, describes the former management (management in the previous 10-year period) and the status of forests at the beginning of the new 10-year period. So far, four General FMAPs have been prepared:

- General FMAP encompassing the period from 1986-1995 (General FMAP 1986-1995),

[26] Forest Act (Official Gazette No. 68/18, 115/18, 98/19, 32/20, 145/20, 101/23, 36/24).

- General FMAP encompassing the period from 1996-2005 (General FMAP 1996-2005),
- General FMAP encompassing the period from 2006-2015 (General FMAP 2006-2015),
- General FMAP encompassing the period from 2016-2025 (General FMAP 2016-2025).

Summarized, the total forest land in Croatia constitutes of one forest management area which is established in order to ensure the unique and sustainable management of the forest land. Therefore, according to the national criteria, both forest land with and without tree cover is sustainably managed regardless of their ownership, purpose, forest stand etc.

Based on the forest management type, according to the *Ordinance on Forest Management*, forest stands are managed either as even-aged or uneven-aged forests. In case of uneven-aged forests two types of selection systems can be performed. In these forests two types of uneven-aged forest management are applied:

- a group-tree-selection system (Type 1 of the uneven-aged forest management), or
- a single-tree selection system (Type 2 of the uneven-aged forest management).

In case of Type 1 a group of trees of the same age and development stages within (sub)compartment, needs to be larger than 0.2 ha and up to maximum of the 2.0 ha.

Even-aged Forest stands make regular forests with a share of about 52% of total growing stock (excluding maquis, shrub, garigue and scrub). Uneven-aged forests take share of 30 % of total growing stock (excluding maquis, shrub, garigue and scrub). Type 1 uneven-aged forests take share of about 18 % of total growing stock.

State forests are managed either by “Croatian Forests Ltd.” or by other legal bodies. As regarding the private forests, the Forest Advisory Service (FAS) was established in 2006 (began working in 2007). Its function was to assist private forest owners in management and improvement of private forests' condition. This service was merged with the Croatian Forests Ltd. in 2010. In February 2014 Croatian Government adopted changes to Forest Act re-establishing this service again under the Ministry of agriculture.

Furthermore, detailed information on the system within state forests managed by “Croatian Forests” is provided. It should be emphasized that the management system of “Croatian Forests” has the international FSC certification (Forest Stewardship Council A.C.) proving that state forests are managed sustainable.

The system is divided in 17 organizational and territorial units – regional Forest administrations (Figure 6.3-1). This division was established in 1996.

Regional forests administrations consist of regional forest offices. Croatian area is divided into 169 regional forest offices. The forest office is the basic organizational unit for performing all expert and technical activities in forest management and they are directly supervised by the regional forest administration. Forest management in forest offices is based on forest management plans for individual management unit approved by the Ministry of Agriculture. An example of one forest administration divided into 12 forest offices is presented in Figure 6.3-2.

Each forest office manages a certain number of management units. The division of forest management area on management units is performed to facilitate the implementation of forest management plans. The area of a management unit is usually between 1,000 and 3,000 ha. The area of management units is determined by the Forest Management Area Plan and usually they are not changed (now there is about 653 management units). The number of management units governed by a certain forest office is variable. Figure 6.3-3 shows forest office “Cerna” and its division into three management units.

Management unit is divided into compartments and sub-compartments. Compartment is considered as the permanent and basic unit regarding the management forest division. They are established in order to facilitate the management, inspection and field orientation. The compartment area, except for first age class, shrub, scrubs, maquis, garigue and barren wooded land, in general can not be larger than 60 ha. Figure 6.3-4 shows the division of the management unit “Krivsko ostrvo” on 33 compartments.

Compartments are divided into smaller areas (sub-compartments) and a sub-compartment is the smallest variable, basic area regarding the management division of forests which is specially managed as a stand. Stands are included in sub-compartments depending on their stand origin, stand form, development stage, tree species, age, management goal, mixture ratio and tree coverage. The smallest area of a sub-compartment is 1 ha except in private forests and separated forest area when it can be even smaller, and the largest sub-compartment area is determined by the compartment size. However, the sampling is performed within the sub-compartment on a 0.05 ha grid. Figure 6.3-5 shows that compartment 7 of the management unit “Krivsko ostrvo” is divided into 3 sub-compartments.

Figure 6.3-1: Spatial division of the Republic of Croatia on Forest Administrations (FAs)

Figure 6.3-2: Division of forest district "Vinkovci" on related forest office (example, UŠP refers to FA)

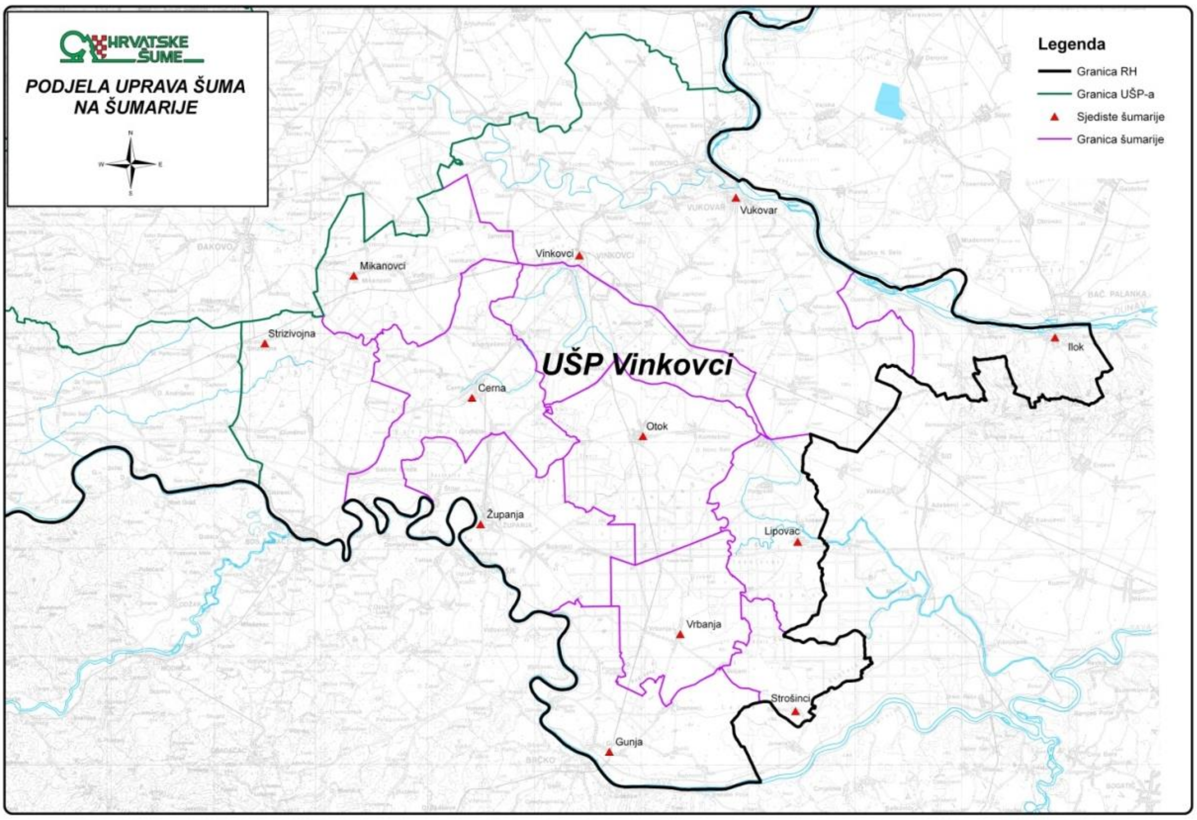



Figure 6.3-3: Area of a forest office "Cerna" with the spatial division on related management units (example)

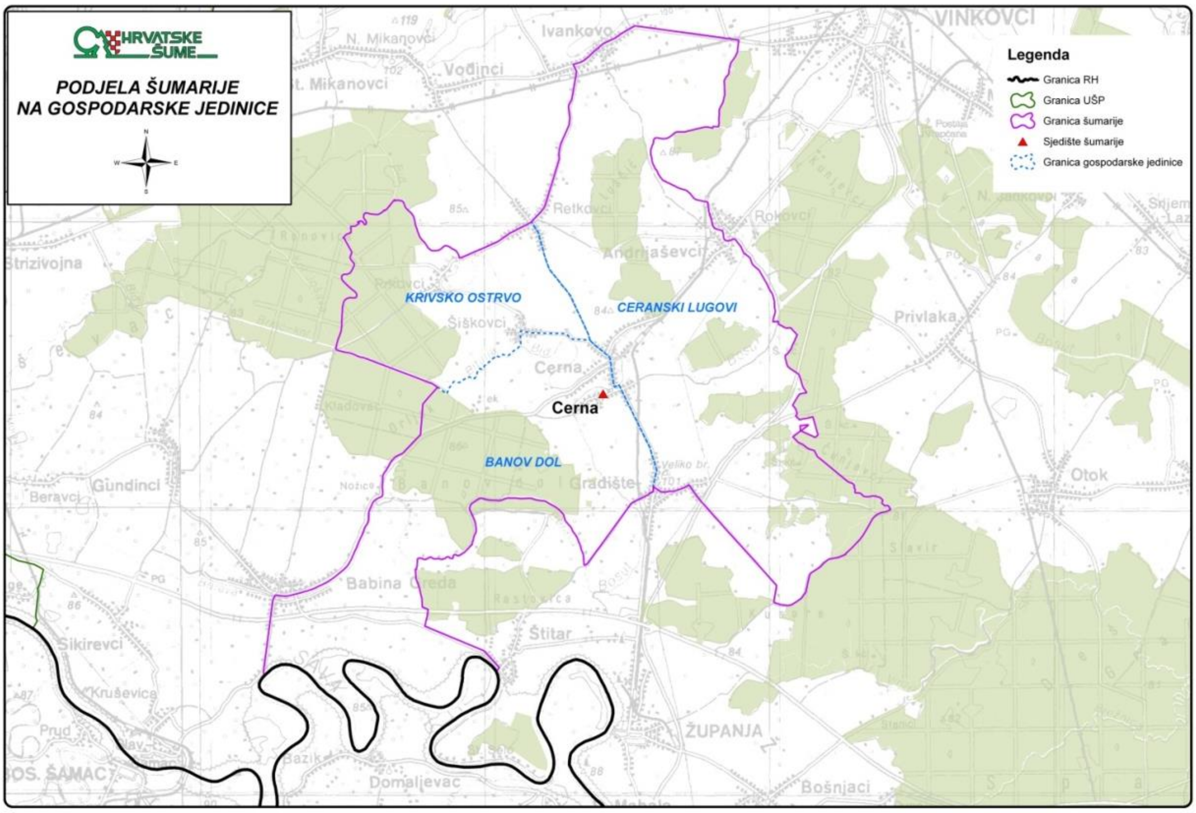


Figure 6.3-4: Area of a management unit "Krivsko ostrvo" divided into compartments (example)

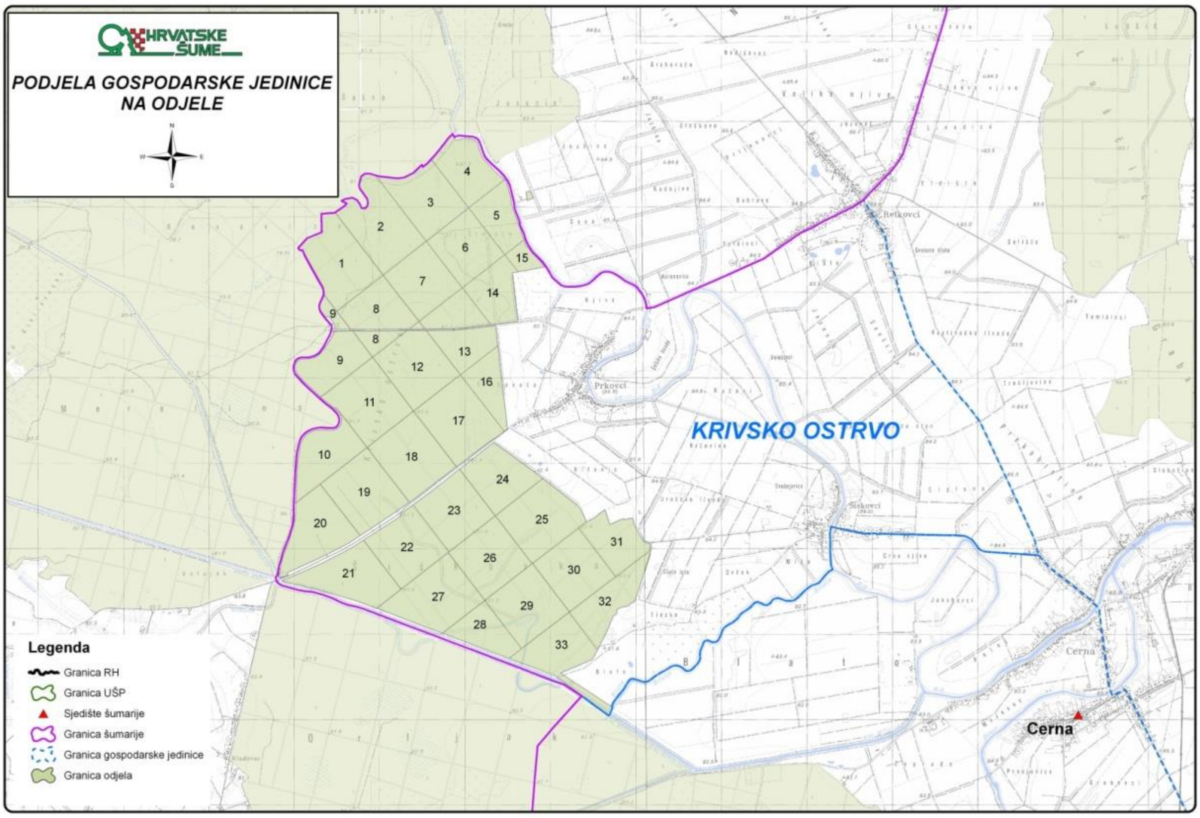
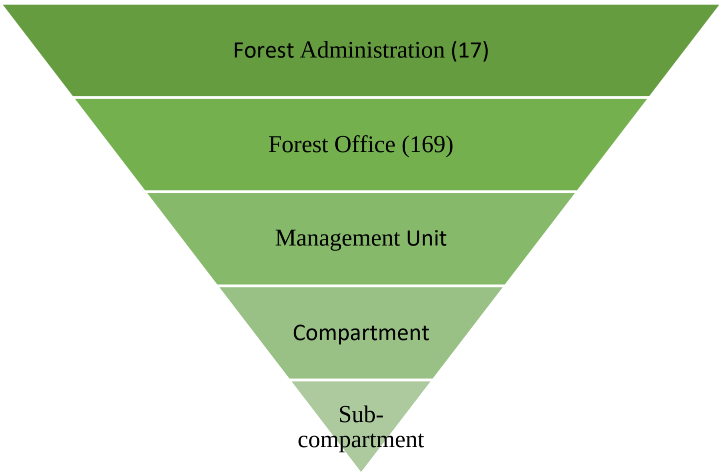



Figure 6.3-5: Compartment area divided into sub-compartments (example)

Short scheme of the system's structure is presented in Figure 6.3-6.

Figure 6.3-6: The scheme of the national system's structure




Therefore, it should be emphasized again that the basic unit for forest management in Croatia is the sub-compartment for which, based on field measurements on a 0.05 ha grid and the analysis of the related results, data on area, land category, growing stock and increment on diameter class (above 10 cm in diameter at 130 cm above ground, classes by 5 cm), age, ecological and management type, crown cover, height above sea level, the level of fire vulnerability, tree species and related number of trees etc. are determined. Furthermore, for each sub-compartment a felling and silvicultural treatment rule is prepared which is recorded each year.

The *Forest Act* regulates the growing, protection, usage and management of forest land as a natural resource aimed to maintain biodiversity and ensure management based on principles of economic sustainability, social responsibility and ecological acceptability. It prohibits the renewal of forests by clear cutting, thus natural rejuvenation is the principal method for renewal of all natural forests.

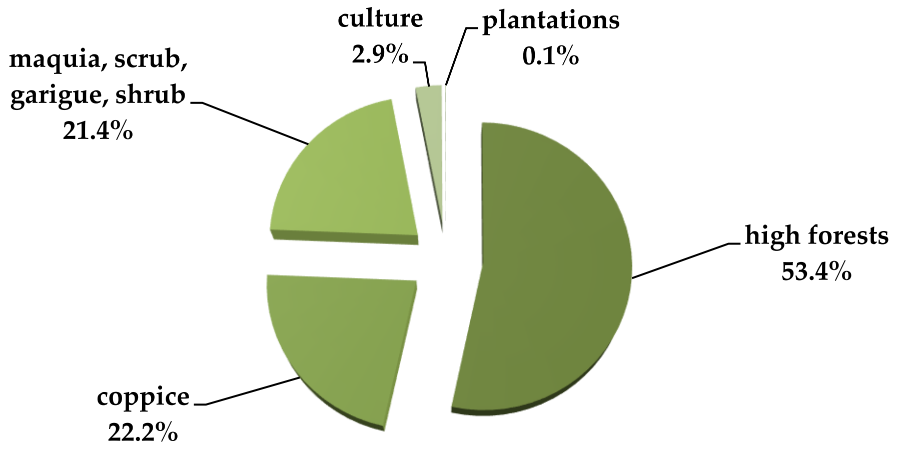
The following figures are based on data for 2016 provided in the General FMAP 2016-2025 and present forest area in Croatia as defined by *Forest Act* and *Ordinance on Forest management*.

Based on the forest stands, forest land with tree cover is divided as follows:

- High forests,
- Plantations,
- Forest cultures,
- Coppice,
- Maquia, scrub, garigue, shrub (Out of the Yield),

The share of forest land with tree cover in the forest land with tree cover is shown in Figure 6.3-7.

Figure 6.3-7: The share of each forest stands in forest land with tree cover, General FMAP 2016-2025




According to the Forest Act forests are classified in three categories:

- management forests (which made about 57 % of total forest area in 2016)
- protection forests (which made about 25 % of total forest area in 2016)
- forests with special purpose (which made about 18 % of total forest area in 2016).

Based on the ownership, there are two types of forests in Croatia:

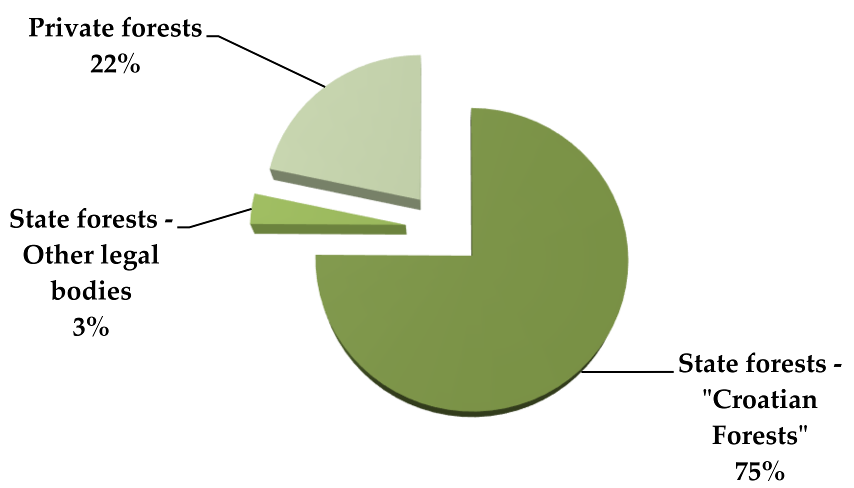
a) State forests owned by the state and managed by

- the public enterprise "Hrvatske šume d.o.o." (Croatian Forests Ltd.)
- legal bodies owned by the state (e.g., national parks, Faculty of Forestry, Ministry of Defence, "Croatian Waters" etc.)

b) Private forests

State forests make about 75% of total forest area, while the remaining 22% are privately owned and 3% are State forests – other legal bodies (figure 6.3-8).

Figure 6.3-8: The ownership structure of forest area in Croatia, General FMAP 2016-2025




The area of forests is determined based on all available cadastral maps in various scales. However, while preparing the FMAP 2016-2025, it was noticed that cadastral data on forest area did not match real conditions – private forests were larger than those presented in the cadastre. Since private forests are highly fragmented and scattered over the entire Croatian territory, most precise determination of their area and their spatial position was accomplished by applying the remote sensing methods for the forest area extraction and field work to determine forests' condition. The forest area was extracted in three ways:

- by using the orthophoto (scale 1:5,000),
- by using the digital cadastral maps,
- by using other available forest maps.

The FMAP 2016-2025 determines total growing stock of about 418 mil. $m^3$ in 2016 (shares shown in figures 6.3-9 and 6.3-10) by calculation based on the following measured data:

- diameters at breast height (dbh)
- height of living trees above the taxation level (10 cm in breast height diameter).

The growing stock is not measured for the first age class of even-aged forest and this is why carbon stock changes in these forests are not taken into consideration in the report. In case of maquies and shrub forests estimation was performed using the expert judgement on increment in these forests.

Figure 6.3-9: The share of growing stock in state and private forests, General FMAP 2016-2025

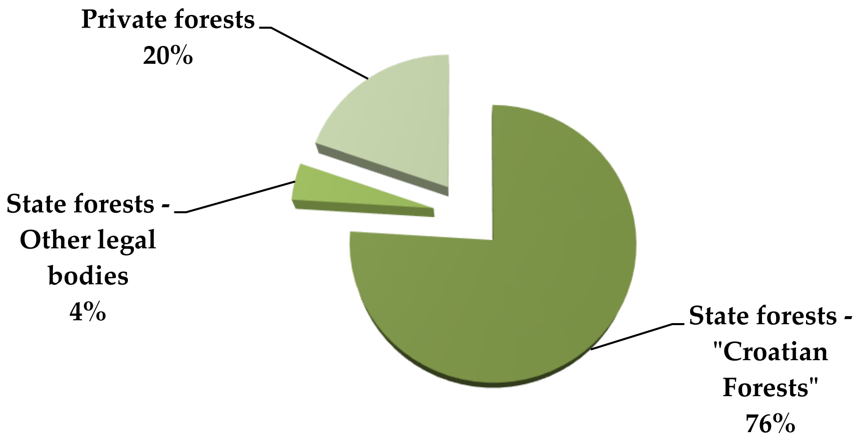
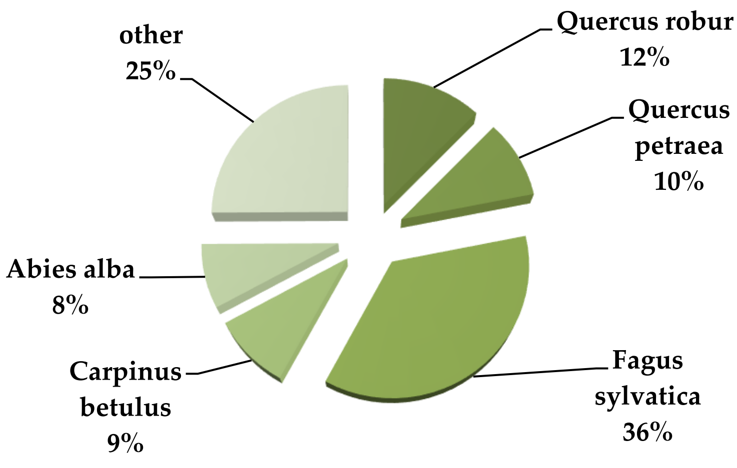



Figure 6.3-10: Share of main species in total growing stock, General FMAP 2016-2025



At least 2% in even-aged stands of the second age class regarding the high forests in area that is subject of FMAP, forests with limited management, coppices, protection forests and private forests.

At least 5% in even-aged stands of high forests (age classes above the second age class) in area that is subject of FMAP and in uneven-aged forests.

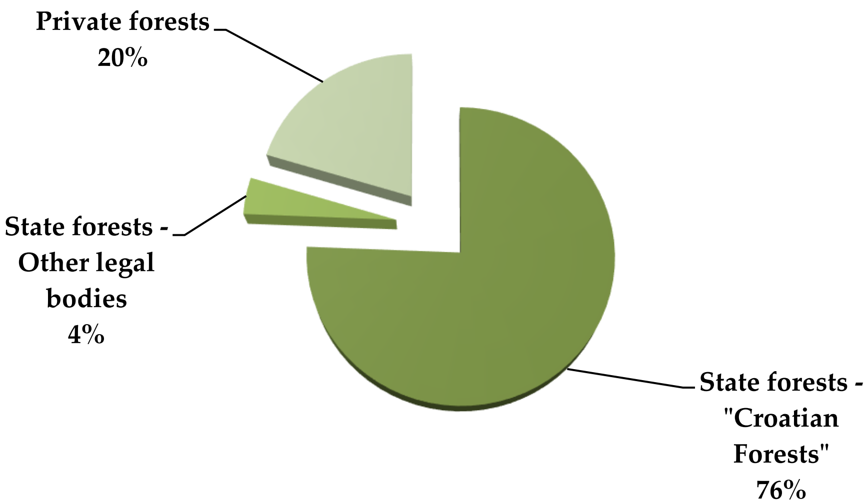
For example, planned work normative for state forests managed by Croatian Forests Ltd. for the year 2010 included:

- Extracting the sub-compartment at 143,000 ha
- Measurements of breast diameters at 69,000 sample plots of the 5% sample trees
- Measurements of breast diameters at 25,000 sample plots of the 2% sample trees
- Measurements of breast diameters of all trees at 6,000 ha
- Measurements of 123,000 tree heights
- Taking 43,000 bores.

Based on the legislation[27], when preparing the FMAPs, the increment value is determined based on the volume tables and measured diameter increment. Measuring of the diameter increment has been performed for the main tree species. In even-aged stands, samples for diameter increment measuring are grouped for each tree species according to their origin and stand quality and age, and in uneven-aged stands on management classes and stand quality. In case of coppice forests only mean total increment of growing stock has to be determined. The increment cores are taken at breast height (1,30 m) with Pressler's borer.

The share of increment in state and private forests is presented in Figure 6.3-11.

Figure 6.3-11: The share of increment in state and private forests, General FMAP 2016-2025




Representation of the Forest land in this report is based on the definitions provided in the following chapter (Chapter 6.4). The related data have been obtained from the FMAPs. Forests in Croatia are presented by forest type as broadleaved and coniferous forests and out of yield forests (maquies and shrub forests).

[27] Ordinance on Forest Management (OG 97/18, 101/18, 31/20, 99/21).

### 6.3.2. Cropland (4.B)

To present cropland area in Croatia data from the Croatian Bureau of Statistics (CBS), CORINE LAND COVER ('Coordination of Information on the Environment' Land Cover, CLC) database (years 1980, 1990, 2000, 2006, 2012 and 2018) and ARKOD database were reviewed. Significant changes among data obtained from these databases were observed, requiring data adjustments for certain time periods.

CLC database has been established in 1985 as the European program with the aim of a computerized inventory on land cover of the EC member states and other European countries, at an original scale of 1: 100,000. It uses 44 classes of the 3-level Corine nomenclature of which each describes a different land cover. The minimum mapping unit is 25 ha for land cover and 5 ha for mapping land cover changes since year 2000.

In 2002 Croatia joined the program and first CLC database for Croatia was established. Now within this database Croatia has information about land cover for years: 1980, 1990, 2000, 2006, 2012 and 2018. During the CLC 2000 development process 39 of 44 CLC classes were detected in Croatia while developing the CLC 2006 40 classes were detected. Also, continuing to participate in this EU program, Croatia managed to develop following databases on land cover changes: CLC change 1980-1990, CLC change 1980-2000, CLC change 1990-2000, CLC change 2000-2006 and CLC change 2006-2012 and CLC change 2012-2018. For the purposes of this reporting Croatian Agency for Environment and Nature developed special CLC change database that refers to the period 1990-2006[28]. This database have been used for determine the conversions between land use categories and reporting. For this reporting Croatia uses previsioned CLC change databases.

ARKOD presents a national system of identification of land parcels and use of agricultural land in Croatia, it is based on digital ortho-photo maps at a scale of 1:5,000, which serve as a basis for interpreting and determining the area of agricultural land farms.

The Ministry of Agriculture and the Paying Agency for Agriculture, Fisheries and Rural Development established this system in 2009 as part of the Croatian alignment with EU requirements, ARKOD makes an integral part of the Integrated Administration and Control System (IACS) by which EU member countries allocate, monitor and control direct EU payments to farmers. Full ARKOD application starts with the Croatian membership to the EU. Since 2011 this system has been used to track the payments of nationally paid subsidies.

Now ARKOD is not complete. It contains data for only about 1 million ha of agricultural land in Croatia and needs to be gradually completed. The majority of ARKOD data was taken over from the Farm Register established in Croatia in 2003 for the purpose of granting subsidies to farmers. This Register is based on cadastral data.

Since ARKOD contains data (approximately for about 60% of all agricultural land) only on agricultural land under the incentive system, it is not complete and could not be used for the purpose of this report.

For future reporting purposes, this database should be taken into consideration, in particular since the entry of Croatia into the EU when the ARKOD will have to contain information on all farms in Croatia.

For the purpose of this report the CBS data from the time series before 1990 were used. Although these CBS data are consistent during the period 1960-2000, a deviation in data series 1992-1997 due to War influences was recorded. In order to adjust this period, linear interpolation of the CBS data from the period 1991-1998 was used.

These CBS data are used to define the total Cropland area in Croatia in period 1990-2019. From the total area, areas that belong to perennial and annual cropland are defined. For this purpose, CBS data on shares

[28] Croatian Agency for Environment and Nature, Corine Land Cover database. See list of References.

between annual and Perennial Croplands are used. Final tuning in the total cropland area was performed subtracting the difference of areas that are converted to and from cropland area in corresponding years.

When analysing CBS data for the purposes of this reporting the significant changes in cropland and grassland area in the period after 2000 was notice. It was caused by difference in the CBS data collection and application of new EUROSTAT methodology, as follows: *''In 2005, the Croatian Bureau of Statistics gathered for the first-time crop production statistics data concerning private family farms by using the interview method on a selected sample with the help of interviewer. This meant abandoning a long-lasting method of collecting data by using the estimation method done by agricultural estimators based on cadastre data. The sample for agricultural households was selected from the 2003 Agricultural Census data basis and was completely random: the only condition was that at least three households were situated in the same settlement. The sample size was conditioned by inimical means allotted from the State Budget of the Republic of Croatia. As much as 11 000 households were selected in the sample. The criterion for the sample selection was based on seven sizes: the total used agricultural land area, size of arable land, size of garden area, size of meadow area, size of pasture area, size of orchard area and size of vineyard area. All obtained data were expanded, compared to data from previous years to data from the 2003 Agricultural Census and available administrative sources (the Register of Agricultural Holdings of the Ministry of Agriculture, Fisheries and Rural Development). If necessary, corrections have been made based on all available data*.

Due to abandoning of a long-standing method of compiling data through estimates done by agricultural estimators based on cadastral data, there emerged significant differences in data on land areas of some crops, vineyards, and orchards. They mostly relate to the reduction of land areas, which could have been caused by the tardiness of the cadastre.

Data on area for the period from 2000 to 2004 were revised according to the Agricultural Census 2003 data. Since there were Agricultural Census data and estimates of statistical experts available for 2003, that year was selected as the most suitable to be do used for the recalculation of data on areas. The data for the period from 2000 to 2004 were recalculated by multiplying the 2003 data by indices of annual changes derived from expert estimates.

The main purpose of this revision was the methodological harmonisation of data and methods of estimating data for the mentioned period. The methodology is fully harmonised with the EUROSTAT recommendations[29].

Applying the new EUROSTAT methodology and the interview method on private family farms in its statistical work after 2005, the CBS needed to focus only on categories of utilized agricultural area that was used for production in a year in question and actually utilized arable land in a year in question. Collecting data in such a way, the CBS completely omitted records on the traditionally less managed or unmanaged areas in Croatia that were not used in year of question (mostly grassland areas such as meadows and pastures). Before the new methodology was applied, these areas were recorded as unutilized agricultural land (and were traced based on the cadastral data), subcategory that does not exist within the new methodology. Comparison between data gathered using official definitions in CBS work before and after 2005 shows difference of more than 1,0 million ha in grassland areas and explains the difference between the CBS data series for the period 1990-1999 and the period 2000-2010.

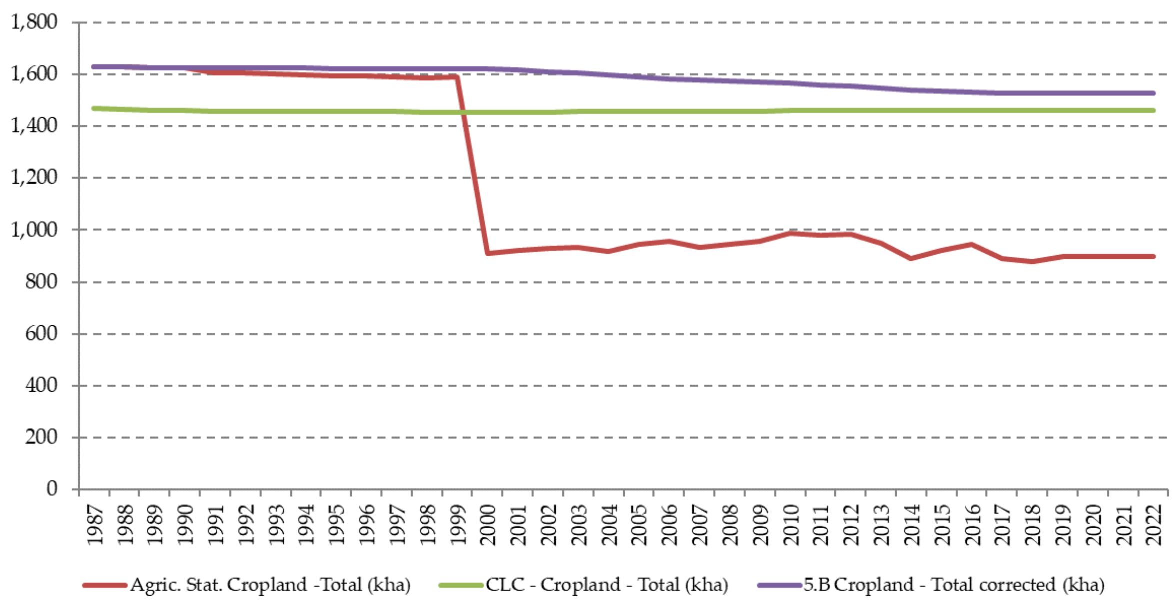
In order to define Total cropland area in Croatia, data from all available data sources were analysed. It was concluded that for this land category data available in State Bureau of Statistic (CBS) and Corine Land Cover database should be used. However, due to the changes in CBS methodology for data collection that occurred in 2000 and 2005, adjustment of these data needed to be performed. Description of the conducted process in adjusting the CBS data is presented here. After the adjustment in CBS data for the whole time series, the total corrected CL areas were defined using the CBS data for total CL area

[29] Statistical Yearbook of the Republic of Croatia 2012. See list of References.

in 1987 (which was found to be reliable by the group of national experts) are used adding the areas remaining form total LUC to cropland after subtracting areas converted from CL areas to other categories of land. Total corrected CL areas in following years are estimating using the areas from total CL in previous year and adding the areas remaining form total LUC to cropland after subtracting areas converted from CL areas to other categories of land in corresponding year.

Croatia analysed all data available in different data sources for the land matrix development. This included ARKOD data too. ARKOD contains only data on agricultural land that is under the incentive system (approximately 60% of all agricultural land in Croatia). Thus, ARKOD do not contain all data on agricultural land and because of this fact ARKOD data are in no way used for matrix purposes and this reporting, including the defining “corrected cropland area”. However, new project started in 2020 (abbreviated called CROLIS) which will complement ARKOD with currently missing data on agricultural land. In future (year 2024) ARKOD data will be used for LULUCF reporting. New data that will be incorporated in ARKOD are to be collected using the Sentinel 2 images and other available techniques for collecting spatially explicit land data. Thus, Approach 3 will be implemented for collecting remaining ARKOD data on agricultural land in Croatia.

Figure 6.3-12: Total Cropland area, corrected, kha



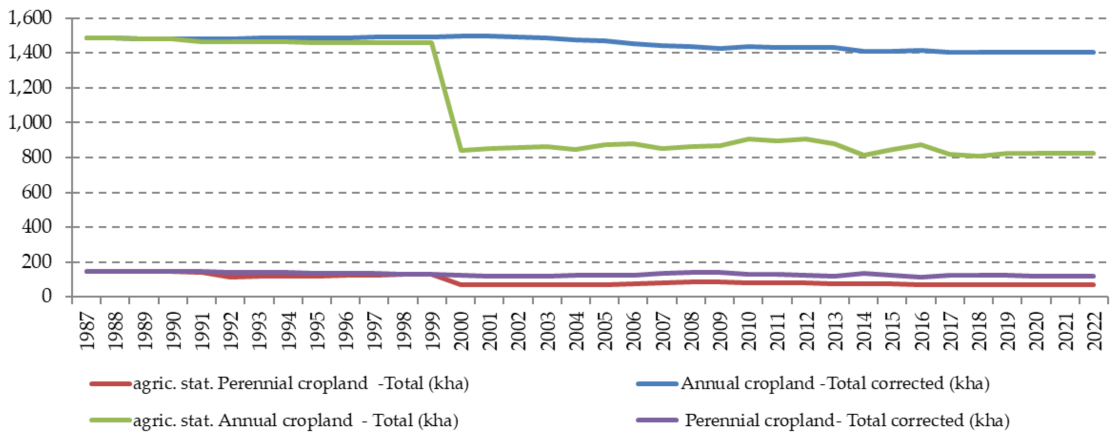

The share of perennial cropland in the adjusted total cropland area since 2000 has been estimated based on the relative shares of perennial cropland according to CBS data from the 2000ies. For the years before 2000 the CBS data on annual and perennial cropland area were used. The relative shares of perennial and annual cropland are rather consistent across the whole time series (0.1 vs. 0.9).

The area of annual cropland and perennial cropland used for LULUCF reporting depends on official CBS data on perennial cropland (pCL) and annual cropland (aCL) areas in Croatia on yearly basis. So far Croatia does not dispose with better data source on pCL and aCL areas.

New data on land areas that will be gained through the recently started LIFE CROLIS project will be used in future improvements of the NIR.

Regarding the identification of land areas converted to Cropland, during the expert work it was concluded that conversion from Forest land and Grassland category to Cropland exists in Croatia. The area of Forest land that is converted to Cropland was detected during the implementation of LULUCF 1 project (please see Chapter 6.3.5) and for the conversion on yearly basis from Grassland to pCL and aCL CLC database changes were used.

Figure 6.3-13: Area of Annual and Perennial cropland in Croatia after adjustments of CBS data, kha




For the comparison in this figure the CLC results are based on linear interpolation between the single CLC assessment years (1980–1990, 1990-2006, 2006-2012, 2012-2018) and for the years after 2018, the average value from the period 2012-2018 was applied.

### 6.3.3. Grassland (4.C)

For the presentation of grassland area in Croatia data from the Croatian Bureau of Statistics (CBS) and the CLC databases (years 1980, 1990, 2000, 2006, 2012 and 2018) were reviewed. Significant changes were observed requiring data adjustments for the whole time series.

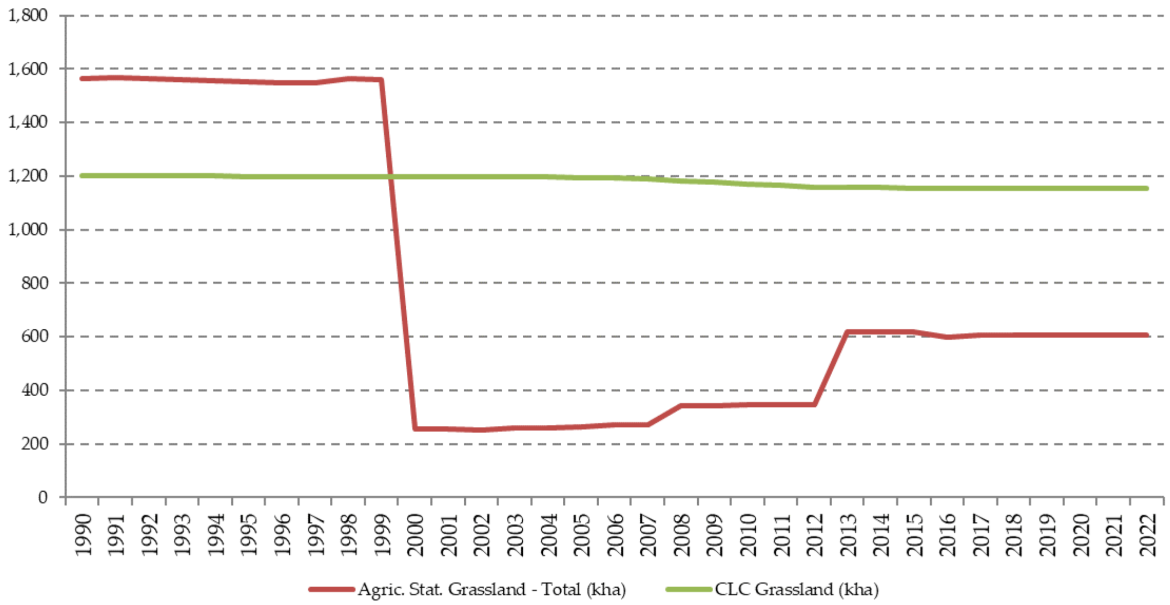
The complete examination of CBS data demonstrated its inadequateness related to the total area of Croatia. The adjustment of CBS data with CLC data for the time series since 2000 had the same results, leading to the exceedance of the total area of Croatia. At the same time, self-standing CLC data fitted adequately to the Croatian area and were used in this report for this reason.

Data from the CBS are the result of the Croatian statistical surveys in the field of agriculture. Since 2005 the CBS has been applying in its work a new methodology defined by EUROSTAT in year 2000.

Before the year 2005 the CBS recorded data on private family farms were collected separately using the estimation method by agricultural estimators based on cadastre data. Data gathered on private family farms using the new methodology showed significant reduction of the grassland area in Croatia in the period 1992-1995 compared to the previous as well as the following years (i.e., in 1987 the area was 1.56 million ha, while in 1995 it was 1.10 million ha). The main reason for this difference was the Croatian Homeland War, because of which investigation could not be carried out on the whole of Croatian territory. A separate and additional problem was areas contaminated with mines. On this land, forest vegetation was gradually taking over due to the stop of grassland management at these lands. More information about present and previously methodology used by CBS for area presentation are given Chapter 6.3.2.

To analyse the CBS data for the purpose of this report, linear interpolation of trend 1991-1996 of the CBS data were used to adjust the data for the years with partial data in the period 1992-1995 (Figure 6.3-14).

Figure 6.3-14: Total Grassland area in Croatia according to the CBS data and CLC database, kha




In this report CLC data were used to present grassland area in Croatia in the years 1980, 1990, 2000, 2006, 2012 and 2018. Linear interpolation of the CLC trend between these CLC assessment years was carried out. Extrapolation of the CLC trend was applied for the years after 2018.

CLC trends can be found in land matrix in the CRF tables.

Land use change in subcategories Cropland converted to grassland and Grassland converted to cropland uses CLC for determination of Activity Data.

### 6.3.4. Wetlands (4.D)

To present the wetland area in Croatia data presented in the Corine Land Cover databases (years 1980, 1990, 2000, 2006, 2012 and 2018) and the GIS database on the distribution of habitat types in Croatia were compared. A habitat map was built in a scale of 1:100,000, with a minimum mapping unit of 9 hectares, also containing data on wetlands in Croatia protected under the Ramsar Convention. The primary mapping method was the analysis of Landsat ETM+ satellite images, in combination with other data sources (air photos, literature data) and field work. Habitats throughout the Croatian territory were mapped. No significant differences between the wetland areas according to these databases were found and it was decided that CLC data would be used for the wetlands area presentation.

Linear interpolation of the CLC trend was carried out using the data from CLC database changes 1980-1990, 1990-2006, 2006-2012, 2012-2018. For the years after 2018 extrapolation of the CLC trend was applied.

CLC trends the wetland area can be found in land matrix. The LUC from cropland to wetland was divided into annual and perennial cropland according to the share of these land uses in total cropland (0.9 vs 0.1).

An assessment of the land use changes according to CLC suggested that the observed wetland area increase comes only from the cropland area in Croatia.

### 6.3.5. Settlements (4.E)

In order to present the settlements area in Croatia data presented in the Corine Land Cover databases (years 1980, 1990, 2000, 2006, 2012 and 2018) and the State Geodetic Administration's Register of spatial units were found useful for this report.

Although the Register contains information on state, county, city of Zagreb, town, municipality, settlements, protected areas, cadastral municipality, statistical range etc., it turned out that the data presentation was not in line with the requirements of this report (i.e. build-up areas are not presented in the Register). Therefore, expert judgment recommended to use data from the CLC databases.

Comparing CLC data under the settlements category with the same data in other countries (Austria and Luxemburg), it was observed that the total CLC settlement area in Croatia represents only 3.1 % of total land while in other countries it is significantly higher. Furthermore, it has been observed that roads and railroads within the Croatian CLC settlements category were represented only with 2.3%. Detailed Austrian and Luxembourgian data report that 45 to 50 % of the settlement area is composed of roads and railroad lines.

It was expert judgment that the difference between Croatian CLC settlements area and Austrian and Luxembourgian area were most likely since the roads and railroads area outside of the settlements in Croatia and it was not covered by the CLC database due to the area resolution of CLC and the insignificant narrow areas represented by these traffic lines in the CLC assessment units. Because of that, Croatian CLC settlements data needed to be adjusted for these uncovered countryside traffic areas. The data adjustment was done using the correction factor which is estimated to be:

((1/ (1-0.45+0.031)) - (0.033 x 0.45 x total area of Croatia)

This correction factor is multiplied with the CLC settlement area to estimate the adjusted settlement area. The term 1/ (1-0.45+0.031)) expands the settlement area for traffic lines (45 % of the settlement area are assumed to be traffic lines, of which only 3.1 % are covered by the CLC results and need to be added to avoid an overestimate). In a next step of this correction factor estimate -(0.033 x 0.45 x total area of Croatia) those 45% area share of traffic lines that fall within the detected CLC settlement areas (3.3 % of total area of Croatia) but which are also assessed as other settlement categories than traffic lines due to the area dominance of other categories (e.g. urban fabric) have to be subtracted to avoid traffic area double accounting.

After that linear interpolation of the CLC trend was carried out using the data from CLC database changes 1980-1990, 1990-2000. 200-2006, 2006-2012, 2012-2018. For the years after 2018 extrapolation of the CLC trend was applied.

The LULUCF 1 project was used to trace and record Forest land converted to Settlemnets and other land use categories. According to the Croatian *Forest Act*[30], conversion from Forest land to other land categories impleys clear cutting of forest in order to use area for other non-forestry purposes of which activities that lead to the conversion to Settlemt category are the biggest (i.e. road construction). Deforestation has to be performed in accordance with the spatial planning documents or provisions of the Decree on procedures and criteria for easement establishment on a forest or forest land owned by the Republic Croatia to cultivation of perennial crops[31]. Therefore, for an activity to be referred as land converted from forests (deforestation), certain forest area must be excluded from the national forest management area which is strictly regulated by the Forest Act (Articles 32, 35, 51, 51a and 52). Based on the latter, land use changes from forest to other land use categories are allowed in very limited circumstances (e.g. for important infrastructure projects etc.).

[30] Ibid.
[31] OG 12/2008, Article 1.

Based on the recommendations given by the ERT in ARR 2012, Croatia carried out a special survey in order to trace and identify all deforested areas regardless ownerships and types of forests. The work was performed in the framework of the LULUCF 1 project.

All data and information concerning deforested areas are presented in a separate document[32] as one of outcomes of the LULUCF 1 project. The same procedure was applied for identification of these areas in years 2013-2022.

During the period 1990-2012 deforestation did not occur in state forests that are managed by other legal bodies in Croatia than Croatian Forests according to the data and information gained through the conducted survey. This was expected outcome since forests belonging to this type of ownership have rigorous or some degree of protection under the provisions of Law on nature protection. Consequently, data and information presented in this report and concerning deforested areas and corresponding emissions refer to state owned forests managed by Croatian forests Ltd. and private forests.

When performing the survey under the LULUCF 1 project Approach 3 and wall to wall mapping was applied in identification and traceability of areas that were subject of deforestation activity in period 1990-2012.

For a start, in case of state-owned forests, all permits officially issued by the Ministry of Agriculture for the purposes of extraction of forests from forest management area in Croatia and its conversion to other land use were collected and then checked in order to secure that areas which were deforested were forest according to the thresholds set by Croatia for UNFCCC reporting purposes. Issuing of permits for exclusion of forests from forest management plans and its use for purposes other than for forest management has been regulated by provisions of Forest Act. Then, data and information recorded in each single permit that referred to forest area according to the UNFCCC definition had to be checked on a level of forest sub-compartment in each single management unit verifying that deforestation allowed by permit was executed on the field. In this work were used:

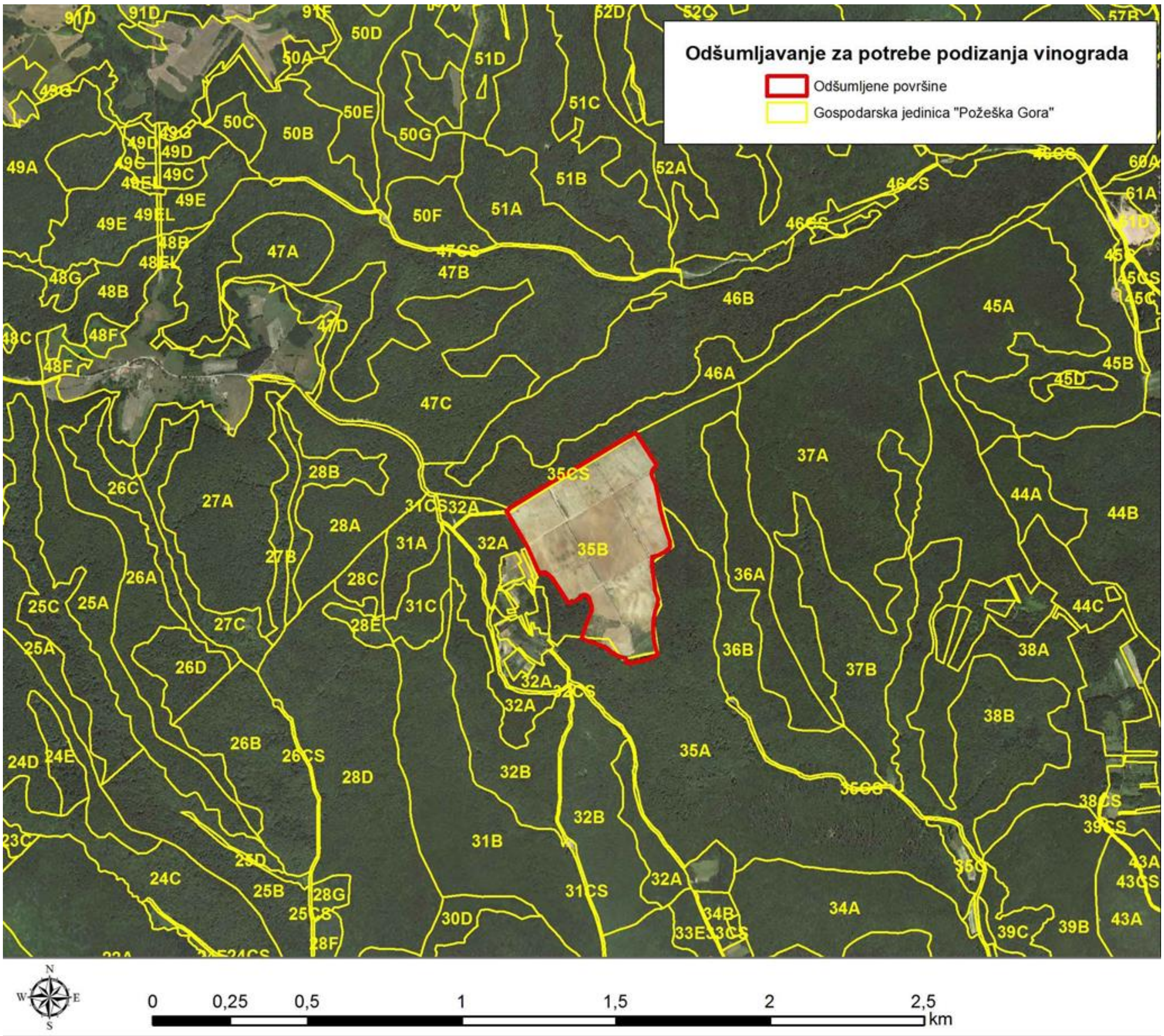
- old scanned and recently digitized map of forest management units
- Croatian base map 1:5,000
- topographic maps 1:25,000
- digital ortho-photo
- digital cadastral maps

In order to avoid situation that some of deforested areas are not identified because they were not subject of permitting (i.e. due to War disturbance), additional checking was performed on fields on a level of single management unit. Identified deforested areas not covered by permitting had to be officially mapped and registered for the purposes of this reporting.

An example on identified deforested area is shown in Figure 6.3-15.

[32] D. Janeš, G. Kovač, A. Durbešić (2014), Identification of deforested areas in Croatia according to the requirements of Article 3.3 of the Kyoto Protocol.

Figure 6.3-15: Map of forest management unit with deforested area marked in red (Forest Administration Požega, Management unit “Požeška gora”, total deforested area 22.47 ha)




Deforested areas in the period 1990-2012 in private forests were identified on the level of forest sub-compartment in each single forest office by using maps of forest management units or by cadastral maps in cases where forest management program for private forests has not been developed yet. Areas had to be officially registered and in cases that they were not mapped before, this had to be performed for the purposes of this reporting.

When collecting data and information on deforested areas (regardless the ownership type) regional forest offices had to provide all information and data requested by specially designed Questionnaire for the purposes of KP reporting besides the mapping of deforested areas. Data and information requested by questionnaire were: **a)** the name of Forest Administration; **b)** the name of Forest office; **c)** the name of management unit (FMU); **d)** FMU code; **e)** information about the ownership; **f)** year of deforestation; **g)** compartment code; **h)** sub-compartment code; **i)** sub-compartment size area; **j)** size of sub-compartment area deforested; **k)** management type; **l)** growing stock deforested; **m)** reason for deforestation. In part of questionnaire that refers to management type additional data were collected providing information about species of coniferous and deciduous types of forests and information about maquies and shrub. Also, part of questionnaire that refers to growing stock deforested was further subdivided into coniferous and deciduous part.

The whole process was performed in several steps on different levels of Croatian Forests Ltd. administration. In order to support Croatian UNFCCC reporting, new recording system for identification and traceability of deforested lands after 2012 was introduced.

The result of the work on tracing the *Forest land converted to Settlement* has been presented in Table 6.3-1 while the result of the total Forest land converted to other categories of land (Settlements and Cropland) has been presented Figure 6.3-16.

Table 6.3-1: Forest area converted to Settlements in period 1990-2022 (kha/year)

| Year | Deciduous | Coniferous | Maquies and shrubs | Total |
|---|---|---|---|---|
| 1990 | 0.09 | 0.13 | 0.00 | 0.23 |
| 1991 | 0.09 | 0.12 | 0.00 | 0.21 |
| 1992 | 0.08 | 0.12 | 0.00 | 0.20 |
| 1993 | 0.08 | 0.11 | 0.00 | 0.19 |
| 1994 | 0.10 | 0.14 | 0.00 | 0.24 |
| 1995 | 0.09 | 0.13 | 0.00 | 0.23 |
| 1996 | 0.09 | 0.13 | 0.00 | 0.22 |
| 1997 | 0.08 | 0.13 | 0.07 | 0.28 |
| 1998 | 0.14 | 0.17 | 0.07 | 0.38 |
| 1999 | 0.16 | 0.16 | 0.07 | 0.40 |
| 2000 | 0.30 | 0.18 | 0.08 | 0.55 |
| 2001 | 0.34 | 0.20 | 0.35 | 0.90 |
| 2002 | 0.42 | 0.30 | 0.38 | 1.11 |
| 2003 | 0.47 | 0.32 | 0.41 | 1.19 |
| 2004 | 0.60 | 0.36 | 0.53 | 1.49 |
| 2005 | 0.70 | 0.39 | 0.72 | 1.81 |
| 2006 | 0.75 | 0.40 | 0.98 | 2.12 |
| 2007 | 0.78 | 0.44 | 0.97 | 2.19 |
| 2008 | 0.90 | 0.50 | 1.06 | 2.46 |
| 2009 | 0.99 | 0.51 | 1.07 | 2.56 |
| 2010 | 1.05 | 0.57 | 1.12 | 2.74 |
| 2011 | 1.06 | 0.59 | 1.12 | 2.77 |
| 2012 | 1.11 | 0.68 | 1.12 | 2.91 |
| 2013 | 1.17 | 0.68 | 1.15 | 3.00 |
| 2014 | 1.16 | 0.65 | 1.15 | 2.96 |
| 2015 | 1.22 | 0.65 | 1.15 | 3.03 |
| 2016 | 1.23 | 0.67 | 1.15 | 3.05 |
| 2017 | 1.23 | 0.66 | 1.08 | 2.98 |
| 2018 | 1.18 | 0.61 | 1.08 | 2.88 |
| 2019 | 1.19 | 0.61 | 1.08 | 2.88 |
| 2020 | 1.06 | 0.59 | 1.08 | 2.74 |
| 2021 | 1.06 | 0.57 | 0.83 | 2.46 |
| 2022 | 1.06 | 0.56 | 0.80 | 2.42 |
| **Total** | **20.96** | **12.47** | **19.91** | **53.34** |

Figure 6.3-16: The spatial distribution of deforested land in period 1994-2022 (areas marked in brown)


Based on the CLC data on LUC areas and the information gained through LULUCF 1 project on deforestation areas it was concluded that LUCs in settlements come from the Forest Land, Grassland and Cropland category. According to the specially designed CLC 1990-2006 database of changes and other CLC database of changes, 35% of the settlements area increase based on agricultural land comes from cropland and 65% from grassland subcategories. The area coming from cropland was divided into annual cropland and perennial cropland according to the share of these land uses in total cropland (0.9 vs. 0.1).

The annual increase in the settlements area coming from forest land was recorded based on the data delivered by the Croatian Forests Ltd.

### 6.3.6. Other Land (4.F)

To present the category of other land area in Croatia data presented in CLC the database (years 1980, 1990, 2000, 2006, 2012 and 2018) were examined.

According to the definition of CLC classes, the following areas were included into this land use category:

- Beaches, dunes, sands,
- Bare rocks,
- Sparsely vegetated areas,
- Burnt areas.

According to CLC, the total other land category ranged between 71.13 and 80.26 kha in the period 1990-2022, which does not match the available area of the total area of Croatia due to area consistency with the area of total Croatia and those of the other sub-categories. Total area of other land is reported according to the 2006 IPCC Guidelines as the difference between the area of all land use categories except other land and the total area of Croatia.

Table 6.9.-1 presents activity data for Other Land. As can be seen, there are annual decreases of the area of other land.

The other land category has been included into the key category. The analysis using Tier 1 and Tier 2 Level and Trend methods excluded other land as a key category. The uncertainty of this subcategory has not been defined.

The calculation of data for category 4.F was included in the overall QA/QC system of the Croatian GHG inventory.

The uncertainty assessment model applied in Croatia does not include the other land category into the calculation. Inclusion of this category of land into the uncertainty estimate is planned as one of long-term improvements in Croatian LULUCF reporting.

## 6.4. Forest land (CRF category 4.A)

### 6.4.1. Description

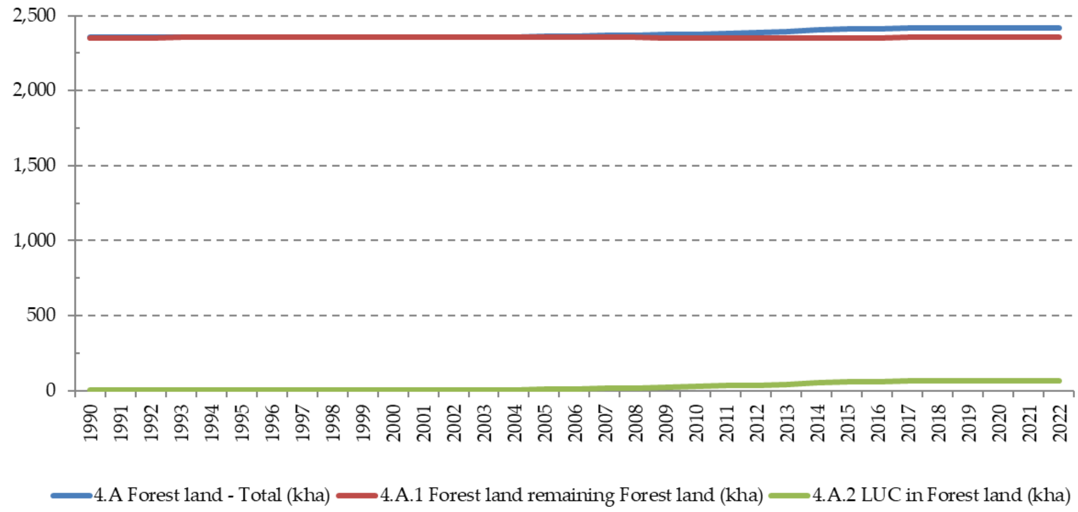
Under this land category, $CO_2$ emissions/removals from soil and living biomass[33] , soil, litter, dead wood (DW), and Harvested Wood Products (HWP) in the subcategories *Forest land remaining Forest land* and/ from *Land converted to Forest land* have been reported. For carbon stock changes (CSC) in dead organic matter (DOM) and in soil of Forest land remaining Forest land the IPCC GPG Tier 1 approach is used which assumes no C stock changes in these pools. $CO_2$ and non-$CO_2$ emissions due to wildfires are estimated and reported for the Forest land remaining Forest land and Land converted to Forest land separately based on the data and information that are gained through the survey under the LULUCF 1 project. Emissions for total category of Forest land are presented in Table 6.4.1 and detailed description of conducted survey is presented in Chapter 6.15. Emissions due to fires are presented in Table 6.4.2.

Regarding the areas affected by forest fires, Croatia informs that cut volume on these areas has to be separately recorded as s called random yield and it refers to the partially burnt and harvested wood. After the conducted consultation with the forest experts, it was concluded that 60% of the biomass is fully burnt during the forest fires, while the remaining 40% is only partially burnt. It was assumed that 60% of areas correspond to 60% of wood (fully) burnt. However, for this year submission the emissions of $CO_2$, $N_2O$ and $CH_4$ are estimated for the total areas that were subject of forest fires following the ERT's request.

According to the *Ordinance on Forest Management* (OG 97/18, 101/18, 31/20, 99/21) provisions, all areas subject of natural disturbances needs to be remediated and prescribed forest activities have to be performed securing that forest area remain forest area.

[33] Below ground biomass is combined with the above ground and thus the notation key IE is used for below ground biomass.

Figure 6.4-1: Trend of Forest land* and LUC to Forest land in period 1990-2022 (kha)




*Forest land area including Out of yield forests

$CO_2$ removal by sinks from *Forest land remaining Forest land* in 2022 are -5348.40 kt $CO_2$ and from *Land converted to Forest land* -268.65 kt $CO_2$. Therefore, the share of removals from Land conversion in total Forest land makes only 5 %.

Annual emissions/removals* from each land use category to Forest land are presented in Table 6.4-1.

Table 6.4.-1: Emissions (+) / removals (-) of $CO_2$ in Forest land category (kt $CO_2$)

| 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 Settlement converted to Forest land | 4.A.2.5 Other land converted to Forest land |
|---|---|---|---|---|---|---|---|---|
| 1990 | -6,510.90 | -6,482.01 | -28.89 | NO | -28.89 | NO | NO | NE |
| 1991 | -8,205.51 | -8,179.72 | -25.79 | NO | -25.79 | NO | NO | NE |
| 1992 | -8,533.20 | -8,506.84 | -26.36 | NO | -26.36 | NO | NO | NE |
| 1993 | -8,791.95 | -8,766.79 | -25.15 | NO | -25.15 | NO | NO | NE |
| 1994 | -8,599.93 | -8,573.59 | -26.34 | NO | -26.34 | NO | NO | NE |
| 1995 | -9,010.91 | -8,983.78 | -27.12 | NO | -27.12 | NO | NO | NE |
| 1996 | -8,809.96 | -8,782.89 | -27.07 | NO | -27.07 | NO | NO | NE |
| 1997 | -8,333.25 | -8,304.60 | -28.64 | NO | -28.64 | NO | NO | NE |
| 1998 | -8,377.12 | -8,348.87 | -28.26 | NO | -28.26 | NO | NO | NE |
| 1999 | -8,555.18 | -8,526.95 | -28.23 | NO | -28.23 | NO | NO | NE |
| 2000 | -8,349.25 | -8,319.08 | -30.17 | NO | -30.17 | NO | NO | NE |
| 2001 | -8,423.64 | -8,393.07 | -30.57 | NO | -30.57 | NO | NO | NE |
| 2002 | -8,585.17 | -8,554.30 | -30.87 | NO | -30.87 | NO | NO | NE |

| 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 Settlement converted to Forest land | 4.A.2.5 Other land converted to Forest land |
|---|---|---|---|---|---|---|---|---|
| 2003 | -8,367.14 | -8,335.22 | -31.92 | NO | -31.92 | NO | NO | NE |
| 2004 | -8,229.40 | -8,198.49 | -30.91 | 0.25 | -31.16 | NO | NO | NE |
| 2005 | -8,342.77 | -8,343.24 | 0.46 | 0.46 | 0.00 | NO | NO | NE |
| 2006 | -8,253.51 | -8,245.18 | -8.33 | 0.07 | -8.40 | NO | NO | NE |
| 2007 | -7,736.19 | -7,736.81 | 0.62 | -0.06 | 0.68 | NO | NO | NE |
| 2008 | -7,637.91 | -7,593.81 | -44.09 | -1.10 | -43.00 | NO | NO | NE |
| 2009 | -7,966.23 | -7,947.24 | -18.99 | -1.44 | -17.56 | NO | NO | NE |
| 2010 | -7,779.68 | -7,739.70 | -39.98 | -2.41 | -37.57 | NO | NO | NE |
| 2011 | -6,761.51 | -6,724.91 | -36.60 | -4.07 | -32.53 | NO | NO | NE |
| 2012 | -6,620.03 | -6,532.16 | -87.87 | -4.81 | -83.06 | NO | NO | NE |
| 2013 | -6,640.56 | -6,553.65 | -86.91 | -6.99 | -79.92 | NO | NO | NE |
| 2014 | -6,342.45 | -6,245.82 | -96.63 | -7.07 | -89.57 | NO | NO | NE |
| 2015 | -5,989.52 | -5,847.32 | -142.20 | -6.01 | -136.19 | NO | NO | NE |
| 2016 | -5,836.83 | -5,601.33 | -235.50 | -19.22 | -216.28 | NO | NO | NE |
| 2017 | -5,614.63 | -5,406.36 | -208.27 | -19.22 | -189.05 | NO | NO | NE |
| 2018 | -5,540.11 | -5,294.38 | -245.73 | -19.22 | -226.51 | NO | NO | NE |
| 2019 | -5,803.77 | -5,539.96 | -263.80 | -19.22 | -244.58 | NO | NO | NE |
| 2020 | -6,266.78 | -5,998.93 | -267.86 | -19.22 | -248.63 | NO | NO | NE |
| 2021 | -5,924.56 | -5,658.41 | -266.15 | -19.22 | -246.93 | NO | NO | NE |
| 2022 | -5,617.06 | -5,348.40 | -268.65 | -19.22 | -249.43 | NO | NO | NE |

*without emissions from biomass burning

Table 6.4.-2: Emissions ($CO_2$-eq) from wildfires for period 1990-2022

| Year | Area burnt (ha) | $CO_2$ emissions (kt) | $CH_4$ emissions ($CO_2$-eq (kt)) | $N_2O$ emissions ($CO_2$-eq (kt)) |
|---|---|---|---|---|
| 1990 | 482.15 | 14.98 | 0.04 | 0.00 |
| 1991 | 1,291.45 | 40.12 | 0.12 | 0.01 |
| 1992 | 5,863.79 | 182.17 | 0.55 | 0.03 |
| 1993 | 14,101.90 | 438.09 | 1.31 | 0.07 |
| 1994 | 4,591.34 | 142.64 | 0.43 | 0.02 |
| 1995 | 3,010.79 | 93.53 | 0.28 | 0.02 |
| 1996 | 6,493.73 | 201.74 | 0.60 | 0.03 |
| 1997 | 6,884.57 | 213.88 | 0.64 | 0.04 |

| Year | Area burnt (ha) | $CO_2$ emissions (kt) | $CH_4$ emissions ($CO_2$-eq (kt)) | $N_2O$ emissions ($CO_2$-eq (kt)) |
|---|---|---|---|---|
| 1998 | 17,092.83 | 531.01 | 1.59 | 0.09 |
| 1999 | 1,829.71 | 56.84 | 0.17 | 0.01 |
| 2000 | 37,363.79 | 1,160.75 | 3.48 | 0.19 |
| 2001 | 6,879.85 | 213.73 | 0.64 | 0.04 |
| 2002 | 2,413.60 | 74.98 | 0.22 | 0.01 |
| 2003 | 15,395.45 | 478.28 | 1.43 | 0.08 |
| 2004 | 839 | 26.06 | 0.08 | 0.00 |
| 2005 | 912.5 | 28.35 | 0.08 | 0.00 |
| 2006 | 2,322.00 | 72.14 | 0.22 | 0.01 |
| 2007 | 12,574.66 | 390.65 | 1.17 | 0.06 |
| 2008 | 3,642.58 | 113.16 | 0.34 | 0.02 |
| 2009 | 2,043.60 | 63.49 | 0.19 | 0.01 |
| 2010 | 687.67 | 21.36 | 0.06 | 0.00 |
| 2011 | 6,478.26 | 201.25 | 0.60 | 0.03 |
| 2012 | 15,270.09 | 474.38 | 1.42 | 0.08 |
| 2013 | 614.97 | 19.10 | 0.06 | 0.00 |
| 2014 | 78.83 | 2.45 | 0.01 | 0.00 |
| 2015 | 4,067.94 | 126.38 | 0.38 | 0.02 |
| 2016 | 2,829.01 | 87.89 | 0.26 | 0.01 |
| 2017 | 25,273.87 | 785.16 | 2.35 | 0.13 |
| 2018 | 291.71 | 9.06 | 0.03 | 0.00 |
| 2019 | 733.42 | 22.78 | 0.07 | 0.00 |
| 2020 | 12261.23 | 380.91 | 1.14 | 0.06 |
| 2021 | 1644.28 | 51.08 | 0.15 | 0.01 |
| 2022 | 11287.13 | 350.65 | 1.05 | 0.06 |

## 6.4.2. Methodological issues

### 6.4.2.1. Forest land remaining Forest land (4.A.1)

The dataset required for presenting the biomass carbon stock change encompasses the entire period from 1990-2022 and the main data source is the General Forest Management Area Plan (general FMAP 2016-2025). Data are divided based on the forest type upon which the related emission/removal calculation was performed using primarily Tier 1. Thus, estimation is performed for coniferous, deciduous and out of yield forests (maquies and shrub) and data are presented in CRF the same way. The calculation refers only to living biomass. The C stock changes of the other pools (dead wood, litter, soil) are reported according to IPCC Guidelines Tier 1, no C stock change is assumed. Shortly, the calculation can be presented as follows:

$\Delta C_{FFLB} = \Delta CFFGj - \Delta CFFLj$

where:

| | | |
|---|---|---|
| $\Delta C_{FFLB}$ | = | annual change in carbon stocks in living biomass (includes above and below ground biomass) in the *Forest land remaining forest land*, $Cyr^{-1}$ |
| $\Delta CFFL_j$ | = | annual decrease in carbon stocks due to biomass loss, |

where j = 1 - broadleaved
2 - coniferous
3 –maquies and shrub

The activity data for $CO_2$ emission/removal calculation includes data on forest area, increment and harvest. Methodological issues are explained in detail below.

Based on the ERT recommendations, the data collected through the first National Forest inventory conducted in period 2005-2009 on the plot level (CRONFI) were thoroughly examined. Through the CRONFI only the data referring to aboveground biomass and dead wood pools were collected, while the data relevant for the estimation on carbon stock changes in other pools i.e. below ground biomass, litter, soil and HWP were not collected within the CRONFI process. During the analysis it was realised that the majority of methods used for the collection of relevant data during the CRONFI process differed from the methods used for forests plans/programs development (i.e., the intensity of forest measurements for the CRONFI purpose (a grid 4 x 4 km)). Therefore, the results are not comparable with the survey used for the preparation of forest management plans/programs (measurement on 2-5% of the total forest area or the measurement of all trees in stands that are subject of final cutting). In addition, the General FMAPs as well as other forest programs/plans are developed every ten years regularly since many decades while CRONFI was performed once so far. Due to the differences in method applied, it was concluded that only the data on dead wood stock on deforested areas can be used for the UNFCCC reporting purposes. However, it was concluded that even for these data separate project needs to be initiated in order to prepare data for this reporting. This project was executed in 2018 and DW CS data has been used for the reporting.

Forest area

Data on forest area are in line with the relevant definitions and therefore exclude afforested area.

Increment

Following recommendation given by ERT during the in-county review 2012 Croatia decided to apply same approach to calculate carbon gains in increments for all forests regardless the ownership structure. For this reporting purposes, Croatian forests delivered data about increment presented as per ha value for all types of forests ownership. Increment is presented per broadleaved, coniferous and maquies and shrub forests for all type of forest ownerships. Data are presented in CRF tables for coniferous, deciduous, and out of yield forests (maquies and shrub) without previously used disaggregation on forest ownerships. Emissions/removals in this category of land are calculated for forest areas in Croatia regardless the ownership type.

Since the War period, in Croatia there is an active process of returning previously confiscated forests to private owners[34] which makes difficult to follow difference in area based on ownership structure which was one of reasons for performing estimation of emissions/removals for whole Croatia without separating forests based on forests ownership.

Harvest

The carbon loss due to harvest (felling) is calculated using Tier 2 and equation 2.12 from 2006 IPCC Guidelines.

Croatia uses national values for wood densities for coniferous, deciduous and maquies and shrub species based on the scientific papers and published data.

Since felling already include the volume cut after natural disturbances, carbon losses due to natural disturbances are allocated within the carbon losses due to felling. Therefore, notation key IE was used in the CRF tables (see Chapter 6.4.1).

Data used in the $CO_2$ emission/removal calculation are presented in Table 6.4-3.

Table 6.4-3: Data used in the $CO_2$ emission/removal calculation

| Forest type | Wood density (WD) | $BEF_1$ | R/S | $BEF_2$ | CF |
|---|---|---|---|---|---|
| | $tonnes_{d.m.} \cdot m^{-3}$ | dimensionless | dimensionless | dimensionless | $(tonnes_{d.m.})^{-1}$ |
| Deciduous | 0.56 | 1.20 | 0.23 | 1.19 | 0.48 |
| Coniferous | 0.39 | 1.15 | 0.29 | 1.04 | 0.51 |
| Out of Yield (maquies and shrub) | 0.68 | 1.10 | 0.46 | 1.15 | 0.47 |

*d.t. – dry matter, BEF – Biomass Expansion Factors, R/S – root to shoot ratio, CF – carbon friction

According to the harvest practices applied in Croatia, in period of last five reporting years 14.5% of harvested volume is left on the site in case of deciduous forests and 20.1% in case of coniferous forests. Number of total volumes harvested in these of type of forests were corrected with corresponding percentages.

Based on the wood density values available through the nationally conducted scientific investigations[35] and share of species in total groing stock in Croatia[36], it is estimated that wood density in deciduous species is 0.558 t d.m/ha and 0.398 t d.m/ha in case of coniferous species. For these estimations, wood densities of absolute dry wood per fresh volume ($m_o/V_{WET}$) were used except in case of common hornbeam wood density where value for wood density in absolute dry were used and corrected by the shrinkage factor of 17.1% [37].

In case of common fir, it was concluded that wood density is highly dependable on geological basis and amounts of 0.37 t d.m/$m^3$ or 0.405 t d.m/$m^3$ depending on whether common fir appears on silicate or

[34] Draft strategy for management and disposal of property of the Republic of Croatia 2013-2017. See list of References.

[35] Scientific papers of Badjun, Horvat,Sinković, Govorčin, Štajduhar. See list of References.

[36] Forest Management Area Plan of the Republic of Croatia 2006-2015. See list of References.

[37] Scientific paper of Sinković, Govorčin and Sedlar. See list of References.

limestone[38]. Since there is no exact data about area of common fir on silicate and limestone, mean value of 0.387 t d.m/$m^3$ was used when calculating contribution of common fir wood density to the wood density of coniferous species in general.

It was concluded by expert judgement that oriental hornbeam should be used as representative specie of maquies and scrub forests. Wood density of hornbeam in absolute dry[39] were used and corrected by the shrinkage factor of 19.7% in order to calculate wood density of absolute dry wood per fresh volume. Since shrinking factor for oriental hornbeam was not subject of scientific investigation on national level so far, shrinkage factor determined on national level as valid for all *Carpinus* genus was used[40].

Biomass pool is significant pool of this subcategory. BEFs on the national level should be further defined as a part of a new project that will be developed. That would increase transparency and accuracy of reporting in the future. For now, Croatia uses BEF values from IPCC Guidelines 2006.

For the estimation of CSC changes in biomass pool Croatia uses *Gain-Loss* method and the Equations 2.7, 2.10 and 2.12 from the 2006 IPCC Guidelines. The detailed overview of the approach is shown below:

$$\Delta C_B = \Delta C_G - \Delta C_L$$

$$\Delta C_G = \Sigma_{i,j} (A_{i,j} \times I_V \times BEF_1 \times D_1 \times (1+R) \times CF)$$

where:

| | | |
|---|---|---|
| $\Delta C_B$ | = | annual change in carbon stocks in biomass, tonnes C $yr^{-1}$ |
| $\Delta C_G$ | = | annual increase in carbon stocks due to biomass growth, C $yr^{-1}$ |
| $\Delta C_L$ | = | annual decrease in carbon stocks due to biomass losses, C $yr^{-1}$ |
| $\Delta C_G$ | = | annual increase in carbon stocks due to biomass growth in forest land remaining forest land by vegetation type and climatic zone, tonnes C $yr^{-1}$ |
| A | = | area of land remaining in the same land-use category, ha |
| i | = | ecological zone (i=1 to n) |
| j | = | climate domain (j=1 to n) |
| $I_V$ | = | average net increment for specific vegetation type, $m^3 ha^{-1} yr^{-1}$ |
| $BEF_1$ | = | biomass conversion and expansion factor for conversion of net annual increment in volume (including bark) to above ground biomass growth for specific vegetation type, tonnes above-ground biomsss growth ($m^3$ annual increment)$^{-1}$ |
| $D_1$ | = | basic wood density |
| R | = | ration of below-ground biomass to above-ground biomass for a specific vegetation type, in tonne d. m. below ground biomass (tonne d. m. above-ground biomass)$^{-1}$ |
| CF | = | carbon fraction of dry matter (tonne d.m)$^{-1}$ |
| $\Delta C_L$ | = | $L_{wood\text{-}removals} + L_{fuelwood} + L_{disturbance}$ |

[38] Scientific paper of Horvat. See list of References.

[39] Scientific paper of Govorčin, Sinković, Trajković, Šefc. See list of References.

[40] Mali šumarsko-tehnički priručnik. See list of References.

| | | |
|---|---|---|
| $L_{wood\text{-}removals}$ | = | $\Sigma$ H x $BEF_2$ x $D_R$ x (1+R) x CF |
| where: | | |
| $\Delta C_L$ | = | annual decrease in carbon stocks due to biomass losses inforest land remaining forest land |
| A | = | area of land remaining in the same land-use category, ha |
| H | = | annual wood removal, roundwood, $m^3$/ha |
| $BEF_2$ | = | biomass expansion factor for conversion for wood removal ($m^3$ of removals)$^{-1}$ |
| $D_R$ | = | basic wood density |
| R | = | ration of below-ground biomass to above-ground biomass for a specific vegetation type, in tonne d. m. below ground biomass (tonne d. m. above-ground biomass)-1 |
| $L_{fuelwood}$ | = | annual biomass loss due to fuelwood removals, tonnes C $yr^{-1}$ (Equation 2.13) |
| $L_{disturbance}$ | = | annual biomass loss due to fuelwood removals, tonnes C $yr_{-1}$ (Equation 2.14) |

A) Changes in the carbon stock in the dead organic matter – dead wood

As regarding the calculation of carbon stock change in this pool, Croatia uses IPCC Tier 1 approach assuming that there are no changes in the dead wood stock in all managed forests.

B) Changes in the carbon stock in the dead organic matter - litter

As regarding the calculation of carbon stock change in this pool, Croatia uses IPCC GPG Tier 1 approach assuming that there are no changes in the litter stock in all managed forests.

C) Soil

There was no change regarding the forest management in the past 20 years. Because of that it is assumed that the average carbon stock in Croatian soils is stable following the approach of the IPCC 2006 Tier 1 methodology.

#### 6.4.2.2. Land converted to Forest land (4.A.2)

Emission/removals from land conversion activities have been calculated using the IPCC Tier 2 method for living biomass, soil, litter and dead wood pools for the entire period from 1990-2022.

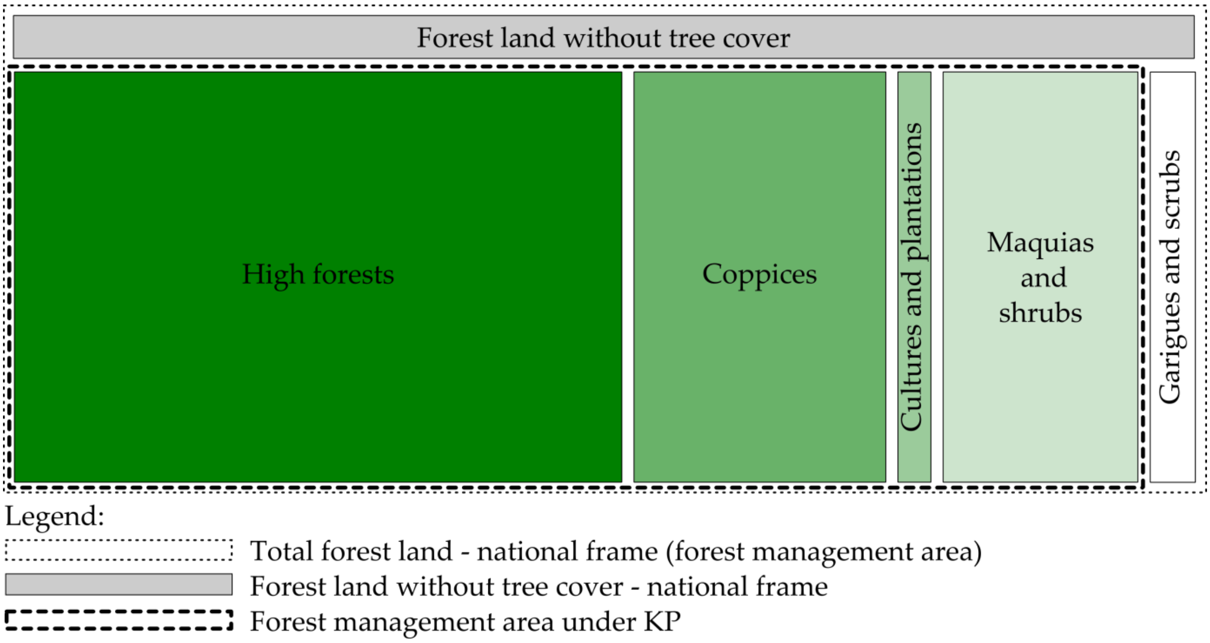
The related definition of Land converted to Forest land is provided in Chapter 6.2.1. According to the national legislation, the forest land definition was in line with the 2006 IPCC Guidelines. However, definition of forest area in the national context has a broader framework than defined by Croatia within selected values for the purposes of reporting under the UNFCCC. By the national framework forest land with tree cover (forests) and without tree cover (land under the forest management) constitutes one forest management area which is sustainable managed based on the FMAPs regardless the ownership type, purposes, forest stands etc. (see Chapter 6.3. for detail explanation).

Therefore, the area under the forest land according to the criteria set for UNFCCC reporting is not identical to forest management area in the national framework (Figure 6.4-2).

Croatian forest land area for the purposes of UNFCCC reporting refers to the area of high forests, cultures, plantations, coppice, maquis and shrub forests.

All forests fulfilling the definition of forests as defined in Table 6.4-1 are managed since the entire Croatian forest area is defined as managed forest lands.

Figure 6.4-2: Forest land area under the UNFCCC and within the national framework (based on the relative share of forest types in total forest management area in Croatia)




The basic input data for the estimation of emissions/removals was the area of land converted to Forest ladn (afforested land). To identify complete afforested areas, both types of afforestation were included in the survey as defined by 2006 IPCC Guidelines: afforestation by seeding and planting and afforestation due to human induced promotion of natural seed sources. The survey was conducted within the framework of project "*Improving Croatian reporting in Land use, Land use change and Forestry (LULUCF) sector in the First commitment period of the Kyoto Protocol*" (LULUCF 1) in order to comply with requirements, set in ARR 2012. The project was initiated by Ministry of Environmental and Nature Protection (now: Ministry of economy and sustainable development) through cooperation with relevant institutions.

All data and information concerning afforested areas are presented in a separate document[41] as one of outcomes of the project. The survey conducted during the LULUCF 1 project addressed the issue of increasing forest area in a way that:

1. Forest area increase on the basis of afforestation that happened before 1st January 1990 was determined (e.g. in 1993 a regulation[42] by the Croatian law gave the obligation to Croatian Forests to take over all existing forest land covered under previous forest management plan and also from other enterprises). The background for this law was that all forest area in Croatia should be under forest management plans. As a result of this law also mature forests were for

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[41] Janes *et al.* (2014), Separation of areas under the Article 3.3 and 3.4 of the Kyoto protocol. See list of References.

[42] The Regulation on amendments to the Law on Forests (OG 14/93, Article 18) and Law on amendments to the Law on Forests (OG 76/93, Article 22).

the first time counted as forest land under the new forest management plans. Croatia counted these lands under FL-FL subcategory.

2. Afforestation and the former land use after 1st January 1990 and direct human induced LUC were identified. These areas are registered under the Land converted to Forest land subcategory with the exact type of conversion starting from 1990.

3. Afforestation not direct human induced were examined. There is no afforestation in Croatia that can be considered as not direct human induced.

All forests regardless the type and ownership were included in the survey. The same procedures were applied for years 2013-2022.

In the part of survey that concerns identification and traceability of areas that were subject of afforestation, by the survey both types of afforestation as defined by IPCC were covered: afforestation by seeding and planting and afforestation due to human induced promotion of natural seed sources. The survey was performed in all forest areas the ownership and forest types. Pursuant to Article 27 of the Ordinance on forest management, afforestation in national circumstances is the activity within the forest regeneration and it refers to establishment of forests (afforestation) on non-forest land and to the establishment of plantations of fast-growing species. Forest regeneration is a part of the Forest Management plans/programs (FMAPs) and thus afforestation done by seeding and planting is clearly human induced.

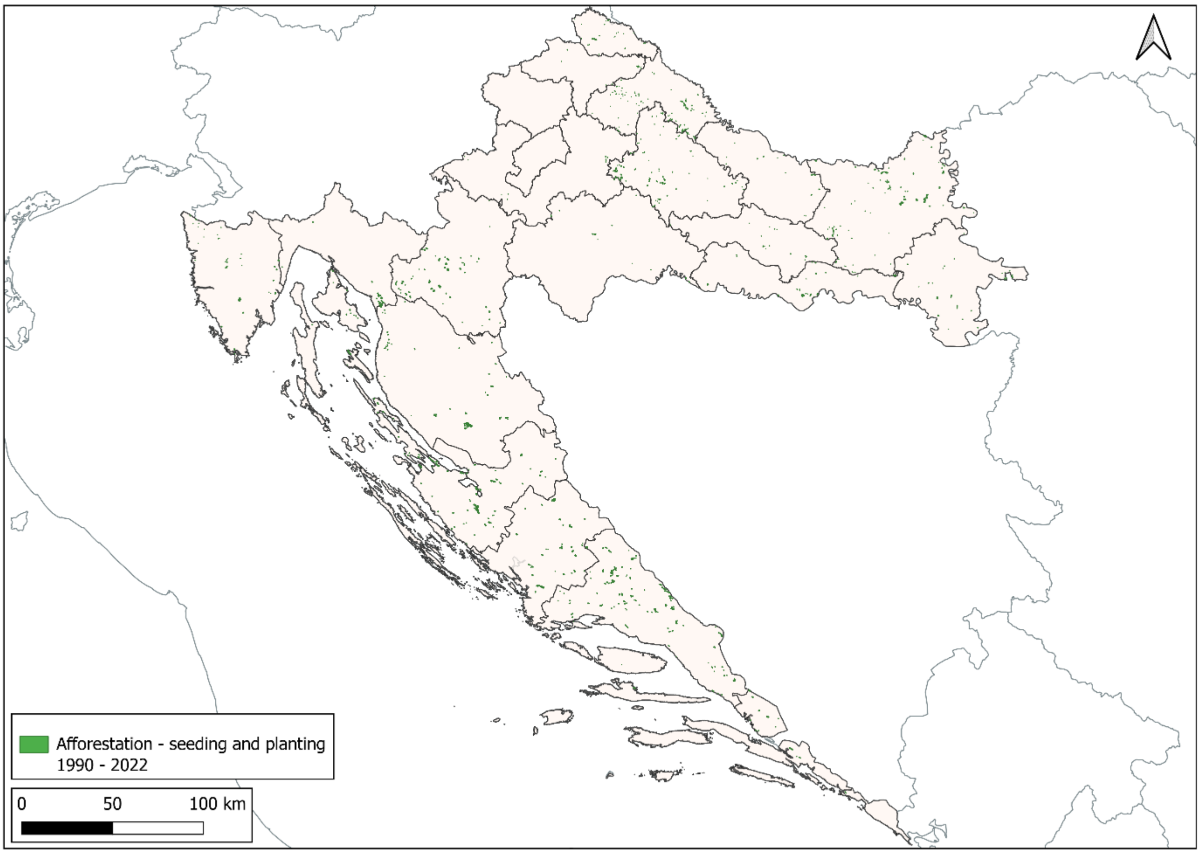
The Approach 3 and wall to wall mapping was applied during the survey for collecting data and information on areas afforested through seeding and planting regardless the ownership and forest types. A special Questionnaire was designed for this purpose. Data and information requested by questionnaire were collected at two levels of forestry administrations:

1) The level of Forest Administration such as: a) the name of Forest Administration; b) the name of regional Forest office; c) the name of management unit (FMU); d) FMU code
2) The level of regional forest office providing the data and information at the time of afforestation e) Period of validity of forest management program; f) year of afforestation; g) compartment code; h) cub-compartment code; i) sub-compartment size area; j) size of sub-compartment area afforested
3) The level of regional forest office providing the data and information at present time such as: k) period of validity of forest management plan/program; l) compartment code; m) sub-compartment code; n) size of sub-compartment area afforested; o) GIS afforested area.

The questionnaire was designed in order to review all previously data reported by Croatia under the UNFCC and KP, and to develop a unique map of areas afforested in Croatia through seeding and planting in period 1990-2012. After the LULUCF 1 project was finalized in 2015, new recording system was introduced in database system of Croatian forests Ltd. in order to support Croatian KP reporting in part of identification and traceability of lands that are subject of afforestation and deforestation activities and securing application of Approach 3 in the reporting during the 2nd Commitment period. Areas afforested in Croatia through seeding and planting in period 1990-2022 are presented in Figure 6.4-3.

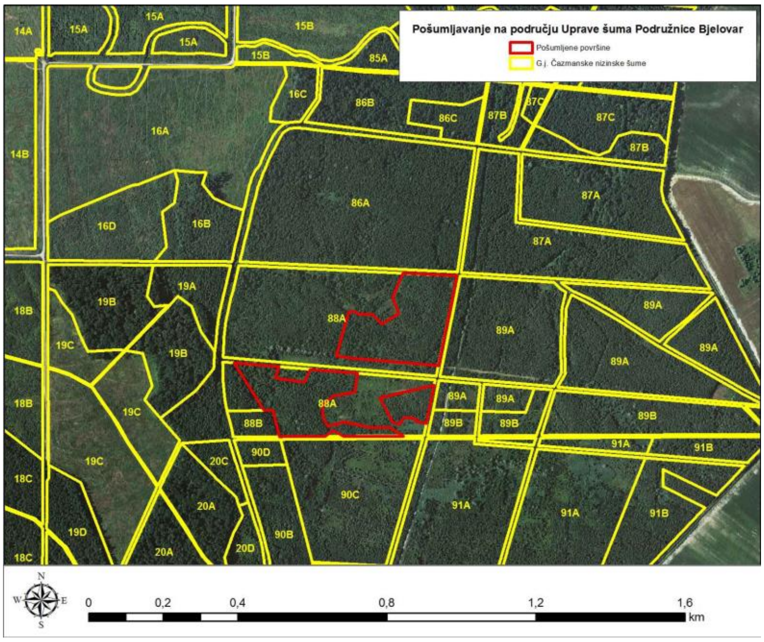
Data and information collected at the level of Forest administration and level of regional forests offices were merged within GIS layer of forest management types to perform final checks using the topographical map (1:25,000) from 1970s, new topographical maps, Croatian base map 1:5,000 and old management maps. An example of performed checks is presented in Figure 6.4-4.

Figure 6.4-3: Areas afforested in Croatia through seeding and planting in 1990-2022 (marked green)




When performing this work, all areas that were previously reported as afforestation areas and for which was found mismatch with IPCC definition of term afforestation in fully, exclusion from the areas eligible for UNFCCC and KP reporting was done.

Figure 6.4-4: An example of afforested area registered on forest management map with orto-photo background layer showing present state of areas (Forest Administration Bjelovar, FMU "Čazmanske nizinske šume", sub-compartments 88 a and b, year of afforestation 1993, afforested area 10.01 ha)



Croatia believes that collecting the data on the level of a part of area of sub-compartment on which afforestation was successful, complete and detailed analyses of afforestation through seeding and planting was performed.

Afforestation due to human induced promotion of natural seed sources were performed for all type of forests and forests ownership. Performed analyses differed depending on forest ownership. In case of state-owned forest managed by Croatian forests Ltd. Approach 3 and wall to wall mapping was performed as presented below.

For the extraction of surface vector layer in ESRI, .shp format of forests expanded by spreading of seeds on new areas software packages ESRI's ArcEditor 10, QGIS Desktop 2.4 and AutoCAD Map 3D with raster design module were used.

Spatial vector and raster data associated with official “HS fond” (contains all data on parameters relevant for forest sector) database of “Croatian forests Ltd” were used as an input data. Areas and boundaries (polygons) of the compartments/sub-compartments of every single FMU were analysed. Additionally, in the analyses was used a vector layer of forest boundaries obtained by using GIS methods from old topographic maps in scale 1:25,000. Raster data used during the analyses were primarily topographic maps 1:25,000 whose content corresponds to situation in period 1971 – 1980, digital ortho-photo raster data from period 1998-2006, and recent data from digital ortho-photo in 2012.

Performed GIS analysis is presented in nine steps on the example of one Forest Administration (Našice). Small methodological difference could be noted when taking into consideration whether analyses is performed in even aged forests (all nine steps necessary to identify area increase) or uneven aged forests (steps four and seven not needed).

Step 1: Forest management maps presenting areas on sub-compartment level and maps showing boundaries of Forest Administration were used (Figure 6.4-5).

Step 2: All areas that do not comply with KP definition of forests (i.e. garigues and scrubs) as well as forest area that are not grown naturally (cultures, plantations) were identified in order to be removed from the analyses (Figure 6.4-6).

Step 3: All areas that are not cover by forests are detected in order to be removed from the maps and future analyses (Figure 6.4-7).

Step 4: All area covered with forests older than 24 years are identified and removed from the analyses (in case of even aged forest, Figure 6.4-8) because they were forests already in 1990.

Step 5: Forest areas that remain after conducting steps 1-4 were then overlapped with topographical maps (1:25000) from 1980 on which vector layer of forests were created using the GIS methods for this purpose. The result of the overlap was a vector layer presenting forest area that were not forest before 1990 (Figure 6.4-9).

Step 6: In this step correction in areas was made due to difference in scale of maps used (i.e. basis for present forest management maps is cadastre and its maps in scale 1:2,000 or 1:2,880 or digital orto-photo in scale of 1:5,000 while forest areas in 1980 are presented in topographical maps in scale of 1:25,000). Correction was made after overlapping with topographical maps - all areas that were not forests were removed (Figure 6.4-10).

Step 7: In this step all areas that were younger than 24 years and which grows on areas that were registered as forest area even before 1990 were identified in order to be removed from the analyses. This step was needed because some of areas went through natural regeneration before 1990 without adequate result and were subject of replanting and were not detected on topographical maps. (Figure 6.4-12.)

Step 8: Areas that were remaining after steps 1-7 were conducted were subject of final control which was done using the state orto-photo from 2012. Due to use of different maps with different scales it was not possible to get full compliance among cadastral and forest management maps and there were cases in which remained identified areas were actually arable land or unfertile land and not forests. For this reason in this step of analyses, all these areas were checked on the level of regional forest offices on the site (Figure 6.4-13).

Step 9: Areas identified as a subject of human induced promotion of natural seed sources on level of each of 16 Forests Administrations were merged in order to present these areas on a single map (Figure 6.4-14).

Figure 6.4-5: Forest Administration Našice (boundary of Administration marked in green dots, forests area according to national definitions in 2014 marked in green)

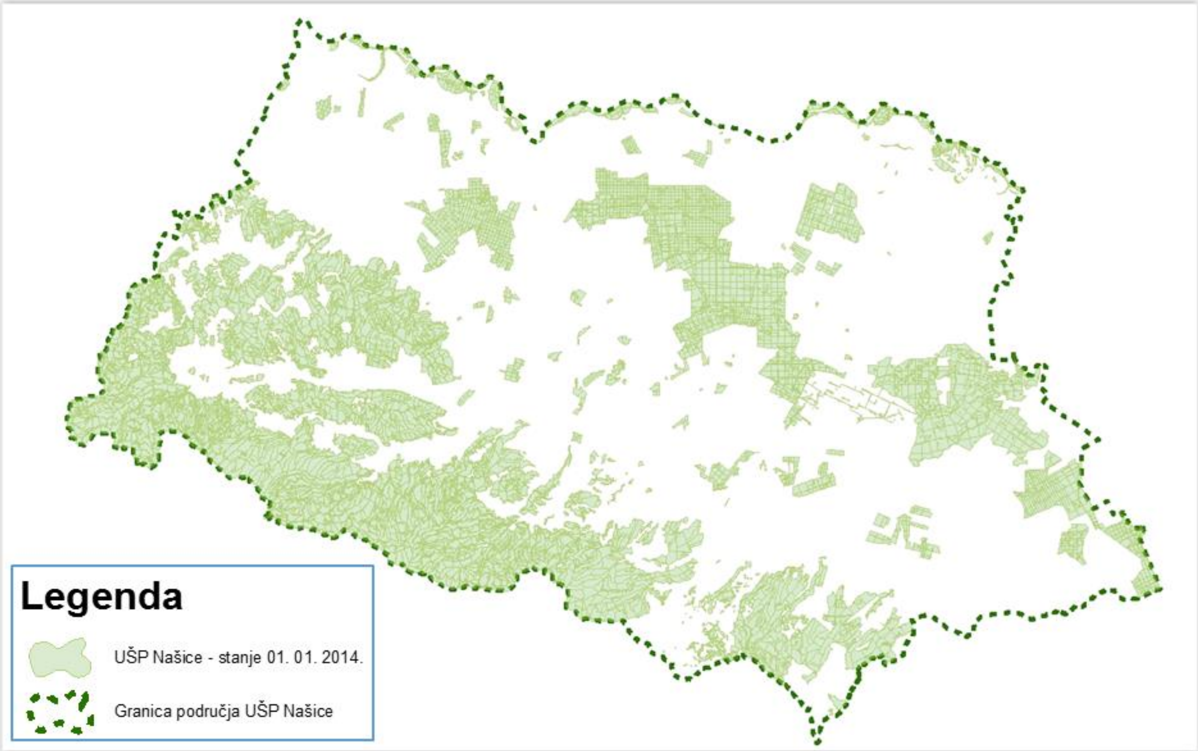



Figure 6.4-6: Forest Administration Našice (boundary of Administration marked in green dots, forests area according to KP definition of forests marked in pink, area not complying with KP definition of forests marked in green)

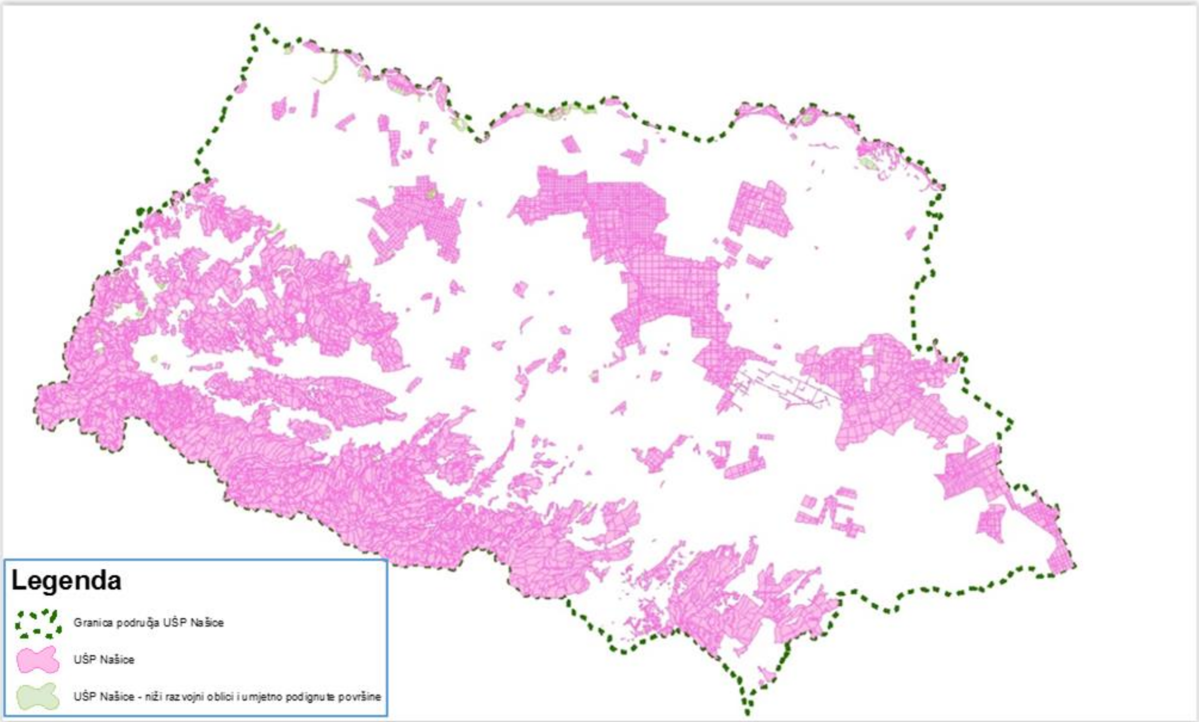


Figure 6.4-7: Forest Administration Našice (boundary of Administration marked in green dots, forests area marked in yellow, non-stocked forest area (i.e. clearings) marked in green)

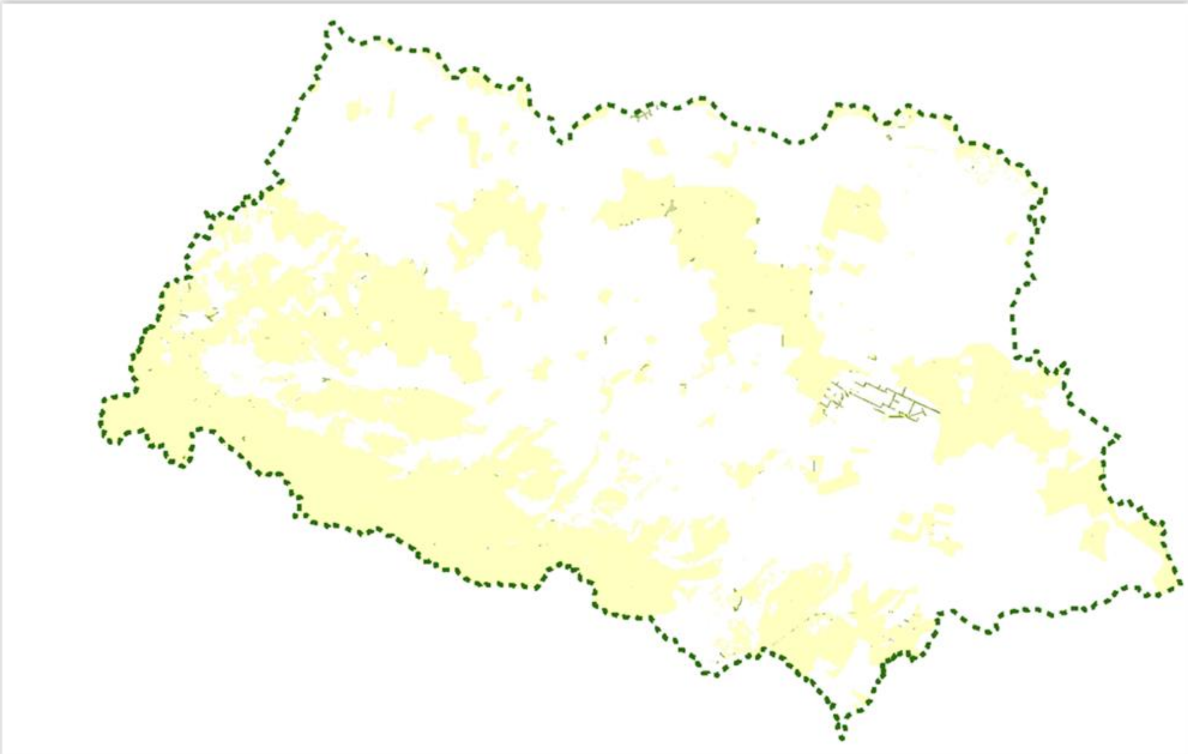


Figure 6.4-8: Forest Administration Našice (boundary of Administration marked in green dots, forests older than 24 years marked in green, remaining forest area marked in pink)

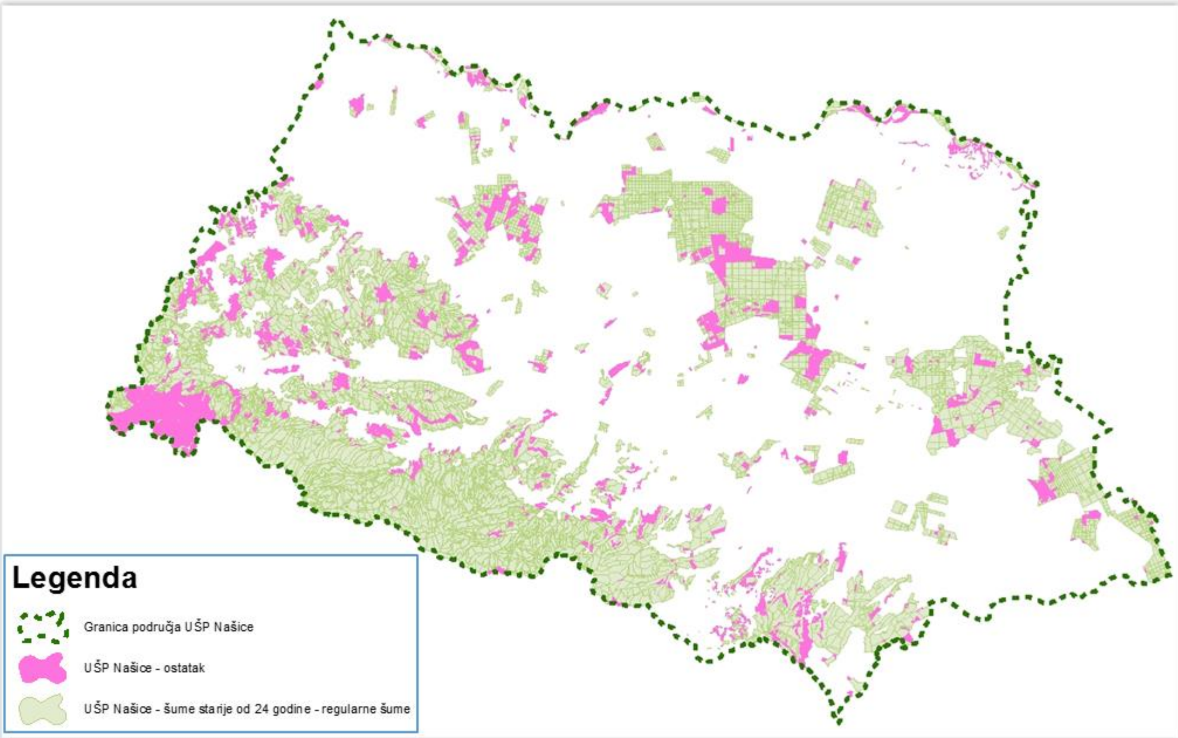


Figure 6.4-9: Forest Administration Našice (boundary of Administration marked in green dots, forests according to polygons of forests from topographical map marked in green, remaining forest area marked in pink)

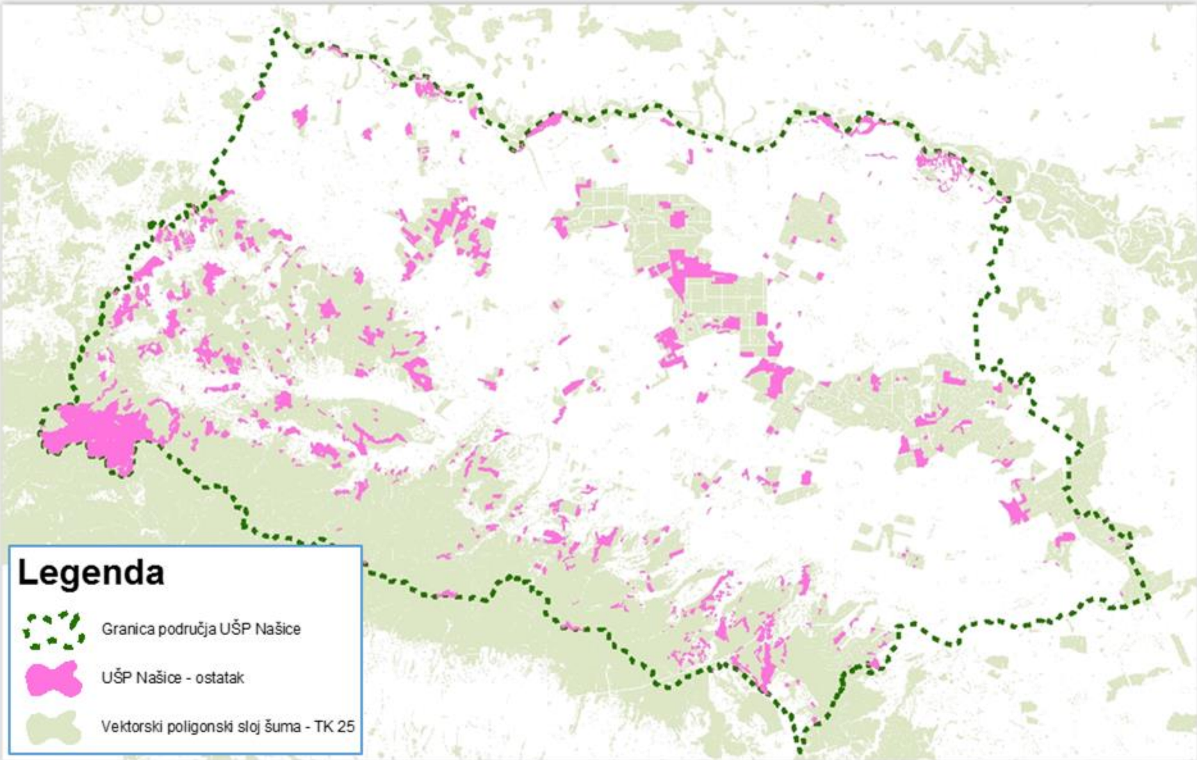



Figure 6.4-10: Forest Administration Našice (boundary of Administration marked in green dots, forests according to topographical map marked in green, remaining forest area after overlapping with topographical map marked in pink)

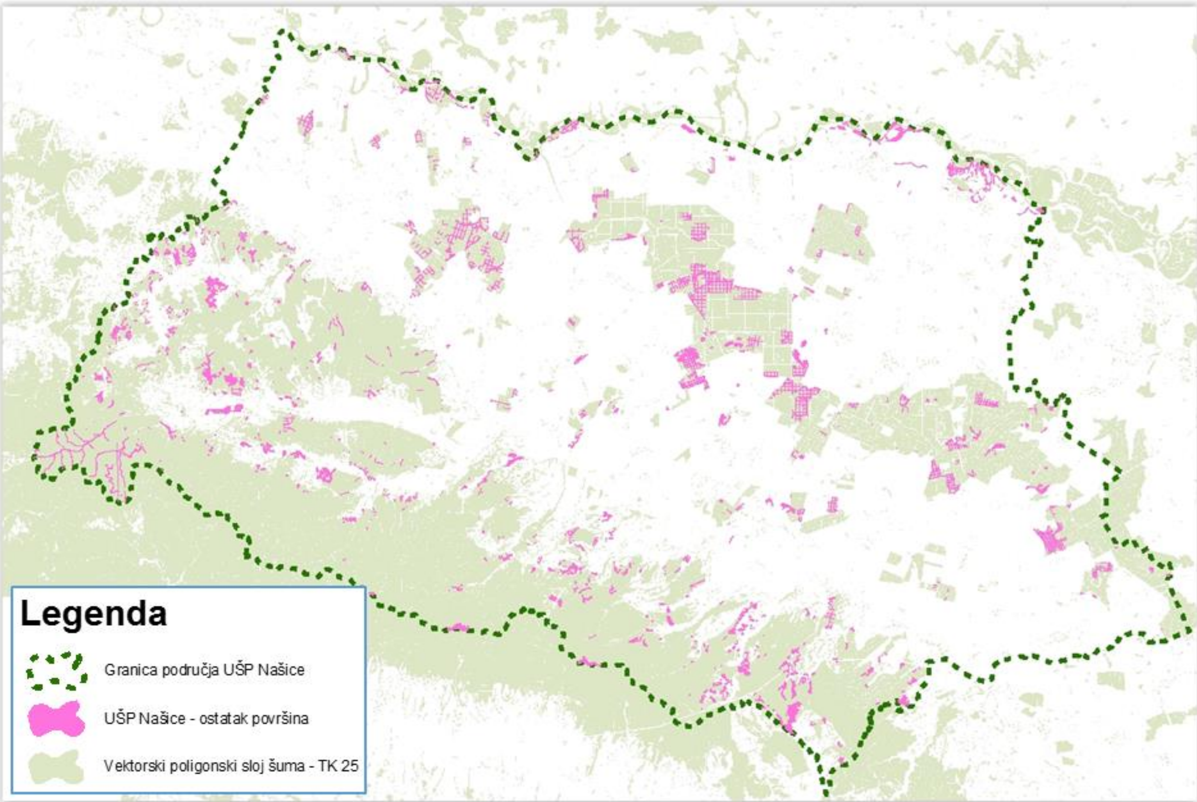


Figure 6.4-11: Forest Administration Našice (boundary of Administration marked in green dots, forests according to topographical map marked in green, remaining forest area after conducting step No. 6 marked in blue)

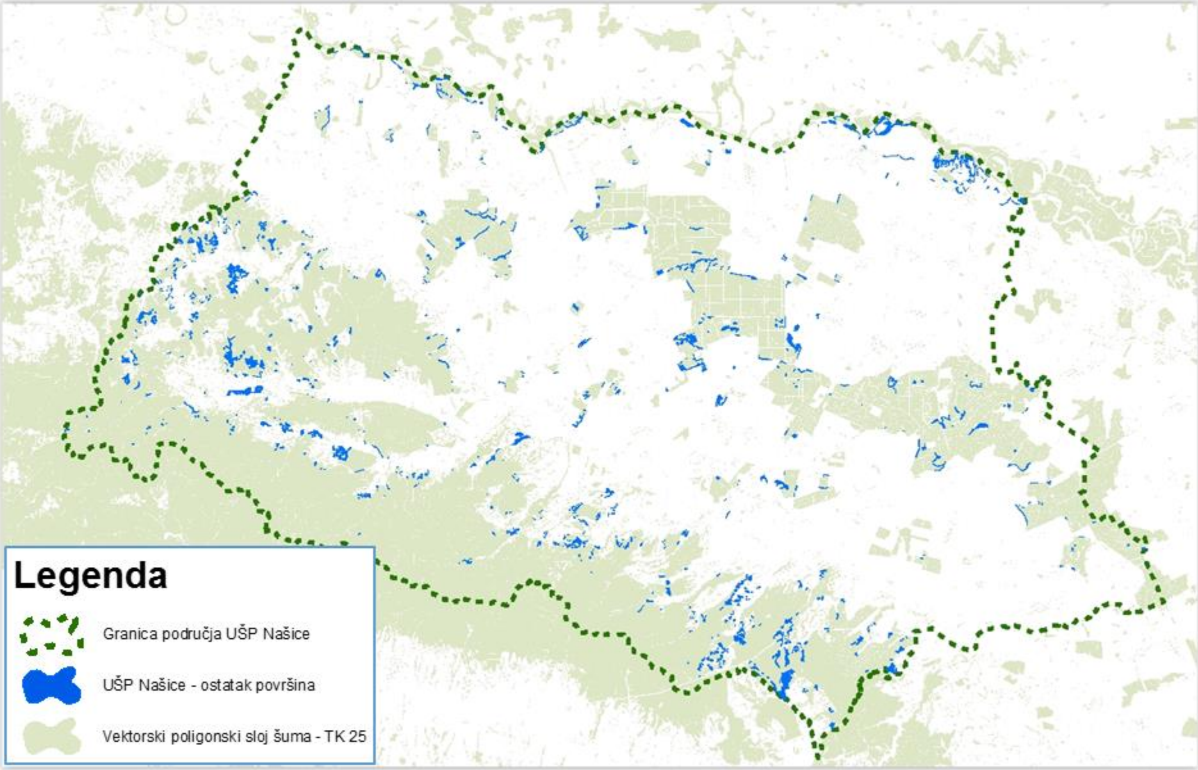



Figure 6.4-12: Forest Administration Našice (boundary of Administration marked in green dots, forest areas younger than 24 years marked in blue, remaining forest area marked in purple)

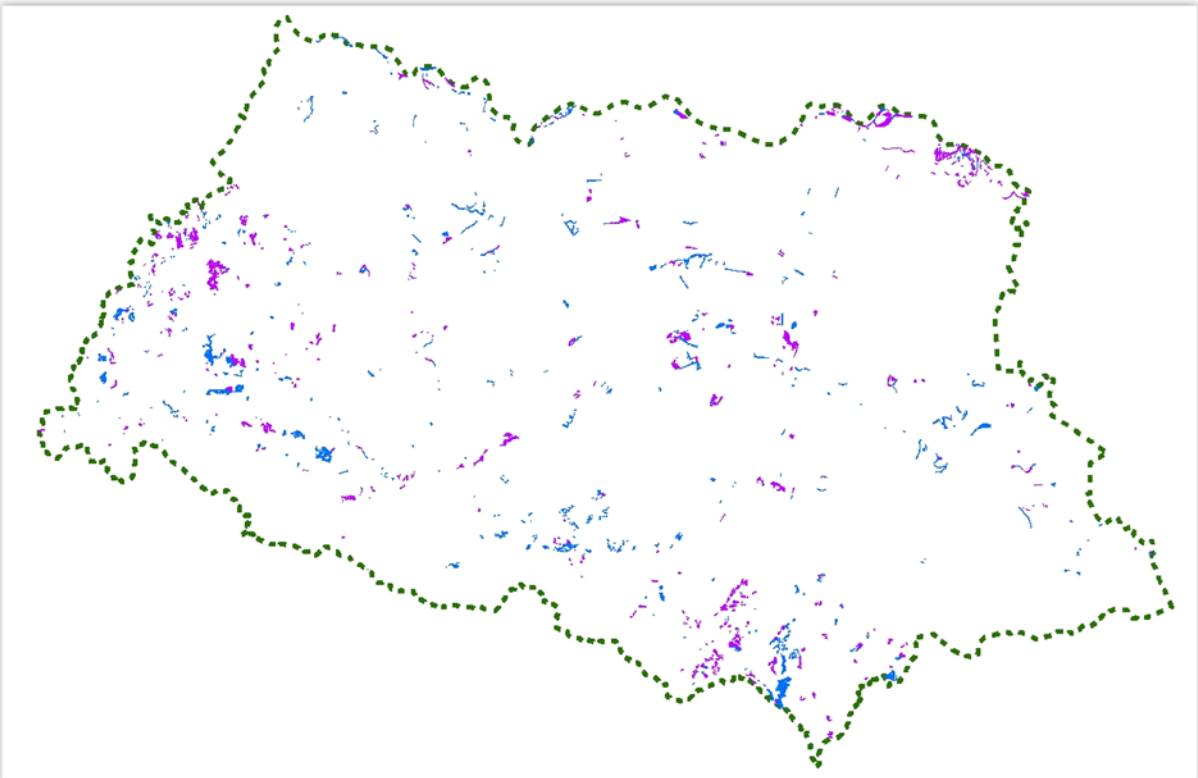
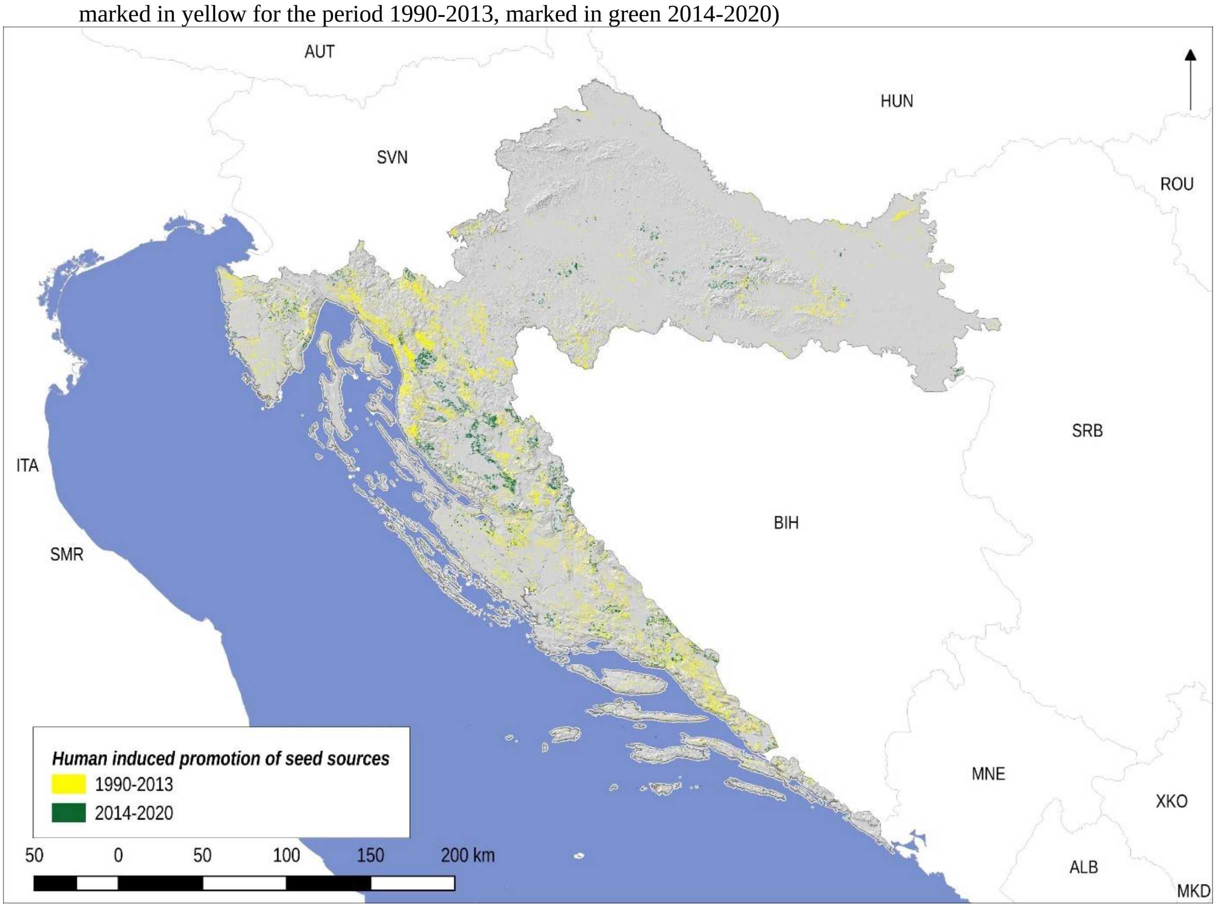


Figure 6.4-13: Forest Administration Našice (boundary of Administration marked in green dots, areas identified as not forests after step No 8. marked in red, areas identified as afforested after steps No1-No8 were performed marked in green)


After analyses were done, forests area that are identified as a result of afforestation due to human induced natural promotion of seed sources in state owned forests were presented in below map (Figure 6.4-14).

Figure 6.4-14: Identified afforested areas as a result of human induced promotion of seed sources in period 1990-2020 (areas marked in yellow for the period 1990-2013, marked in green 2014-2020)




According to the national legislation and forest practices applied in Croatia, afforested areas on which seeding/planting are conducted have to be separately registered. This means that these areas were well known before the LULUCF 1 project was conducted in Croatia. Regarding the identification of afforested lands due to human induced promotion of seed sources in private forests it was not possible to conduct survey on the same way as for state owned forests managed by Croatian forests Ltd. These forests are mostly managed as uneven aged forests, their area is not fully covered with official forest management programs (only 50% of area) at that time and there were no sufficient number of quality data and information on their previous state. Using the results of conducted survey in state owned forests proxy estimate was done. In order to determine category from which conversion to private forests happened, data and information from 10% of private forests covered by forest management programs were taken and expanded to whole area of private forests. This 10% represents 63.217,44 ha of private owned forests. At the time of LULUCF 1 project implementation 50% of private owned forests were covered by the forest management programs.

In case of State-owned forests that are managed by other legal bodies, conducted analyses proved that there is no increase of forests area in this type of forest ownership due to conversion from other land use categories. This applies conversion to forest land in case of afforestation by seeding and planting and afforestation due to human induced promotion of natural seed sources. This was an expected outcome since forests belonging to this category of ownership are under strict or certain type of protection under provisions of Low of nature protection and their area is fixed, well known, and cannot be changed without strict legal procedures that require involvements of many institutions in Croatia.

Conducted survey showed that increase in forest area happens in state owned forests managed by Croatian forests Ltd., and private forests because of afforestation due to human induced promotion of natural seed sources in period 1990-2012. Additionally, analyses proved that conversion to forest land due to afforestation by seeding and planting occurs only in case of state-owned forests managed by Croatian forests Ltd.

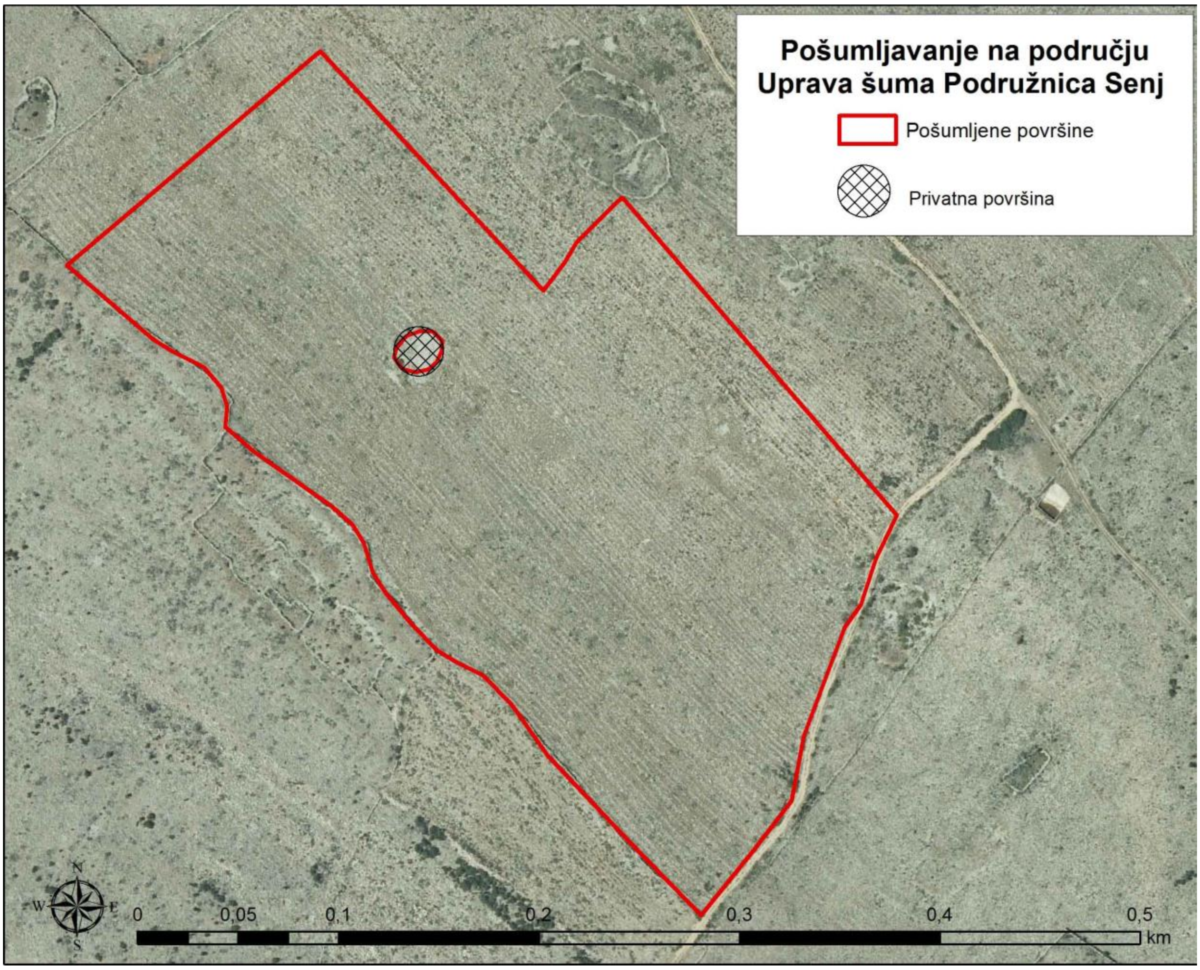
In case of afforestation in private forests generated through planting and seeding measures, analyses conducted through LULUCF 1 project proved that in period 1990-2012 in private forests no afforestation has occurred through planting and seeding measures. This was expected outcome, since according to the Ordinance[43] that prescribes rules for entitlement to funding for work performed in private forests and *Article 9* of the *Ordinance on the Register of forest owners*[44], funds can be obtained by private owners only for works performed on area that is registered in cadastre as forest or land under the forest management. Comparison between national definition of land under the forest management and IPCC definitions of categories of land shows that partially the IPCC category of Grasslands falls under the definition of land under the forest management according to the national definition. Potentially, this meant that some of afforestation work could occur on grasslands owned by private owners. The type of land that is without real forest cover on private lands and which is in cadastre registered as forest land is mainly present in karst region in Croatia. Based on the facts that afforestation works in karst region are very demanding, expensive and require to be performed by adequate species which are mostly economically less valid, it is understandable that afforestation in private forests in karst region on land that has not been forested for a period of at least 50 years did not occur.

Through the conducted survey detailed data and information about conversion to forest land category through seeding and planting measures were collected and areas of conversion are well known (Figure 6.4-2).

[43] Regulations on the procedure for granting funds from fees for the use of beneficial functions of forests for work performed in private forests (OG 66/06, 25/11). See list of References.

[44] Ordinance on amendments to the Ordinance on the Register of forest owners (OG 84/2008). See list of References.

Figure 6.4-15: State owned area of land under the forests management (grassland) converted to Forest land (marked in red) and area of private grasslands excluded from conversion, marked as circle




Total area of Grassland, Annual cropland and Perennial cropland converted to Forest land in period 1990-2012 for state and private owned forests through afforestation measures (seeding and planting and human induced promotion of natural seed sources) on yearly bases as it is determined through conducted survey under the LULUCF 1 project is presented in Table 6.4-4. After the LULUCF 1 project was finalized, new recording system was introduced in database systems of Croatian forests Ltd. in order to support UNFCCC and KP reporting in field of forestry, especially for the identification and traceability of lands that are converted to/from Forest land.

Table 6.4-4: Land converted to Forest land, annual LUC (kha/year)

| Year | LUCs | | |
|---|---|---|---|
| | aCL – FL | pCL - FL | GL - FL |
| 1990 | NO | NO | 0.00 |
| 1991 | NO | NO | 0.21 |
| 1992 | NO | NO | 0.16 |
| 1993 | NO | NO | 0.30 |
| 1994 | NO | NO | 0.26 |
| 1995 | NO | NO | 0.23 |
| 1996 | NO | NO | 0.29 |

| Year | LUCs | | |
|---|---|---|---|
| | aCL – FL | pCL - FL | GL - FL |
| 1997 | NO | NO | 0.20 |
| 1998 | NO | NO | 0.26 |
| 1999 | NO | NO | 0.33 |
| 2000 | NO | NO | 0.24 |
| 2001 | NO | NO | 0.25 |
| 2002 | NO | NO | 0.30 |
| 2003 | NO | NO | 0.28 |
| 2004 | 0.03 | NO | 0.62 |
| 2005 | 0.06 | 0.01 | 2.99 |
| 2006 | 0.06 | 0.01 | 2.81 |
| 2007 | 0.08 | 0.01 | 3.88 |
| 2008 | 0.08 | 0.01 | 1.75 |
| 2009 | 0.11 | 0.01 | 4.33 |
| 2010 | 0.15 | 0.01 | 4.64 |
| 2011 | 0.13 | 0.01 | 5.90 |
| 2012 | 0.24 | 0.02 | 4.76 |
| 2013 | 0.30 | 0.03 | 6.81 |
| 2014 | 0.38 | 0.04 | 7.93 |
| 2015 | 0.55 | 0.05 | 5.77 |
| 2016 | NO | NO | 1.43 |
| 2017 | NO | NO | 3.93 |
| 2018 | NO | NO | 1.73 |
| 2019 | NO | NO | 0.54 |
| 2020 | NO | NO | 0.34 |
| 2021 | NO | NO | 0.46 |
| 2022 | NO | NO | 0.30 |

To perform estimation, in case of period before 1990 (transition period of 20 years), the mean afforestation area 1990-1994 was used.

In case of a forest area increase beyond the traced afforestation from grassland to forest land that as an intermediate solution – was counted as LUC from other land to forest land and that was reported by Croatia in NIR 2013, within the scope of LULUCF 1 project Croatia performed a survey to determine reasons for the forest area increase that comes from other land category. The analyses included all types of forests and all type of forests ownerships. After the conducted analyses and determination of forest area increase because of human induce promotion of natural seed sources, conclusion is that there is no conversion from other land to forest land category. Only types of conversion that are identified and geographically explicit determined are conversion from Grassland, Annual and Perennial cropland to Forest land. In case of conversion of other land to Forest land Croatia reports *Not occurring* (NO).

Conducted survey confirmed that beyond the increase of forest area in state owned forests managed by Croatian forests because of afforestation through seeding and planting, an additional increase in area of Private forests and in state owned forests managed by Croatian forests Ltd., due to human-induced promotion of natural seed sources.

The largest part of the forest area in Croatia is managed in a sustainable manner and little is intensively managed. Extensive forest management as such, does not exist in Croatia. According to the forest experts' judgement, the area of land converted to intensively managed forest (in our case plantations) is very small. Since these data were not provided in this form, the calculation assumed that afforestation resulted in the area of land converted to sustainable managed forest.

As for wildfires, area caught by fire has been estimated also based on the survey conducted through LULUCF 1 project and $CO_2$ and non-$CO_2$ emissions are reported under the Forest land remaining Forest land and Land converted to Forest land subcategory in CRF tables.

A) Biomass

To determine the changes in biomass carbon stocks in areas converted to Forest land in Croatia equations 2.7 and 2.10 from the 2006 IPCC Guidelines as well as results and outcomes of the conducted survey under the LULUCF 1 project (referring to period 1990-2012) were used as presented below:

1. During the reporting period, there was no conversion to forest land from other categories of land in case of state-owned forests managed by other legal bodies. The same is valid for years 2013–2018.
2. In private forests conversion from Grassland and Annual and Perennial cropland occurred since 1998. According to the conducted survey, 82.1% conversion refers to conversion of Grasslands, 16.3% to conversion of annual Cropland and 1.6% to conversion of Perennial cropland to Forest land. These figures were determined by using and comparing data and information from two consecutive Forest management programs in private forests presenting 10% of areas of private forests that are covered by official forest management programs. These shares are applied for period 2013–2020.
3. In case of state-owned forests conversion that happens refers only to Grassland converted to Forest land. This is a result of the conducted survey based on checks performed using and comparing data and information available at two consecutive forest management plans/programs when performing survey. This is valid also for period 2013–2020.

For the purposes of estimation, below presented values according to the type of conversion (from Grassland or Cropland) and type of forests were used:

1) Average annual increments from the 2006 IPCC Guidelines were used for the aboveground biomass in natural regeneration.
2) Values for the Temperate Forest in age class ≤ 20 years and ≥ 20 years were applied
3) The applied values are the same for both age classes (3 tdm/ha annually (for coniferous), 4 tdm/ha (for deciduous), and 0.5 tdm/ha (for maquies and shrub).
4) Mean values of the average Root to Shoot ratio (R/S) from 2006 IPCC Guidelines were used (0.4 (for coniferous in age class ≤ 20 years), 0.46 for deciduous forests. Regarding the maquies and shrub forests the expert judgement was applied when deciding to use the value of 0.46 from 2006 IPCC Guidelines.
5) Applied Carbon fraction values were the same used in the estimation of carbon stock change: 0.51 tC/ t dm for coniferous, 0.48 tC/ t dm for deciduous and 0.47 tC/ t dm for maquie and shrubs.

Based on the above-mentioned factors, average biomass growth was calculated to be 2.14 tC/ha annually in case of coniferous forests in age class ≤ 20 years and 1.97 tC/ha in age class ≥ 20 years. Value of 2.8 tC/ha was used s average biomass growth for deciduous. Average biomass growth was calculated to be 0.34 tC/ha for maquies and shrub forests.

To calculate the biomass carbon stock losses because of grassland and cropland conversion to the forestland, the nationally determined value of 4.29 tC/ ha annually for grassland category and 5.67 tC/ha annually for annual Cropland category were used. When estimating carbon stock losses due to conversion of perennial Cropland to forestland the value of 8.9 tC/ha annually was used as determined under nationally conducted project in 2021 (so called LULUCF 3 project). The value of 8.9 tC/ha annually presents a half of the CS defined in pCL in Croatia under the LULUCF 3 project. Half of the stock has been used because the new land use will require the land immediately after the decison of land use change independent of the age of the stocks and half stocks would be the likely average.

Although, estimation was performed taking into consideration also type of forests (i.e. area of grassland that are converted to deciduous forests, to coniferous forests and to maquies and shrub forests separately) data that corresponds to whole forest area in specific years are presented in CRF database under specific categories of LUC.

B) Soil and litter pool

The soil data collected through the scientific investigation performed in 2017 (Chapter 6.5.2.1) were analysed and the mean values determined for each land use category are taken into calculation.

The estimation was performed using the national value of 9 for C/N ratio in case of Grassland mineral soils that are converted to Forest land.

The estimates of the soil carbon stock changes at land converted to forest land (afforestation) follow the equation below:

$\Delta C_{LFMineral} = [(SOC_{ref} – SOC_{Non\ Forest\ Land}) \text{ x } A_{Aff}]/T_{Aff}$

where:

$\Delta C_{LFMineral}$ = annual change in carbon stock I n mineral soils for inventory year

$SOC_{ref}$ = reference carbon stock

$SOC_{Non\ Forest\ Land}$ = stable soil organic carbon on previous land use

$T_{Aff}$ = duration of the transition from $SOC_{Non\ Forest\ Land}$ to $SOC_{ref}$ (20 years)

$A_{Aff}$ = total afforested/reforested area after conversion

The median values of soil carbon stock for the soil depth of 0-30 cm determined through the national scientific soil survey conducted in 2017 were used in order to present the carbon stock changes in soil (see Chapter 6.5.2.1). The results of national survey and determined mean values of carbon stock changes in soil are:

- Cropland (annual): 52.71 t C/ha,
- Cropland (perennial): 71.01 t C/ha,
- Forest land: 69.86 t C/ha,
- Grassland: 75.75 t C/ha,
- Settlements: 86.91 t C/ha.

Soil removal factor determined in this case is 0.695 tC/ha annually.

Table 6.4-5 provides information on annual change in carbon stock in living biomass and soil for the Land converted to Forest land. Since 1990 the conversion from other land use categories to the Forest land results in $CO_2$ removal.

For this year submission data used from the scientific investigation on determining carbon stock in soil and litter pool are used (Chapter 6.5.2.1).

Annual carbon stock changes in litter at lands converted to / from forests are calculated using the equation 2.23 form the IPCC 2006 GL as follows:

$\Delta C_{LT} = A^* (C_n – C_o)/T$

$\Delta C_{LT}$ = average annual carbon stock change in litter (t C/a)

A = annual D area, respectively the AR area following a transition period of 20 years.

$C_n$ = carbon stock in litter under the new land use category (4,57 t C/ha in case of land converted to FL and 0,00 in case of land converted from FL)

$C_o$ = carbon stock in litter under the old land use category (0,0 t C/ha in case of land converted to FL and 4,57 tC/ha in case of land converted from FL)

T = transition period from old to new land use category (1 year for D areas, 20 years for AR areas)

Table 6.4-5: Annual change in carbon stock in living biomass, soil, litter and deadwood for Land converted to Forest land

| Year | Biomass carbon stocks - gains | Biomass carbon stocks - losses | Net carbon stock change in biomass | Net carbon stock change in soil | Net carbon sock change in litter | Net carbon sock change in deadwood | Total |
|---|---|---|---|---|---|---|---|
| kt C | | | | | | | |
| 1990 | 8.07 | 0.00 | 8.07 | -1.04 | 0.81 | 0.04 | 7.88 |
| 1991 | 8.15 | -0.92 | 7.23 | -1.05 | 0.82 | 0.04 | 7.03 |
| 1992 | 8.08 | -0.70 | 7.38 | -1.04 | 0.81 | 0.04 | 7.19 |
| 1993 | 8.34 | -1.28 | 7.06 | -1.08 | 0.84 | 0.04 | 6.86 |
| 1994 | 8.50 | -1.11 | 7.39 | -1.10 | 0.85 | 0.04 | 7.18 |
| 1995 | 8.60 | -0.99 | 7.60 | -1.11 | 0.86 | 0.04 | 7.40 |
| 1996 | 8.83 | -1.23 | 7.60 | -1.14 | 0.89 | 0.04 | 7.38 |
| 1997 | 8.87 | -0.84 | 8.02 | -1.14 | 0.89 | 0.04 | 7.81 |
| 1998 | 9.04 | -1.12 | 7.92 | -1.17 | 0.90 | 0.05 | 7.71 |
| 1999 | 9.35 | -1.42 | 7.92 | -1.21 | 0.94 | 0.05 | 7.70 |
| 2000 | 9.50 | -1.05 | 8.45 | -1.23 | 0.95 | 0.05 | 8.23 |
| 2001 | 9.66 | -1.09 | 8.57 | -1.25 | 0.97 | 0.05 | 8.34 |
| 2002 | 9.94 | -1.29 | 8.65 | -1.28 | 0.99 | 0.05 | 8.42 |
| 2003 | 10.16 | -1.22 | 8.94 | -1.31 | 1.01 | 0.05 | 8.70 |
| 2004 | 11.49 | -2.85 | 8.64 | -1.41 | 1.14 | 0.08 | 8.45 |
| 2005 | 13.37 | -13.18 | 0.18 | -2.19 | 1.84 | 0.10 | -0.06 |
| 2006 | 15.11 | -12.44 | 2.67 | -2.91 | 2.50 | 0.12 | 2.38 |
| 2007 | 17.52 | -17.16 | 0.36 | -3.93 | 3.42 | 0.15 | 0.00 |
| 2008 | 20.54 | -8.02 | 12.52 | -4.33 | 3.85 | 0.21 | 12.25 |
| 2009 | 25.08 | -19.32 | 5.76 | -5.45 | 4.91 | 0.27 | 5.49 |
| 2010 | 32.44 | -20.92 | 11.52 | -6.69 | 6.13 | 0.38 | 11.33 |
| 2011 | 36.97 | -26.19 | 10.78 | -8.26 | 7.56 | 0.43 | 10.51 |
| 2012 | 46.67 | -22.03 | 24.64 | -9.41 | 8.86 | 0.59 | 24.68 |
| 2013 | 55.57 | -31.22 | 24.35 | -11.07 | 10.65 | 0.72 | 24.65 |
| 2014 | 63.51 | -36.55 | 26.96 | -13.01 | 12.80 | 0.84 | 27.59 |
| 2015 | 67.49 | -28.41 | 39.09 | -14.17 | 14.62 | 0.90 | 40.45 |
| 2016 | 70.68 | -6.13 | 64.55 | -14.51 | 14.89 | 0.96 | 65.89 |
| 2017 | 74.20 | -16.88 | 57.32 | -15.61 | 15.74 | 1.02 | 58.47 |
| 2018 | 75.06 | -7.44 | 67.62 | -16.04 | 16.08 | 1.03 | 68.68 |
| 2019 | 74.86 | -2.31 | 72.55 | -16.10 | 16.12 | 1.03 | 73.61 |

| Year | Biomass carbon stocks - gains | Biomass carbon stocks - losses | Net carbon stock change in biomass | Net carbon stock change in soil | Net carbon sock change in litter | Net carbon sock change in deadwood | Total |
|---|---|---|---|---|---|---|---|
| 2020 | 75.13 | -1.47 | 73.66 | -16.13 | 16.14 | 1.04 | 74.72 |
| 2021 | 75.19 | -1.98 | 73.20 | -16.19 | 16.19 | 1.04 | 74.25 |
| 2022 | 75.18 | -1.29 | 73.89 | -16.19 | 16.19 | 1.04 | 74.93 |

### 6.4.3. Uncertainties and time-series consistency

For the purpose of defining uncertainties in LULUCF sector in Croatia, special questionnaire was developed in 2013 and several different experts from several Croatian institutions were consulted. This work was supported with the expert help secured through the EU project "*Assistance to Member States for effective implementation of the reporting requirements under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC)*" in 2013. Since then, the uncertainty estimate was performed for NIR 2015. There is on-going project initiated by Ministry of economy and sustainable development which deals with uncertainty in LULUCF sector. Results of this project should be included in future submissions.

The input uncertainties, associated with the different emission factors and the activity data as well as the sources of information (default values, empirical data or expert judgment) are presented in Tables 6.4-6 and Anex I. Some of the uncertainty values defined by experts are determined comparing two different statistics and were influenced with the fact that Croatia presented some of its area using the CLC data with its low resolution. The highest uncertainties defined by the experts refer to LUC to and from Cropland area caused due to the major change in official methodology used by CBS since 2005 and its data gathering and presentation. In this category, uncertainty was determined based on land use change area in certain time periods and applying more pessimistic values in case of more options (conservative estimation).

Table 6.4-6: Uncertainties of the emissions factors and the activity data and sources of information

| Inputs | Uncertainty | Source of information |
|---|---|---|
| Area of Forest land | 10% | Expert judgment |
| Increment | 7% | Expert judgment |
| Fellings | 5% | Expert judgment |
| Afforestation area | 2% | Expert judgment |
| Deforestation area | 2% | Expert judgment |
| Wood density | 30% | Default, IPCC 2006 |
| R/S (Root to Shoot ratio) for coniferous in Forestland | Range 0.12-0.49 | Default, IPCC 2006 |
| R/S (Root to Shoot ratio) for deciduous in Forestland | Range 0.17-0.30 | Default, IPCC 2006 |
| R/S (Root to Shoot ratio) for coniferous in afforestated areas | 42% | Default, IPCC 2006 |
| $BEF_1$ for coniferous | Range 1-1.3 | Default, IPCC 2006 |
| $BEF_1$ for deciduous | Range 1.1-1.3 | Default, IPCC 2006 |
| $BEF_2$ for coniferous | Range 1.15-4.2 | Default, IPCC 2006 |

| Inputs | Uncertainty | Source of information |
|---|---|---|
| $BEF_2$ for deciduous | Range 1.15-3.2 | Default, IPCC 2006 |
| CF factor | 3% | Expert judgment |
| Soil C stock in Forestland | 92% | Empirical data |
| Area of Cropland | 12% | Expert judgment |
| aCL area | 12% | Expert judgment |
| pCL area | 9% | Expert judgment |
| LUC area aCL-pCL | 500% | Expert judgment |
| LUC area pCL-aCL | 500% | Expert judgment |
| LUC area GL - aCL | 100% | Expert judgment |
| LUC area GL - pCL | 500% | Expert judgment |
| Yield biomass at LUC areas to and from aCL | 156% | Expert judgment |
| Other aboveground biomass at LUC areas to and from aCL | 156% | Expert judgment |
| Belowground biomass at LUC areas to and from aCL | 75% | Default, IPCC 2006 |
| pCL aboveground biomass | 75% | Default, IPCC 2006 |
| Organic soil area | 12% | Expert judgment |
| Soil C stock in annual Cropland | 57.1% | Empirical data |
| Soil C stock in perennial Cropland | 76,3% | Empirical data |
| Emission factor for organic Grassland soils | 90% | Default, IPCC 2006 |
| Emission factor for organic Cropland soils | 90% | Default, IPCC 2006 |
| Area of Grassland | 30% | Expert judgment |
| LUC area aCL-GL | 100% | Expert judgment |
| LUC area pCL-GL | 100% | Expert judgment |
| R/S factor in Grassland | 95% | Default, IPCC 2006 |
| Organic soil area | 30% | Expert judgment |
| Soil C stock in Grassland | 61.2% | Empirical data |
| Emission factor for organic Grassland soils | 90% | Default, IPCC 2006 |
| C/N ratio grassland soils | 10.6% | Empirical data |
| Yield biomass at LUC areas to and from Grassland | 75% | Default, IPCC 2006 |
| Area of Wetland | 1% | Expert judgment |
| LUC area aCL-WL | 300% | Expert judgment |
| LUC area pCL-WL | 300% | Expert judgment |
| Soil C stock in Wetlands | 67% | Empirical data |
| Area of Settlement | 30% | Expert judgment |
| LUC area FL-SL | 2% | Expert judgment |

| Inputs | Uncertainty | Source of information |
|---|---|---|
| LUC area aCL-SL | 300% | Expert judgment |
| LUC area pCL-SL | 300% | Expert judgment |
| LUC area GL-SL | 200% | Expert judgment |
| Biomass growth in pCL-SL | 50% | Expert judgment |
| Soil C stock in Settlements | 65.4% | Empirical data |

For all categories of land, uncertainty was performed using the Tier 1 and Tier 2 method.

When performing Tier 2 method, based on *Monte Carlo* simulation technique, normal distribution has been assumed for most of the inputs. The number of the applied iterations was 10,000. For each category of land, uncertainty is determined by subcategories and by gases. Relative value uncertainties in LULUCF sector was used when estimating uncertainty of all sectors.

According to the uncertainty estimate performed in LULUCF sector, the relative combined uncertainty of $CO_2$ equivalent emission/removal ranges in Forest land remaining forest land have been calculated using the uncertainties for emission factors and area presented in Tables 6.4-6 and presented in Annex II. In case of LUC to Forest land uncertainty of $CO_2$ equivalent is calculated and presented in Annex II.

### 6.4.4. Category-specific QA/QC and verification

During the preparation of inventory submission, all activity data were checked. The emission calculation was performed by one person and afterwards independently checked by another person within the institution that prepared the inventory. Institution that leads the technical work has approval of the Ministry of Environment and Energy for carrying out the GHG calculations. Activities related to quality control were also focused on completeness and consistency of emission estimates and on the proper use of notation keys in the CRF tables.

The input data, estimates and results were checked as follows:

1) Bottom-up check

  a. Input data
  - Check for the plausibility of the activity data and their trend
  - Check for plausibility of the emission factors as well as the related input data and their trends
  - Check of input data for completeness

  b. Estimations
  - Check of the correctness of all equations in the estimate files
  - Check of the correctness of all interim results
  - Check of the plausibility of the results and their trends
  - Check of the correctness of all data and results transfer

2) Top-down check

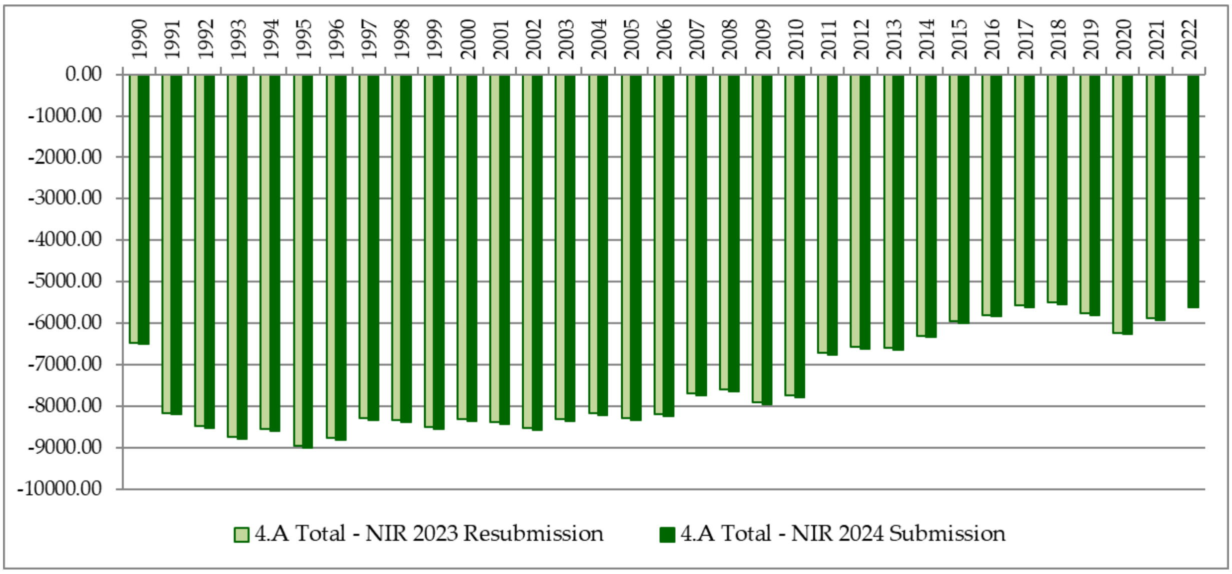
During the preparation of inventory, experts from all relevant fields were included. All input data were checked by the experts. The definitions, factors and methods applied in the report were agreed with the experts in relevant fields, ensuring in that way consistency and completeness of input data. The final calculated data were sent to the experts for their approval. The used activity data and emission factors were also compared with the data from other data sources (e.g. from literature, results in NIRs of other comparable regions, IPCC default values).

### 6.4.5. Category-specific recalculations

Since the NIR 2014 and start of applying the Approach 3 in identification of Land converted to and from Forest land and determining the Forest land remaining Forest land, some of the management plans and programs ceased to be valid and new plans/programs were developed. When developing new plans/programmes a due attention is given to the identification and traceability of forests that are result of human induced afforestation before 1990. When these areas are identified, changes in forest areas occur and these areas are registered and reported under the 1990 forest areas in corresponding NIR. The change in forest areas that comes from the forest areas defined under the two consecutive plans/programs led to the difference between areas reported under the FL-FL areas in NIR 2023 and NIR 2024. For NIR 2024 reporting it was traced 14,209.45 ha of new areas as the result of human induced afforestation before 1990. In addition, corection in matrix was performed for years 2003 and 2004 related to cropland area converted to Forest land. In case of Grassland category converted to coniferous forests the biomass stock chane was calculated using the transition period of first 20 years and corresponding stock in first age class forests. In other forest categories there has not been changes since the CS in biomass in first and second age class was the same. The performed changes in forest areas resulted with the decrease of removals in total Forest land category for 11.5% comparing the NIR 2023 with NIR 2024 data.

The result of the performed recalculation can be seen in Figure 6.4-16.

Figure 6.4-16: Current and previously reported emissions for category 4.A (kt $CO_2$-eq)




### 6.4.6. Category-specific planned improvements

Further investigation on BEFs is part of a project proposal within the LULUCF sector predicted in the long-term period. Also, Croatia intends to use the results of currently running CROLIS project that will enable application of Approach 3 in identification and traceability of each LULUCF land categories, three years from now.

## 6.5. Cropland (CRF category 4.B)

### 6.5.1. Description

Emissions/removals from cropland management (Cropland remaining cropland and Land converted to cropland) were considered in this category.

Total cropland area ranged from 1,625.38 to 1,522.09 kha in the period 1990-2022. Total emissions from cropland category ranged from 118.42 kt $CO_2$-eq to 275.62 kt $CO_2$-eq to for same period.

Annual LUCs to Cropland occurs from the Forest land and Grassland category.

Tables 6.5-1 and 6.5-2 present the land use change and removals/emissions* from land-use change (LUC) to cropland in the period 1990-2022.

Table 6.5-1: Activity Data of Cropland from 1990 to 2022, in kha

| Year | 4.B Total - Cropland | 4.B.1 Cropland remaining Cropland | 4.B.1.a Annual cropland remaining Annual cropland | 4.B.1.b Perennial cropland remaining Perennial cropland | 4.B.1.c Perennial cropland converted to Annual cropland | 4.B.1.d Annual cropland converted to Perennial cropland | 4.B.2 Land converted to Cropland | 4.B.2.1.b Forest land converted to Perenial cropland | 4.B.2.2.a Grassland converted to Annual cropland | 4.B.2.2.b Grassland converted to Perennial cropland |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1,625.38 | 1,618.43 | 1,473.76 | 143.34 | 0.43 | 0.89 | 6.95 | NO | 6.50 | 0.45 |
| 1991 | 1,625.01 | 1,617.17 | 1,473.39 | 142.15 | 0.56 | 1.07 | 7.84 | NO | 7.12 | 0.72 |
| 1992 | 1,624.69 | 1,615.97 | 1,473.99 | 140.03 | 0.70 | 1.25 | 8.72 | NO | 7.73 | 0.99 |
| 1993 | 1,624.24 | 1,614.63 | 1,474.47 | 137.90 | 0.83 | 1.43 | 9.61 | NO | 8.35 | 1.26 |
| 1994 | 1,623.89 | 1,613.39 | 1,475.04 | 135.78 | 0.96 | 1.61 | 10.50 | NO | 8.96 | 1.54 |
| 1995 | 1,623.50 | 1,612.12 | 1,475.59 | 133.64 | 1.09 | 1.79 | 11.38 | NO | 9.57 | 1.81 |
| 1996 | 1,623.06 | 1,610.79 | 1,476.10 | 131.50 | 1.23 | 1.97 | 12.27 | NO | 10.19 | 2.08 |
| 1997 | 1,622.79 | 1,609.64 | 1,476.76 | 129.36 | 1.36 | 2.15 | 13.15 | NO | 10.80 | 2.35 |
| 1998 | 1,622.48 | 1,608.44 | 1,477.40 | 127.22 | 1.49 | 2.33 | 14.04 | NO | 11.41 | 2.63 |
| 1999 | 1,622.03 | 1,607.10 | 1,476.37 | 126.60 | 1.63 | 2.51 | 14.93 | NO | 12.03 | 2.90 |
| 2000 | 1,621.80 | 1,605.98 | 1,484.76 | 116.77 | 1.76 | 2.69 | 15.81 | NO | 12.64 | 3.17 |
| 2001 | 1,616.08 | 1,599.38 | 1,480.36 | 114.26 | 1.89 | 2.87 | 16.70 | NO | 13.25 | 3.44 |
| 2002 | 1,610.19 | 1,592.61 | 1,473.32 | 114.21 | 2.03 | 3.05 | 17.58 | NO | 13.87 | 3.72 |
| 2003 | 1,604.19 | 1,585.72 | 1,467.12 | 113.21 | 2.16 | 3.23 | 18.47 | NO | 14.48 | 3.99 |
| 2004 | 1,598.07 | 1,578.67 | 1,458.36 | 114.60 | 2.29 | 3.41 | 19.40 | 0.04 | 15.09 | 4.26 |
| 2005 | 1,589.57 | 1,569.26 | 1,449.43 | 113.81 | 2.43 | 3.59 | 20.31 | 0.07 | 15.71 | 4.53 |
| 2006 | 1,581.23 | 1,560.01 | 1,436.59 | 117.08 | 2.56 | 3.77 | 21.23 | 0.10 | 16.32 | 4.81 |
| 2007 | 1,577.33 | 1,550.99 | 1,415.49 | 124.37 | 6.49 | 4.64 | 26.34 | 0.25 | 20.31 | 5.78 |
| 2008 | 1,575.74 | 1,544.30 | 1,400.12 | 128.25 | 10.42 | 5.51 | 31.43 | 0.38 | 24.29 | 6.76 |
| 2009 | 1,571.72 | 1,534.84 | 1,385.52 | 128.59 | 14.35 | 6.39 | 36.88 | 0.87 | 28.28 | 7.74 |
| 2010 | 1,567.10 | 1,525.08 | 1,384.14 | 115.40 | 18.28 | 7.26 | 42.02 | 1.04 | 32.26 | 8.72 |
| 2011 | 1,561.08 | 1,514.81 | 1,371.37 | 113.41 | 22.07 | 7.95 | 46.26 | 1.20 | 35.63 | 9.43 |

| Year | 4.B Total - Cropland | 4.B.1 Cropland remaining Cropland | 4.B.1.a Annual cropland remaining Annual cropland | 4.B.1.b Perennial cropland remaining Perennial cropland | 4.B.1.c Perennial cropland converted to Annual cropland | 4.B.1.d Annual cropland converted to Perennial cropland | 4.B.2 Land converted to Cropland | 4.B.2.1.b Forest land converted to Perennial cropland | 4.B.2.2.a Grassland converted to Annual cropland | 4.B.2.2.b Grassland converted to Perennial cropland |
|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 1,556.12 | 1,505.68 | 1,366.94 | 104.23 | 25.87 | 8.64 | 50.45 | 1.31 | 39.00 | 10.14 |
| 2013 | 1,549.06 | 1,499.60 | 1,365.48 | 99.90 | 25.73 | 8.49 | 49.46 | 1.38 | 38.13 | 9.94 |
| 2014 | 1,540.67 | 1,492.25 | 1,344.00 | 114.32 | 25.58 | 8.34 | 48.42 | 1.40 | 37.26 | 9.75 |
| 2015 | 1,534.44 | 1,486.92 | 1,347.20 | 106.08 | 25.44 | 8.19 | 47.52 | 1.58 | 36.38 | 9.56 |
| 2016 | 1,532.96 | 1,486.49 | 1,356.47 | 96.67 | 25.30 | 8.05 | 46.47 | 1.59 | 35.51 | 9.37 |
| 2017 | 1,528.95 | 1,483.54 | 1,346.10 | 104.38 | 25.16 | 7.90 | 45.41 | 1.59 | 34.64 | 9.18 |
| 2018 | 1,527.14 | 1,482.79 | 1,343.85 | 106.17 | 25.02 | 7.75 | 44.35 | 1.59 | 33.76 | 8.99 |
| 2019 | 1,525.64 | 1,482.35 | 1,346.11 | 103.77 | 24.87 | 7.60 | 43.28 | 1.59 | 32.89 | 8.80 |
| 2020 | 1,524.32 | 1,482.10 | 1,345.92 | 104.00 | 24.73 | 7.45 | 42.22 | 1.59 | 32.02 | 8.61 |
| 2021 | 1,522.94 | 1,481.78 | 1,345.66 | 104.23 | 24.59 | 7.30 | 41.15 | 1.59 | 31.14 | 8.42 |
| 2022 | 1,522.09 | 1,482.00 | 1,345.90 | 104.51 | 24.45 | 7.15 | 40.09 | 1.59 | 30.27 | 8.23 |

Table 6.5-2: Emissions (+) / removals (-) of $CO_2$ in Cropland from 1990 to 2022 (kt $CO_2$-eq)

| Year | 4.B Total - Cropland | 4.B.1 Cropland remaining Cropland | 4.B.2 Land converted to Cropland | 4.B.2.1 Forestland converted to Cropland | 4.B.2.2 Grassland converted to Cropland | 4.B.2.3 Wetlands converted to Cropland | 4.B.2.4 Settlements converted to Cropland | 4.B.2.5 Other land converted to Cropland | 4.B.2 Land converted to Cropland ($N_2O$ in $CO_2$-eq) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 118.42 | 89.06 | 29.36 | 0.00 | 25.85 | NO | NO | NO | 3.52 |
| 1991 | 131.58 | 98.28 | 33.30 | 0.00 | 29.43 | NO | NO | NO | 3.87 |
| 1992 | 133.87 | 97.83 | 36.04 | 0.00 | 31.81 | NO | NO | NO | 4.23 |
| 1993 | 136.16 | 97.38 | 38.78 | 0.00 | 34.19 | NO | NO | NO | 4.59 |
| 1994 | 138.45 | 96.93 | 41.52 | 0.00 | 36.58 | NO | NO | NO | 4.94 |
| 1995 | 140.74 | 96.48 | 44.26 | 0.00 | 38.96 | NO | NO | NO | 5.30 |
| 1996 | 143.03 | 96.02 | 47.00 | 0.00 | 41.34 | NO | NO | NO | 5.66 |
| 1997 | 145.31 | 95.57 | 49.74 | 0.00 | 43.73 | NO | NO | NO | 6.01 |
| 1998 | 147.60 | 95.12 | 52.48 | 0.00 | 46.11 | NO | NO | NO | 6.37 |
| 1999 | 149.89 | 94.67 | 55.22 | 0.00 | 48.49 | NO | NO | NO | 6.73 |
| 2000 | 152.18 | 94.22 | 57.96 | 0.00 | 50.88 | NO | NO | NO | 7.09 |
| 2001 | 154.47 | 93.77 | 60.70 | 0.00 | 53.26 | NO | NO | NO | 7.44 |

| Year | 4.B Total - Cropland | 4.B.1 Cropland remaining Cropland | 4.B.2 Land converted to Cropland | 4.B.2.1 Forestland converted to Cropland | 4.B.2.2 Grassland converted to Cropland | 4.B.2.3 Wetlands converted to Cropland | 4.B.2.4 Settlements converted to Cropland | 4.B.2.5 Other land converted to Cropland | 4.B.2 Land converted to Cropland ($N_2O$ in $CO_2$-eq) |
|---|---|---|---|---|---|---|---|---|---|
| 2002 | 156.76 | 93.32 | 63.44 | 0.00 | 55.64 | NO | NO | NO | 7.80 |
| 2003 | 159.05 | 92.87 | 66.18 | 0.00 | 58.03 | NO | NO | NO | 8.16 |
| 2004 | 163.18 | 92.42 | 70.76 | 1.84 | 60.41 | NO | NO | NO | 8.51 |
| 2005 | 164.86 | 91.97 | 72.89 | 1.23 | 62.79 | NO | NO | NO | 8.87 |
| 2006 | 167.00 | 91.52 | 75.48 | 1.08 | 65.18 | NO | NO | NO | 9.22 |
| 2007 | 380.27 | 283.83 | 96.44 | 9.60 | 75.39 | NO | NO | NO | 11.45 |
| 2008 | 403.09 | 292.66 | 110.42 | 5.27 | 91.48 | NO | NO | NO | 13.68 |
| 2009 | 445.46 | 301.49 | 143.96 | 20.50 | 107.56 | NO | NO | NO | 15.90 |
| 2010 | 457.94 | 310.33 | 147.62 | 5.84 | 123.64 | NO | NO | NO | 18.13 |
| 2011 | 484.84 | 319.61 | 165.23 | 7.89 | 137.34 | NO | NO | NO | 20.00 |
| 2012 | 504.76 | 328.89 | 175.87 | 2.95 | 151.04 | NO | NO | NO | 21.87 |
| 2013 | 316.29 | 136.24 | 180.05 | 3.90 | 154.77 | NO | NO | NO | 21.39 |
| 2014 | 307.04 | 136.51 | 170.53 | -1.60 | 151.22 | NO | NO | NO | 20.90 |
| 2015 | 323.09 | 136.78 | 186.31 | 18.22 | 147.68 | NO | NO | NO | 20.41 |
| 2016 | 301.74 | 137.05 | 164.69 | 0.63 | 144.14 | NO | NO | NO | 19.92 |
| 2017 | 294.42 | 137.32 | 157.10 | -2.93 | 140.59 | NO | NO | NO | 19.44 |
| 2018 | 290.66 | 137.59 | 153.07 | -2.93 | 137.05 | NO | NO | NO | 18.95 |
| 2019 | 286.90 | 137.86 | 149.04 | -2.93 | 133.51 | NO | NO | NO | 18.46 |
| 2020 | 283.14 | 138.13 | 145.01 | -2.93 | 129.97 | NO | NO | NO | 17.98 |
| 2021 | 279.38 | 138.40 | 140.98 | -2.93 | 126.42 | NO | NO | NO | 17.49 |
| 2022 | 275.62 | 138.67 | 136.95 | -2.93 | 122.88 | NO | NO | NO | 17.00 |

* without emissions from biomass burning

### 6.5.2. Methodological issues

#### 6.5.2.1. Cropland remaining Cropland (4.B.1)

This section provides information about emissions/removals from soil and biomass in the cropland category and comprises:

1. Annual cropland remaining cropland annual (aCL-aCL) and Perennial cropland remaining perennial cropland (pCL-pCL)
2. Annual cropland converted to perennial cropland (aCL-pCL)
3. Perennial cropland converted to annual cropland (pCL-aCL)

The soil and biomass gains/or losses of annual cropland due to land use changes to/from annual cropland were presented in this report according to the Guidelines' foreseen method for land use changes within the cropland category. This approach was applied following the fact that annual cropland has a completely different carbon stock and accumulation rate comparing to perennial cropland and following the examples of some other countries (Austria, Bulgaria, Luxemburg[45]) in presenting carbon stock changes in this land use category.

A) Biomass

Since the biomass of annual cropland is harvested annually, there is no long-term carbon storage, thus changes in carbon stocks in biomass are not considered in estimation under the subcategory "Annual cropland remaining Annual cropland".

For the subcategory *Perennial cropland remaining Perennial cropland* the carbon stock changes were estimated using the Tier 1 method. Following this method, the perennial cropland accumulates biomass over the first 30 years of growing, and 3.33% of perennial crops are removed annually resulting in the emissions.

The following IPCC Tier 2 equation was used for calculating carbon stock change of living biomass on perennial cropland remaining perennial cropland:

Annual change in biomass = (area of perennial cropland remaining perennial cropland x carbon accumulation rate) – (area of perennial cropland 30 years* ago x 0.033 x biomass carbon stock at harvest)

* Excluding perennial cropland areas lost due to land use changes

Nationally defined value of 0.45 tC/ha annually was used for estimating the annual carbon accumulation rate in perennial cropland.

The nationally defined value of 17.8 tC/ha annually was used for the aboveground biomass carbon stock at harvest. In case of this subcategory and biomass pool a conservative approach and an assumption that pCL are in balance and they do not grow any more have been used to calculate CSC.

To calculate the annual change in carbon stock of annual cropland living biomass converted to perennial cropland, an approach following the IPCC Tier 2 method for LUCs including partly country specific emission factors (EFs) and equation below were used:

Annual change in carbon stock in biomass = conversion area for a transition period of 20 years x $\Delta C_{Growth}$ + annual area of currently converted land x $L_{Conversion}$

where:

$L_{Conversion} = C_{After} - C_{Before}$

$\Delta C_{Growth}$ = Carbon accumulation rate of perennial cropland = 0.45 tC/ ha annually (nationally defined value)

$C_{Before}$ = biomass carbon stock of annual cropland before conversion is: 5.67 tC/ha annually

$C_{After}$ = carbon stock immediately after conversion = 0 tC/ha (IPCC default value)

The county specific average biomass stock in annual cropland was used for annual cropland biomass losses in the year of LUC from annual to perennial cropland. The source of information for the annual cropland aboveground biomass was CBS Statistical Yearbooks ie. data for the yield biomass of annual crops (i.e. wheat, maize, oats, rye, triticale etc.) in the period 2000-2010. For all annual crops mentioned in the Statistical Yearbooks, the absolute weight of dry matter had to be determined. Since there were no nationally available absolute dry weight factors for this purpose, approaches used by other countries

[45] Bulgaria's National Inventory Report for 2012; Austria's National Inventory Report 2012; Luxembourg's National Inventory Report 2012. See list of References.

were followed (Austria, Bulgaria[46]), as well as expansion factors from the Austrian Expert Panel for Soil Fertility[47]. The related biomass of strew, leaves or other aboveground plants parts have been determined using the expansion factor from Austria also.

The estimated aboveground biomass in annual cropland was multiplied with the root/shoot ratio in order to provide an estimate of the belowground biomass. Root/shoot ratios of the United States Department of Agriculture were applied for this purpose following examples from other countries. The argument for using this root/shoot ratio was acceptable for Croatia too (all the mentioned countries belong to the temperate region).

The weighted mean value of the total biomass per ha was calculated for each year in period 2000-2010 on the basis of yields of individual crops and the corresponding areas in Croatia. These results were a basis for determining the average annual carbon stock in annual cropland biomass for Croatia (5.67 tC/ha).

The IPCC Guidelines Tier 1 method for LUCs with partly country specific EFs and below presented equation were used to calculate the annual change in carbon stock of living biomass of perennial cropland converted to annual cropland:

Annual change in carbon stock in biomass = Annual area of converted land x ($L_{Conversion} + \Delta C_{Growth}$)

where:

$L_{Conversion} = C_{After} - C_{Before}$

$\Delta C_{Growth}$ = annual cropland carbon accumulation rate: 1) 5.7 tC/ha for annual cropland

$C_{Before}$ = carbon stock of perennial cropland biomass before conversion: 17.8 tC/ha (nationally defined value) (accounted only for the year of LUC)

$C_{After}$ = carbon stock immediately after conversion is 0 t C/ ha (IPCC default value)

The gains of the annual cropland biomass during land use changes to annual cropland are accounted only once, in the year of LUC to annual cropland according to the Guidelines.

B) Soil

In order to perform carbon stock change estimation in soil pool for all categories of land in LULUCF sector, Croatia firstly used results of the scientific research program named “Geological Maps of Croatia”. In this investigation wet combustion method was used. Soils samples were taken on depth of 20 cm in such a way that the whole humus layer was included. The contribution of rock fragments to the soil’s total carbon content was not considered. Results of this investigation was used for NIR 2012. Since the method used for carbon stock determination was not in line with the IPCC Guidelines, in 2013 new investigation was performed. In the new investigation, the dry combustion method was applied[48]. The representative number of samples were defined, and the soil samples were taken on the points from the above-mentioned research program. The samples were taken on the depth of 30 cm, but including the whole humus layer (litter). Results of this work were used for the Croatian reporting in 2013-2017. For this year reporting, in 2017 Croatia initiated a new scientific investigation on soil carbon content in

[46] Bulgaria’s National Inventory Report for 2012; Austria’s National Inventory Report 2012; Luxembourg’s National Inventory Report 2012. See list of References.

[47] Bulgaria’s National Inventory Report for 2012; Austria’s National Inventory Report 2012; Luxembourg’s National Inventory Report 2012. See list of References.

[48] Work performed by Croatian Geological Institute. See list of References.

LULUCF categories of land[49]. Representative number of plots from the program "Geological Maps of Croatia" were revisited and samples were taken on 30 cm depth, separating the humus layer from the rest of soil sample. In addition, as part of this work C:N ratio was defined for different categories of land. By this way, Croatia collected and determined carbon stock in soil pool for each LULUCF land category and for litter pool in Forest land. Following the IPCC Guidelines (Tier 1), the annual change in carbon stock of mineral soils of annual cropland converted to perennial cropland is calculated as follows:

Annual change in carbon stock in soil = conversion area for a transition period of 20 years x ΔSOC

$\Delta SOC = (SOC_0 – SOC_{0-T})/20 = 0.95$ tC/ha annually

where:

$\Delta SOC$ = annual change in carbon stock soil

$SOC_0$ = Croatian soil organic carbon stock in the inventory year = 71.01 tC/ha for perennial cropland

$SOC_{0-T}$ = Croatian soil organic carbon stock *T* years prior to the inventory = 52.71 tC/ha for annual cropland

T = Assessment period (20 years)

According to expert judgment there was no change in the relative stock change factors (tillage factor FMG; land use factor FLU, input factor FI) during the past 20 years; these factors are set by default to 1. Thus, there was no change in carbon stocks in soils of annual cropland remaining annual cropland and perennial cropland remaining perennial cropland due to management.

Emission/removals due to changes of carbon stock in soils of perennial cropland converted to annual cropland were calculated using the same national figures for the soil carbon content in perennial cropland as in annual cropland. The equation used for these purposes is the same as above:

Annual change in carbon stock in soil = conversion area for a transition period of 20 years x ΔSOC

$\Delta SOC = (SOC_0 – SOC_{0-T})/20 = -1.57$ tC/ha annually

National value for C/N ratio (9) was used for the estimation in case of Grassland mineral soils that are converted to Cropland.

Organic Soils

Since NIR 2016 submission, based on the recommendation given by ERT, Croatia has been separately reporting on emissions from organic soils under annual and under perennial crops. Organic soils distribution was determined on the basis of current Basic Soil Map of the Republic of Croatia in scale 1:50,000 and available data and information in Land Parcel identification System database of ARKOD. According to the available data, organic soil area in year 2022 in case of Annual cropland was 2.23 kha and 0.23 kha in case of Perennial cropland and with emissions of 22.32 and 2.27 kt $CO_2$ of carbon annually respectively.

For estimating $CO_2$ emissions from organic soils in the Cropland remaining Cropland category the IPCC GPG 2.26 equation was applied:

$\Delta C_{CC\ Organic} = A \times EF$

where:

$\Delta C_{CC\ Organic}$= $CO_2$ emissions from cultivated organic soils (tC/year)

A= land area of organic soils (ha)

[49] Work performed by Croatian Geological Institute, Croatian forest Institut Jastrebarsko and Agency for Agricultural land. ("SOC stock changes, total nitrogen and total organic carbon trends, C:N ratio"). See list of References.

EF= emission factor for warm temperate climate = 10 t C/ha annually (IPCC default value)

### 6.5.2.2. Land use change to Cropland (4.B.2)

#### 6.5.2.2.1 Forest land converted to Cropland (4.B.2.1)

Through the conducted survey within the scope of LULUCF 1 project it was determined that conversion from Forest land to Perennial cropland happens in Croatia starting from 2004 while conversion to annual Cropland did not occur in period 1990-2022. Additionally, it was determined on yearly basis from which type of forests conversion to perennial cropland occurs. By the conducted analyse it was concluded that there is no conversion from coniferous forests to perennial cropland.

When calculating gains due to biomass growth of Cropland, below presented values were used:

- 0.45 tC/ha – for biomass growth in perennial cropland (national value)
- 5.67 tC/ha – for biomass growh in annual cropland (default, IPCC).

Next nationally determined values were used for the purposes of calculating losses due to conversion from forest land:

- 56.9 tC/ha when calculating losses due to conversion of deciduous forests to Perennial cropland (including below-ground biomass),
- 7.36 tC/ha when calculating losses due to conversion of maquies and shrub forests to Perennial cropland (including below-ground biomass).

The source for the maquies and shrub forests conversion factor is the main data provider in forest sector (Croatian forests Ltd.) which records data on harvest on deforested areas as a part of its obligation defined by the national legislation.

The values of soil carbon stock determined through national scientific investigation were used in order to estimate the carbon stock changes in soil due to conversion to Cropland. Conversion that happens refers to perennial cropland to Forest land. Estimation with following soil C stocks:

- Perennial cropland: 71.01 tC/ha
- Forest land: 69.86 tC/ha

Soil removal factor determined in this case is 0.058 tC/ha annually.

In case of Forest land that is converted to Perennial cropland, Croatia performs estimation of carbon stock changes in dead wood pool too as the result of data collected through national project designed for this purpose in 2019.

The equation 2.23 from the 2006 IPCC Guidelines was used for calculating the change of carbon stock in deadwood on forest areas converted to Perennial cropland:

$\Delta C_{Dw} = A_{0N} * (C_N - C_0) / T_{0N}$

where:

$\Delta C_{DW}$ = annual change in carbon stocks in dead wood (tC/ha)

$C_N$ = dead wood/litter stock, under the new land-use category (tC/ha)

$C_0$ = dead wood/litter stock, under the old land-use category (tC/ha)

$A_{0N}$ = area undergoing conversion from old to new land-use category (ha)

$T_{0N}$ = time period of the transition from old to new land-use category, yr

National values of dead wood stock ($m^3$/ha) were determined from the available data collected through the Croatian National Forest Inventory (CRONFI) process, as follows:

Table 6.5-3: National values of dead wood stock in $m^3$/ha

| | Forest type | Standing deadwood | Lying deadwood |
|---|---|---|---|
| Deadwood stock ($m^3$/ha), mean value | Deciduous | 5.84 | 7.28 |
| | Coniferous | 5.16 | 10.32 |
| | Out of Yield (maquies and shrub) | 0.58 | 0.36 |

When determining the carbon stock in dead wood, $BEF_2$ and R/S factor were applied in case of dry, standing wood, thus ensuring the inclusion of all parts of the tree.

Table 6.5-4: Parameters from the 2006 IPCC Guidelines used in calculation

| | Wood density | $BEF_2$ | R/S | Carbon fraction | Deadwood carbon |
|---|---|---|---|---|---|
| | (t d.m./$m^3$) | | | (CF) (tC/ t d.m.) | stock (tC/ha) |
| Deciduous | 0.56 | 1.197 | 0.23 | 0.5 | 4.43 |
| Coniferous | 0.39 | 1.039 | 0.29 | 0,5 | 3.4 |
| Out of Yield | 0.68 | 1.15 | 0.46 | 0.5 | 0.46 |

Annual data on deforestation according to the type of conversion had been collected through the LULUCF 1 project and shown in Table 6.5-5. Estimation of the carbon stock change was performed using the data on deforested areas for each type of forest (deciduous, coniferous, out of yield (maquies and shrub)), and the values were summarized and shown for all types of forests together depending on the type of conversion of forest land and year of the conversion.

Table 6.5-5: Dead wood carbon stock change (kt C) on the deforested areas due to land use change from Forest land to perennial cropland

| Year | Area of deforestated land (kha) | Deadwood carbon stock change (kt C) |
|---|---|---|
| 1990 | NO | NO |
| 1991 | NO | NO |
| 1992 | NO | NO |
| 1993 | NO | NO |
| 1994 | NO | NO |
| 1995 | NO | NO |
| 1996 | NO | NO |
| 1997 | NO | NO |
| 1998 | NO | NO |
| 1999 | NO | NO |
| 2000 | NO | NO |
| 2001 | NO | NO |
| 2002 | NO | NO |
| 2003 | NO | NO |

| Year | Area of deforestated land (kha) | Deadwood carbon stock change (kt C) |
|---|---|---|
| 2004 | 0.04 | -0.02 |
| 2005 | 0.07 | -0.01 |
| 2006 | 0.10 | -0.01 |
| 2007 | 0.25 | -0.14 |
| 2008 | 0.38 | -0.06 |
| 2009 | 0.87 | -0.22 |
| 2010 | 1.04 | -0.08 |
| 2011 | 1.20 | -0.13 |
| 2012 | 1.31 | -0.06 |
| 2013 | 1.38 | -0.10 |
| 2014 | 1.40 | -0.01 |
| 2015 | 1.58 | -0.35 |
| 2016 | 1.59 | -0.07 |
| 2017 | 1.59 | NO |
| 2018 | 1.59 | NO |
| 2019 | 1.59 | NO |
| 2020 | 1.59 | NO |
| 2021 | 1.59 | NO |
| 2022 | 1.59 | NO |

Estimation of carbon stock changes in litter pool was conducted for the first time in NIR 2018, using the equation and carbon stock in litter pool (Chapter 6.4.2.2.) determined on national level in above mention scientific investigation.

###### 6.5.2.2.2 Grassland converted to Cropland (4.B.2.2)

Based on the CLC results, the LUCs to cropland category occur on basis of grassland. The area coming from grassland also had to be divided into LUCs to annual cropland and LUCs to perennial cropland which was done directly on basis of specific CLC subcategories representing annual or perennial cropland or according to the share of these land uses in total cropland (0.9 vs 0.1) for mixed CLC categories which include both, annual and perennial cropland in one CLC category.

Representing a LUC transition period of 20 years, 38.50 kha of grassland area were converted to cropland (aCL and pCL) in 2022. The changes of carbon stocks during the conversion from one category to another vary from year to year. In 1990, LUC in this category resulted in emissions of 25.85 kt $CO_2$ and in 2022 in emissions of 122.88 kt $CO_2$.

In case of Grassland category that is converted to cropland, Croatia uses Tier 1 assumption that DOM pools in non-forest land categories after the conversion is zero.

A) Changes in carbon stocks in biomass

National data were used for the calculation of carbon stock in living biomass of grassland. The source of information for the grasslands' aboveground biomass was the CBS Statistical Yearbooks ie. data for hay yield. The mean value of hay biomass was calculated (2.5 t dm/ha annually) based on data available for the period 2000-2010. The total biomass was calculated (4.29 tC/ha) by adding the aboveground stubble biomass (1.6 t dm/ha, IPCC GPG default value) and the appropriate IPCC GPG root to shoot ratio (2.8) and converting it to tonnes of carbon.

The approach used to determine the accumulation of carbon stock in the biomass of annual cropland in the first year after the conversion is presented in Chapter 6.5.2.1.

The IPCC GPG Tier 1 method was applied to calculate the annual change in carbon stock of grassland living biomass converted to annual and perennial cropland:

Annual change in carbon stock in biomass = annual area of converted land x ($L_{Conversion} + \Delta C_{Growth}$)

where:

$L_{Conversion} = C_{After} - C_{Before}$

$\Delta C_{Growth}$ = carbon accumulation rate which amounts to:

1) 5.7 tC/ha for annual cropland

2**)** 0.45 t C/ ha for perennial cropland = (nationally defined value)

$C_{Before}$ = carbon stock of grassland biomass before conversion = 4.3 tC/ha

$C_{After}$ = carbon stock immediately after conversion = 0 tC/ ha

B) Changes in carbon stocks in soil

For the calculation of the average annual change in carbon stock of mineral soils of grassland converted to cropland, specific data for the country were used and the 2006 IPCC Guidelines, Tier 1 equation was applied, as follows:

$\Delta SOC = (SOC_0 – SOC_{0-T})/20$

where:

$\Delta SOC$ = annual change in carbon stock soil

$SOC_{0-T}$ =soil organic carbon stock in the inventory year, which amounts to:

1) 52.71 tC/ha for annual cropland

2) 71.01 tC/ha for perennial cropland

$SOC_T$ = soil organic carbon stock *T* years prior to the inventory, equals 75.75 tC/ha

T = Assessment period (20 years)

The change in carbon stock in soils of grassland converted to annual and perennial cropland was further calculated by multiplying the emission factor by the area of converted territory in a transition period of 20 years. The emission factor for *Grassland converted to annual cropland* was -1.21 tC/ha annually and 0.36 tC/ha annually for the area of *Grassland converted to perennial cropland*.

The net soil carbon stock changes resulted in removals in the range of -0.11 to -1.95 kt C for *Grassland converted to perennial cropland* for the period 1990-2022. In case of *Grassland converted to annual cropland*, removals were from -7.49 to -34.87 kt C.

#### 6.5.2.3. $N_2O$ Emissions in soils of Land converted to Cropland

The annual release of $N_2O$ due to the conversion of grassland to cropland and forest land to cropland were calculated using the IPCC default value (Tier 1) and equation 11.8 as follows:

$N_2O_{\mathbf{net-min}} - N = EF_{\mathbf{1}} \times \Delta C_{\mathbf{LCmineral}} \times 1/ (C/N\ ratio)$

where:

$EF_1$ = the emission factor for calculating emissions of $N_2O$ from N in the soil = 0.01 kg $N_2O$- N/kg N (IPCC default value)

$\Delta C_{LCmineral}$ = change in the carbon stock in mineral soils in land to cropland

C/N = ratio by mass of C to N in the soil organic matter (9 in case of grassland converted to cropland and 11 in case of forest land converted to cropland)

### 6.5.3. Uncertainties and time-series consistency

The combined uncertainty values for total $CO_2$-eq in category Land converted to cropland using uncertainties for emission factors and area as presented in Table 6.4-6. can be find in Annex II, as well in case of category Cropland remaining Cropland.

Comparison between the uncertainties in calculations Tier 1 and Tier 2 methods by categories and carbon pools is presented in Annex 1.

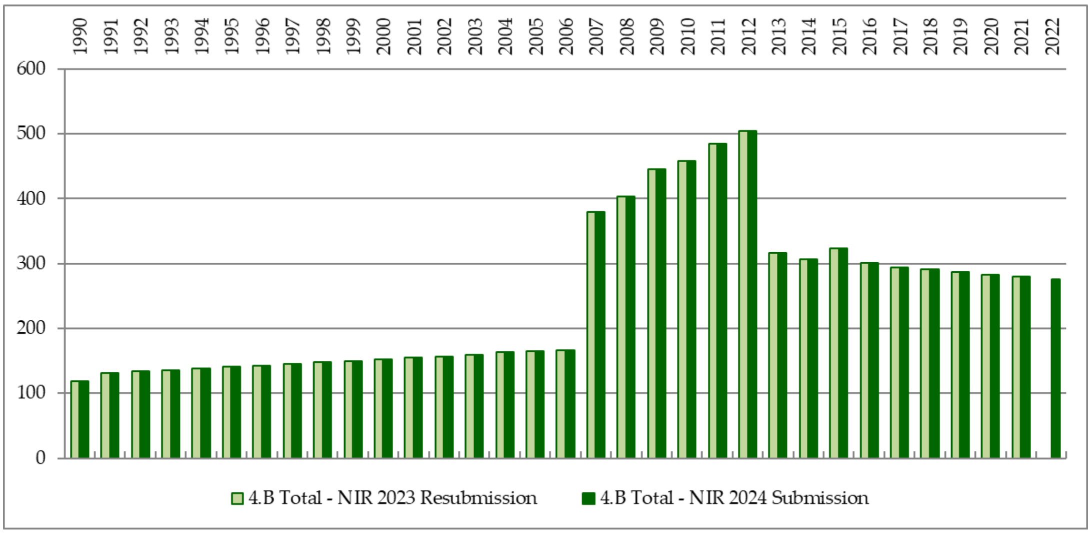
### 6.5.4. Category-specific QA/QC and verification

The data calculation for this category was included in the overall QA/QC system of the Croatian GHG inventory.

### 6.5.5. Category-specific recalculations

For NIR 2024 the CSC in biomass pool for coniferous forests convered to cropland were estimated using the value for the first age class forests in conversion period of 20 years.

Figure 6.5-1: Current and previously reported emissions for category 4.B (kt $CO_2$-eq)




### 6.5.6. Category-specific planned improvements

Currently running LIFE CROLIS project should provide LUC area data for major perennial crops in Croatia (vineyards, orchards, and olive gardens) starting from year 1970 as well as accurate data concerning the areas of annual cropland. The new area data will enable Croatia emission estimation for each defined crop types and it can be expected three years from now.

## 6.6. Grassland (CRF category 4.C)

### 6.6.1. Description

Only emissions/removals from the grassland management (Grassland remaining Grassland and Land converted to Grassland) were considered in this category. A combination of the IPCC Tier 1 and Tier 2 approach was used to calculate the carbon stock changes for the purpose of this report.

The grassland area ranged from 1,201 to 1,153 kha in the period 1990-2022. The change in carbon stock in biomass and soil ranges from removals –7.88 kt $CO_2$ to -302.36 kt $CO_2$ in period 1990-2022.

Annual LUCs to grassland occurred in only the cropland category (annual and perennial).

Some management practices, such as burning of stubble-fields are forbidden in Croatia.

Dead wood and litter pools (DOM) do not exist in the grassland category, so they are not subject to this report.

Tables 6.6-1 and Table 6.6-2 show the land use change and removals/emissions* from LUC to grassland in the period from 1990 to 2022.

Table 6.6-1: Activity Data of Grassland in the period 1990-2022 in kha

| 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.a Annual cropland converted to Grassland | 4.C.2.2.b Perennial cropland converted to Grassland | 4.C.2.3 Wetlands converted to Grassland | 4.C.2.4 Settlements convertet to Grassland | 4.C.2.5 Other land converted to Grassland |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1201.06 | 1198.62 | 2.44 | NO | 2.33 | 0.11 | NO | NO | NO |
| 1991 | 1200.67 | 1197.13 | 3.55 | NO | 3.23 | 0.32 | NO | NO | NO |
| 1992 | 1200.28 | 1195.69 | 4.60 | NO | 4.07 | 0.52 | NO | NO | NO |
| 1993 | 1199.90 | 1194.11 | 5.78 | NO | 5.04 | 0.74 | NO | NO | NO |
| 1994 | 1199.51 | 1192.60 | 6.91 | NO | 5.96 | 0.95 | NO | NO | NO |
| 1995 | 1199.12 | 1191.09 | 8.03 | NO | 6.87 | 1.16 | NO | NO | NO |
| 1996 | 1198.73 | 1189.53 | 9.21 | NO | 7.83 | 1.38 | NO | NO | NO |
| 1997 | 1198.35 | 1188.08 | 10.26 | NO | 8.68 | 1.58 | NO | NO | NO |
| 1998 | 1197.96 | 1186.58 | 11.38 | NO | 9.58 | 1.79 | NO | NO | NO |
| 1999 | 1197.57 | 1184.98 | 12.59 | NO | 10.57 | 2.01 | NO | NO | NO |
| 2000 | 1197.18 | 1183.52 | 13.66 | NO | 11.44 | 2.22 | NO | NO | NO |
| 2001 | 1196.80 | 1180.13 | 16.67 | NO | 14.07 | 2.60 | NO | NO | NO |
| 2002 | 1196.41 | 1176.64 | 19.77 | NO | 16.78 | 2.99 | NO | NO | NO |
| 2003 | 1196.02 | 1173.12 | 22.90 | NO | 19.52 | 3.38 | NO | NO | NO |
| 2004 | 1195.63 | 1169.34 | 26.29 | NO | 22.49 | 3.80 | NO | NO | NO |
| 2005 | 1195.24 | 1163.21 | 32.03 | NO | 27.61 | 4.42 | NO | NO | NO |
| 2006 | 1194.86 | 1157.25 | 37.61 | NO | 32.57 | 5.04 | NO | NO | NO |
| 2007 | 1188.82 | 1146.06 | 42.76 | NO | 37.02 | 5.74 | NO | NO | NO |
| 2008 | 1182.79 | 1137.07 | 45.72 | NO | 39.47 | 6.24 | NO | NO | NO |
| 2009 | 1176.76 | 1125.40 | 51.36 | NO | 44.37 | 6.99 | NO | NO | NO |
| 2010 | 1170.73 | 1113.36 | 57.37 | NO | 49.61 | 7.77 | NO | NO | NO |

| 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.a Annual cropland converted to Grassland | 4.C.2.2.b Perennial cropland converted to Grassland | 4.C.2.3 Wetlands converted to Grassland | 4.C.2.4 Settlements convertet to Grassland | 4.C.2.5 Other land converted to Grassland |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 1164.69 | 1101.23 | 63.47 | NO | 55.02 | 8.44 | NO | NO | NO |
| 2012 | 1158.66 | 1090.24 | 68.43 | NO | 59.41 | 9.02 | NO | NO | NO |
| 2013 | 1157.75 | 1084.28 | 73.48 | NO | 64.11 | 9.37 | NO | NO | NO |
| 2014 | 1156.85 | 1077.12 | 79.72 | NO | 69.90 | 9.82 | NO | NO | NO |
| 2015 | 1155.94 | 1072.13 | 83.81 | NO | 73.72 | 10.09 | NO | NO | NO |
| 2016 | 1155.04 | 1071.53 | 83.51 | NO | 73.55 | 9.95 | NO | NO | NO |
| 2017 | 1154.13 | 1068.30 | 85.83 | NO | 75.78 | 10.06 | NO | NO | NO |
| 2018 | 1153.22 | 1067.32 | 85.91 | NO | 75.95 | 9.96 | NO | NO | NO |
| 2019 | 1153.22 | 1067.64 | 85.58 | NO | 75.76 | 9.82 | NO | NO | NO |
| 2020 | 1153.22 | 1068.02 | 85.20 | NO | 75.52 | 9.68 | NO | NO | NO |
| 2021 | 1153.22 | 1070.23 | 82.99 | NO | 73.61 | 9.38 | NO | NO | NO |
| 2022 | 1153.22 | 1072.99 | 80.23 | NO | 71.21 | 9.03 | NO | NO | NO |

Table 6.6-2: Emissions (+) / removals (-) of $CO_2$ in Grassland for period 1990-2022 (kt $CO_2$)

| Year | 4.C Total - Grassland | 4.C.1 Grassland remaining Grassland | 4.C.2 Land converted to Grassland | 4.C.2.1 Forest land converted to Grassland | 4.C.2.2 Cropland converted to Grassland | 4.C.2.3 Wetlands converted to Grassland | 4.C.2.4 Settlements convertet to Grassland | 4.C.2.5 Other land converted to Grassland |
|---|---|---|---|---|---|---|---|---|
| 1990 | -7.88 | 2.07 | -9.95 | NO | -9.95 | NO | NO | NO |
| 1991 | 3.98 | 2.07 | 1.91 | NO | 1.91 | NO | NO | NO |
| 1992 | -0.24 | 2.07 | -2.31 | NO | -2.31 | NO | NO | NO |
| 1993 | -3.30 | 2.07 | -5.37 | NO | -5.37 | NO | NO | NO |
| 1994 | -7.89 | 2.07 | -9.96 | NO | -9.96 | NO | NO | NO |
| 1995 | -11.98 | 2.07 | -14.05 | NO | -14.05 | NO | NO | NO |
| 1996 | -15.71 | 2.07 | -17.78 | NO | -17.78 | NO | NO | NO |
| 1997 | -20.57 | 2.07 | -22.63 | NO | -22.63 | NO | NO | NO |
| 1998 | -24.06 | 2.07 | -26.13 | NO | -26.13 | NO | NO | NO |
| 1999 | -27.56 | 2.07 | -29.63 | NO | -29.63 | NO | NO | NO |
| 2000 | -32.63 | 2.07 | -34.70 | NO | -34.70 | NO | NO | NO |
| 2001 | -26.55 | 2.07 | -28.62 | NO | -28.62 | NO | NO | NO |
| 2002 | -37.52 | 2.07 | -39.59 | NO | -39.59 | NO | NO | NO |

| 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 Wetlands converted to Grassland | 4.C.2.4 Settlements convertet to Grassland | 4.C.2.5 Other land converted to Grassland |
|---|---|---|---|---|---|---|---|---|
| 2003 | -49.14 | 2.07 | -51.21 | NO | -51.21 | NO | NO | NO |
| 2004 | -59.71 | 2.07 | -61.78 | NO | -61.78 | NO | NO | NO |
| 2005 | -60.56 | 2.07 | -62.63 | NO | -62.63 | NO | NO | NO |
| 2006 | -83.61 | 2.07 | -85.68 | NO | -85.68 | NO | NO | NO |
| 2007 | -101.08 | 2.07 | -103.15 | NO | -103.15 | NO | NO | NO |
| 2008 | -131.78 | 2.07 | -133.84 | NO | -133.84 | NO | NO | NO |
| 2009 | -129.26 | 2.07 | -131.33 | NO | -131.33 | NO | NO | NO |
| 2010 | -149.40 | 2.07 | -151.46 | NO | -151.46 | NO | NO | NO |
| 2011 | -160.97 | 2.07 | -163.04 | NO | -163.04 | NO | NO | NO |
| 2012 | -190.72 | 2.07 | -192.79 | NO | -192.79 | NO | NO | NO |
| 2013 | -219.29 | 2.07 | -221.36 | NO | -221.36 | NO | NO | NO |
| 2014 | -233.84 | 2.07 | -235.91 | NO | -235.91 | NO | NO | NO |
| 2015 | -269.86 | 2.07 | -271.93 | NO | -271.93 | NO | NO | NO |
| 2016 | -308.22 | 2.07 | -310.29 | NO | -310.29 | NO | NO | NO |
| 2017 | -295.00 | 2.07 | -297.07 | NO | -297.07 | NO | NO | NO |
| 2018 | -315.53 | 2.07 | -317.60 | NO | -317.60 | NO | NO | NO |
| 2019 | -317.32 | 2.07 | -319.39 | NO | -319.39 | NO | NO | NO |
| 2020 | -317.91 | 2.07 | -319.98 | NO | -319.98 | NO | NO | NO |
| 2021 | -308.68 | 2.07 | -310.75 | NO | -310.75 | NO | NO | NO |
| 2022 | -302.36 | 2.07 | -304.43 | NO | -304.43 | NO | NO | NO |

*without emissions from biomass burning

### 6.6.2. Methodological issues

Emissions arisen as the result of LUC were estimated by applying country specific values for the average annual growth in grassland biomass (4.29 t C/ha annually).

#### 6.6.2.1. Grassland remaining Grassland (4.C.1)

Since the biomass of Grassland is harvested on an annual basis, there is no long-term carbon storage; thus changes in carbon stocks in biomass were not considered in the estimation (2006 IPCC Guidelines).

The area of Grassland remaining Grassland in 2022 amounts to 1,153 kha.

According to the IPCC Tier 1 there was no carbon stock change in soil in the category Grassland remaining Grassland, since - based on expert judgment - there have been no changes in management practices for grassland in the past 20 years.

The area of organic soils in the Grassland category in Croatia is defined to be 0.23 kha according to the available information.

The emissions from organic soils were calculated using the IPCC GPG default emission factor (Tier 1) for organic grassland soils in warm temperate climates (2.5 tC/ ha annually). Increase in the carbon stock change from organic soils were determined in the value of 0.56 kt C annually for the period 1990-2022.

According to expert judgment liming does not occur in the Grassland category.

#### 6.6.2.2. Land use change to Grassland (4.C.2)

##### 6.6.2.2.1. Forest land converted to Grassland (4.C.2.1)

There has not been conversion from the Forestland to Grassland in the last decades

##### 6.6.2.2.2. Cropland converted to Grassland (4.C.2.2)

According to the CLC results it is concluded that the LUCs into Grassland come from the Cropland area. The area coming from this category of land needed to be also divided into annual Cropland and perennial Cropland. This was done directly on basis of specific CLC subcategories representing annual or perennial cropland or according to the share of these land uses in total cropland (0.9 vs. 0.1) for mixed CLC categories which include both, annual and perennial cropland in one CLC category.

CLC results were used to characterize both gross-fluxes on pluri-annual time scales, even if the area of cropland to grassland was reported as variable to match the variability in total cropland area reported in statistics on cropland reported by the Croatian Bureau of Statistics (CBS).

With respect to the LUC transition period of 20 years, 80.23 kha of Cropland area (aCL + pCL) were converted into grassland in year 2022. The changes of carbon stocks during the conversion from one category to another vary between years. In year 1990 LUCs in this category (CL-GL) resulted in removals of -9.95 kt $CO_2$ and -304.43 kt $CO_2$ in year 2022.

A) Changes in carbon stocks in biomass

National data were used for the calculation of carbon stock in living biomass of Grassland. Source of information for the Grassland aboveground biomass were CBS Statistical Yearbooks with the published data for the hay yield. Based on the available data for period 2000-2010 the mean value of the hay biomass was calculated (2.5 t dm/ha annually). The total biomass was calculated (4.29 tC/ha) by adding of the aboveground stubble biomass (1.6 t dm/ha, IPCC GPG value) and using the IPCC GPG root to shoot ratio (2.8) and the conversion factor to tones of carbon.

To calculate annual change in carbon stock of the living biomass of Cropland converted to Grassland the IPCC GPG Tier 1 equation was applied:

Annual change in carbon stock in biomass = Annual area of converted land x ($L_{Conversion} + \Delta C_{Growth}$)

where:

$L_{Conversion} = C_{After} - C_{Before}$

$\Delta C_{Growth}$ = Carbon accumulation rate in Grasslands in Croatia = 4.29 t C/ ha

$C_{Before}$ = Carbon stock of Cropland biomass before conversion is:

1) 5.7 t C/ ha for annual Cropland and

2**)** 17.8 t C/ha for perennial Cropland (nationally defined value)

$C_{After}$ = Carbon stock immediately after conversion = 0 t C/ha (IPCC default value)

Average annual C stock in perennial cropland in Croatia in t C/ha is a result of the conducted so called LULUCF 3 project. It is assumed that the final stocks are lost because at the end of rotation periods of perennial crops.

B) Changes in carbon stocks in soil

For the calculation of average annual change in carbon stock of mineral soils of Cropland converted to Grassland specific data for the country were used and IPCC 2006, Tier 1 equation was applied, as follows:

$\Delta SOC = (SOC_0 – SOC_{0-T})/20$

where:

$\Delta SOC$ = annual change in carbon stock soil

$SOC_0$ =soil organic carbon stock in the inventory year, which is:

1) 52.71 tC/ha for annual Cropland

2) 71.01 tC/ha for perennial Cropland

$SOC_{0-T}$ = soil organic carbon stock *T* years prior to the inventory, which is 75.75 tC/ha for grassland

The change in carbon stock in soils of annual and perennial cropland converted to grassland was further calculated by multiplying the emission factor by the area of the converted territory in transition of 20 years. Soil emission factor for the *Annual cropland converted to grassland* in Croatia is calculated to be 1.152 tC/ha annually, and 0.237 tC/ha annually for the *Perennial cropland converted to Grassland*.

Net carbon stock change in soils when *Annual cropland converted to grassland* in 2022 was 82.03 kt C and for *Perennial cropland converted to Grassland* was 2.14 kt C.

C) Changes in carbon stocks in dead organic matter

Croatia uses Tier 1 for the estimation of CSC in dead organic matter. In case of Tier 1, according to the Guidelines, dead wood and litter are not present on non-forest categories of land. Since there is no conversion of FL to GL in Croatia the deadwood and litter pools do not occur in this category of land.

### 6.6.3. Uncertainties and time-series consistency

The combined uncertainty values for total $CO_2$-eq in category Land converted to Grassland ranges using uncertainties for emission factors and area as it is presented in table 6.4-6 can be fin in the Annex II, as well as for Grassland remaining Grassland. Also, in Annex II comparison between the uncertainties calculated using Tier 1 and Tier 2 methods by categories and carbon pools is presented.

The Grassland category has been included into the key category analysis. The analysis using Tier 2 Level method confirmed land converted to grassland as a key category; however, every other method applied excluded this category as the key category.

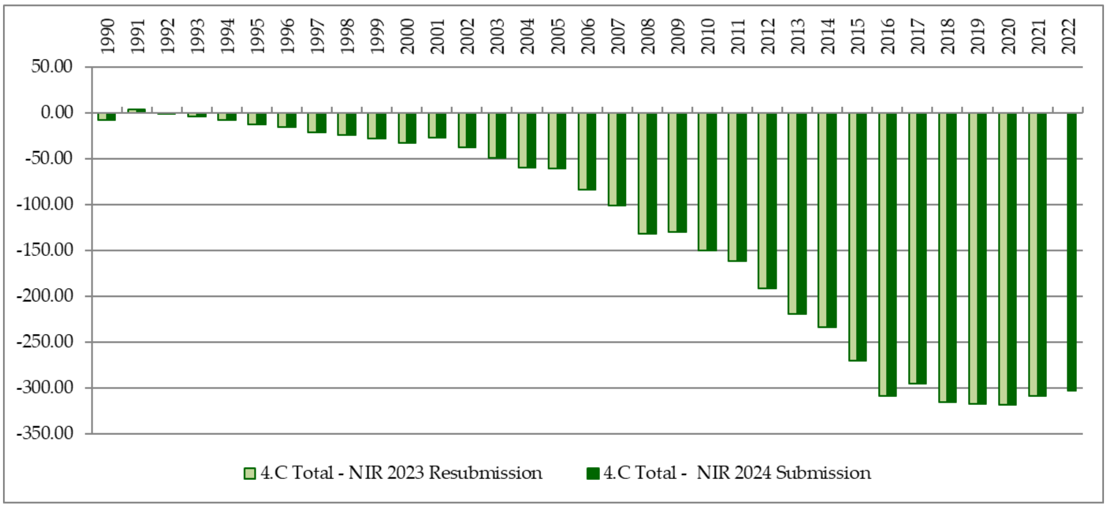
### 6.6.4. Category-specific QA/QC and verification

The calculation of the data for category 4.C was included in overall QA/QC system of the Croatian GHG inventory.

### 6.6.5. Category-specific recalculations

For NIR 2024 reporting the correction in areas of pCL and aCL converted to Grassland for 2018 – 2020 was perfomed resuting in removal increase of 0.08% in period 1990-2022.

Figure 6.6-1: Current and previously reported emissions for category 4.C (kt $CO_2$-eq)




### 6.6.6. Category-specific planned improvements

The results of currently running CROLIS project that will enable application of Approach 3 for each LULUCF land use category are planned to be used three years from now.

## 6.7. Wetlands (CRF category 4.D)

### 6.7.1. Description

In this category only emissions/removals from the sub-categories *Land converted to Wetland* were considered.

Due to lack of information, it was assumed that the carbon stock in biomass in wetland equals zero.

Croatia uses Tier 1 for the estimation of CSC in dead organic matter. In case of Tier 1, according to the 2006 IPCC Guidelines, dead wood and litter are not present on non-forest categories of land. In Croatia there is no conversion from Forestland to Wetland category.

Peat extraction does not occur in Croatia.

The total wetland area ranged from 73.86 kha in 1990 to 75.43 kha in 2022.

The land use change and removals/emissions from the IPCC land use categories to wetland in the period 1990-2022 are presented in Table 6.7-1 and Table 6.7-2.

Table 6.7-1: Activity data of wetland in the period 1990-2022, in kha

| Year | 4.D Total - Wetland | 4.D.1 Wetland remaining Wetland | 4.D.2 Land converted to Wetland | 4.D.2.1 Forest land converted to Wetland | 4.D.2.2a Annual Cropland to Wetlands | 4.D.2.2b Peremmial Cropland 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 |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 73.86 | 66.87 | 6.98 | NO | 6.36 | 0.63 | NO | NO | NO |
| 1991 | 73.90 | 67.22 | 6.68 | NO | 6.08 | 0.60 | NO | NO | NO |
| 1992 | 73.95 | 67.57 | 6.37 | NO | 5.80 | 0.57 | NO | NO | NO |
| 1993 | 73.99 | 67.92 | 6.07 | NO | 5.52 | 0.55 | NO | NO | NO |
| 1994 | 74.03 | 68.27 | 5.76 | NO | 5.24 | 0.52 | NO | NO | NO |
| 1995 | 74.08 | 68.62 | 5.46 | NO | 4.97 | 0.49 | NO | NO | NO |
| 1996 | 74.12 | 68.97 | 5.15 | NO | 4.69 | 0.46 | NO | NO | NO |
| 1997 | 74.17 | 69.32 | 4.85 | NO | 4.41 | 0.44 | NO | NO | NO |
| 1998 | 74.21 | 69.67 | 4.54 | NO | 4.13 | 0.41 | NO | NO | NO |
| 1999 | 74.25 | 70.02 | 4.24 | NO | 3.85 | 0.38 | NO | NO | NO |
| 2000 | 74.30 | 70.37 | 3.93 | NO | 3.58 | 0.35 | NO | NO | NO |
| 2001 | 74.32 | 70.72 | 3.60 | NO | 3.28 | 0.32 | NO | NO | NO |
| 2002 | 74.34 | 71.07 | 3.27 | NO | 2.98 | 0.29 | NO | NO | NO |
| 2003 | 74.36 | 71.41 | 2.95 | NO | 2.68 | 0.27 | NO | NO | NO |
| 2004 | 74.38 | 71.76 | 2.62 | NO | 2.38 | 0.24 | NO | NO | NO |
| 2005 | 74.40 | 72.11 | 2.29 | NO | 2.08 | 0.21 | NO | NO | NO |
| 2006 | 74.42 | 72.46 | 1.96 | NO | 1.78 | 0.18 | NO | NO | NO |
| 2007 | 74.47 | 72.81 | 1.66 | NO | 1.51 | 0.15 | NO | NO | NO |
| 2008 | 74.52 | 73.16 | 1.36 | NO | 1.23 | 0.12 | NO | NO | NO |
| 2009 | 74.56 | 73.51 | 1.05 | NO | 0.96 | 0.09 | NO | NO | NO |
| 2010 | 74.61 | 73.86 | 0.75 | NO | 0.68 | 0.07 | NO | NO | NO |
| 2011 | 74.66 | 73.90 | 0.75 | NO | 0.69 | 0.07 | NO | NO | NO |
| 2012 | 74.70 | 73.95 | 0.76 | NO | 0.69 | 0.07 | NO | NO | NO |
| 2013 | 74.77 | 73.99 | 0.78 | NO | 0.71 | 0.07 | NO | NO | NO |
| 2014 | 74.85 | 74.03 | 0.81 | NO | 0.74 | 0.07 | NO | NO | NO |
| 2015 | 74.92 | 74.08 | 0.84 | NO | 0.77 | 0.08 | NO | NO | NO |
| 2016 | 74.99 | 74.12 | 0.87 | NO | 0.79 | 0.08 | NO | NO | NO |
| 2017 | 75.07 | 74.17 | 0.90 | NO | 0.82 | 0.08 | NO | NO | NO |
| 2018 | 75.14 | 74.21 | 0.93 | NO | 0.85 | 0.08 | NO | NO | NO |
| 2019 | 75.21 | 74.25 | 0.96 | NO | 0.87 | 0.09 | NO | NO | NO |
| 2020 | 75.28 | 74.30 | 0.99 | NO | 0.90 | 0.09 | NO | NO | NO |
| 2021 | 75.36 | 74.32 | 1.04 | NO | 0.94 | 0.09 | NO | NO | NO |
| 2022 | 75.43 | 74.34 | 1.09 | NO | 0.99 | 0.10 | NO | NO | NO |

Table 6.7-2: Emissions of wetland in the period 1990-2022 (kt $CO_2$-eq)

| Year | 4.D Total - Wetland | 4.D.1 Wetland remaining Wetland | 4.D.2 Land converted to Wetland | 4.D.2.1 Forest land converted to Wetland | 4.D.2.2 Cropland 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 | 5.D.2.2 Cropland converted to Wetlands ($N_2O$ in $CO_2$-eq) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 88.34 | NE | 88.34 | NO | 77.23 | NO | NO | NO | 11.11 |
| 1991 | 78.14 | NE | 78.14 | NO | 67.51 | NO | NO | NO | 10.63 |
| 1992 | 74.61 | NE | 74.61 | NO | 64.47 | NO | NO | NO | 10.14 |
| 1993 | 71.08 | NE | 71.08 | NO | 61.43 | NO | NO | NO | 9.65 |
| 1994 | 67.55 | NE | 67.55 | NO | 58.39 | NO | NO | NO | 9.17 |
| 1995 | 64.02 | NE | 64.02 | NO | 55.34 | NO | NO | NO | 8.68 |
| 1996 | 60.50 | NE | 60.50 | NO | 52.30 | NO | NO | NO | 8.20 |
| 1997 | 56.97 | NE | 56.97 | NO | 49.26 | NO | NO | NO | 7.71 |
| 1998 | 53.44 | NE | 53.44 | NO | 46.21 | NO | NO | NO | 7.22 |
| 1999 | 49.91 | NE | 49.91 | NO | 43.17 | NO | NO | NO | 6.74 |
| 2000 | 46.38 | NE | 46.38 | NO | 40.13 | NO | NO | NO | 6.25 |
| 2001 | 42.09 | NE | 42.09 | NO | 36.36 | NO | NO | NO | 5.73 |
| 2002 | 38.30 | NE | 38.30 | NO | 33.09 | NO | NO | NO | 5.21 |
| 2003 | 34.50 | NE | 34.50 | NO | 29.82 | NO | NO | NO | 4.69 |
| 2004 | 30.71 | NE | 30.71 | NO | 26.55 | NO | NO | NO | 4.16 |
| 2005 | 26.92 | NE | 26.92 | NO | 23.28 | NO | NO | NO | 3.64 |
| 2006 | 23.13 | NE | 23.13 | NO | 20.01 | NO | NO | NO | 3.12 |
| 2007 | 20.18 | NE | 20.18 | NO | 17.54 | NO | NO | NO | 2.64 |
| 2008 | 16.68 | NE | 16.68 | NO | 14.53 | NO | NO | NO | 2.16 |
| 2009 | 13.19 | NE | 13.19 | NO | 11.51 | NO | NO | NO | 1.68 |
| 2010 | 9.69 | NE | 9.69 | NO | 8.49 | NO | NO | NO | 1.19 |
| 2011 | 9.72 | NE | 9.72 | NO | 8.52 | NO | NO | NO | 1.20 |
| 2012 | 9.75 | NE | 9.75 | NO | 8.55 | NO | NO | NO | 1.20 |
| 2013 | 10.65 | NE | 10.65 | NO | 9.41 | NO | NO | NO | 1.25 |
| 2014 | 10.99 | NE | 10.99 | NO | 9.69 | NO | NO | NO | 1.29 |
| 2015 | 11.32 | NE | 11.32 | NO | 9.98 | NO | NO | NO | 1.34 |
| 2016 | 11.65 | NE | 11.65 | NO | 10.27 | NO | NO | NO | 1.39 |
| 2017 | 11.99 | NE | 11.99 | NO | 10.56 | NO | NO | NO | 1.43 |
| 2018 | 12.32 | NE | 12.32 | NO | 10.84 | NO | NO | NO | 1.48 |
| 2019 | 12.65 | NE | 12.65 | NO | 11.13 | NO | NO | NO | 1.52 |
| 2018 | 12.99 | NE | 12.99 | NO | 11.42 | NO | NO | NO | 1.57 |
| 2021 | 13.58 | NE | 13.58 | NO | 11.93 | NO | NO | NO | 1.65 |
| 2022 | 14.18 | NE | 14.18 | NO | 12.45 | NO | NO | NO | 1.73 |

### 6.7.2. Methodological issues

#### 6.7.2.1. Land use change to Wetland (4.D.2)

Based on analysed data it was concluded that was no conversion from other land use categories to Wetland except from cropland.

##### 6.7.2.1.1 Cropland converted to Wetland (4.D.2.2)

Changes in carbon stocks in biomass of Cropland and Grassland converted to etland :

For the calculation of the annual change in carbon stocks of living biomass in Cropland converted to Wetland the 2006 IPCC Guidelines equation 7.10 was applied.

The annual change in carbon stocks of living biomass in Cropland converted to Wetland (tC/a):

$\Delta C_{LW\ flood} = \sum A_i \times (B_{after} - B_{before})_i$

where:

$A_i$ = area of land converted annually to flooded land from original land use *i*, ha $yr^{-1}$

$B_{Before}$ = living biomass in land immediately before conversion to wetland:

1) for annual cropland 5.7 t C /ha;

2) for perennial cropland 8.9 t C/ha (nationally defined value);

3) for grassland converted to cropland 4.3 t C/ha

$B_{After=}$ living biomass in land immediately before conversion to wetland (default = 0 t C/ha a)

Changes in carbon stocks in soil of Cropland and Grassland converted to Wetland:

$\Delta C_{\mathbf{LW\ flood}} = \sum A_i \times (B_{after} - B_{before})_i /20$

where:

$A_{\boldsymbol{i}}$ = area of land converted to flooded land for a transition period of 20 years, ha

$B_{\mathbf{Before}}$ = carbon stock in soil immediately before conversion to wetland:

1) for annual cropland 52.71 t C /ha;

2) for perennial cropland 71.01 t C/ha a (See Chapter 6.4.1.);

3) for grassland converted to wetland 75.75 tC/ha

$B_{\mathbf{After}}$ = carbon stock in soil immediately after conversion to wetland (default = 0 t C/ha)

$N_2O$ Emissions in soils of Land converted to Wetland

The annual release of $N_2O$ due to the conversion of Cropland to Wetland were calculated using the IPCC default value (Tier 1) and equation 11.8 as follows:

$N_2O$ net-min-N = EF1 x ΔCLCmineral x 1/ (C/N ratio)

where:

EF1 = the emission factor for calculating emissions of $N_2O$ from N in the soil = 0.01 kg $N_2O$-N/kg N (IPCC GPG default value)

ΔCLCmineral = change in the carbon stock in mineral soils in land to cropland

C/N = ratio by mass of C to N in the soil organic matter (8)

### 6.7.3. Uncertainties and time-series consistency

The uncertainty for the total $CO_2$-eq in category Land converted Wetland ranges according to the Tier 2 method can be find in Annex II. Uncertainties for emission factors and areas used in this estimation are presented in Table 6.4-6. The comparison between the uncertainties calculated using Tier 1 and Tier 2 methods by categories and carbon pools is presented in Annex 5.

The Wetland category has been included into the key category analysis. The analysis using Tier 1 and Tier 2 Level and Trend methods excluded wetland as a key category.

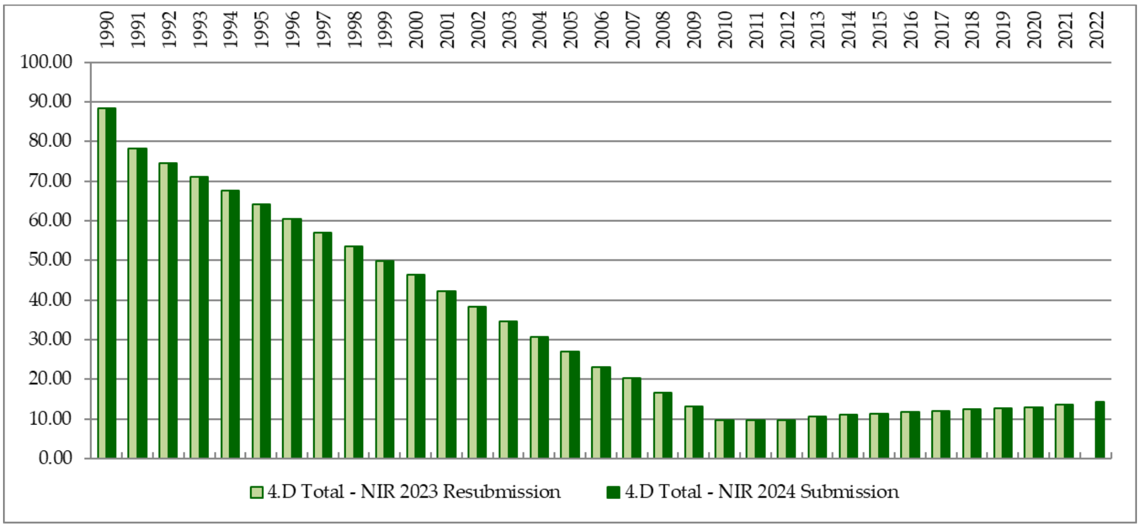
### 6.7.4. Category-specific QA/QC and verification

The calculation of the data for category 4.D was included in overall QA/QC system of the Croatian GHG inventory.

### 6.7.5. Category-specific recalculations

For this reporting Croatia there has not been recalculations in Wetland category.

Figure 6.7-1: Current and previously reported emissions for category 4.D (kt $CO_2$-eq)




### 6.7.6. Category-specific planned improvements

The results of currently running CROLIS project that will enable application of Approach 3 for each LULUCF land use category are planned to be used three years from now.

## 6.8. Settlements (CRF category 4.E)

### 6.8.1. Description

This category considers only emissions/removals from sub-categories “Land converted to Settlements”.

It was assumed that dead wood and litter (DOM) do not occur in the Settlements area.

The settlements area ranges from 200.65 kha in 1990 to 288.88 kha in 2022. Emissions from the change in the carbon stock ranges from 267.61 kt $CO_2$ to 673.39 kt $CO_2$ in 2022.

Annual LUCs to Settlements occur from the subcategories Forestland, Cropland (annual and perennial) and Grassland.

Tables 6.8-1 and Table 6.8-2 show the land use change and removals/emissions from LUC to Settlements in the period 1990 to 2022.

Table 6.8-1: Activity data of Settlements for 1990-2022 in kha

| Year | 4.E Total - Settlement | 4.E.1 Settlement remaining Settlement | 4.E.2 Land converted to Settlement | 4.E.2.1 Forest land converted to Settlement | 4.E.2.2A Annual Cropland to Settlement | 4.E.2.2b Perennial Cropland to Settlement | 4.E.2.3 Grassland converted to Settlement | 4.E.2.4 Wetland converted to Settlement | 4.E.2.5 Other land converted to Settlement |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 200.65 | 174.32 | 26.33 | 0.23 | 15.44 | 1.53 | 9.14 | NO | NO |
| 1991 | 201.15 | 175.64 | 25.51 | 0.21 | 14.96 | 1.48 | 8.85 | NO | NO |
| 1992 | 201.64 | 176.95 | 24.69 | 0.20 | 14.48 | 1.43 | 8.57 | NO | NO |
| 1993 | 202.14 | 178.27 | 23.87 | 0.19 | 14.01 | 1.39 | 8.29 | NO | NO |
| 1994 | 202.64 | 179.59 | 23.05 | 0.24 | 13.50 | 1.33 | 7.99 | NO | NO |
| 1995 | 203.14 | 180.90 | 22.24 | 0.23 | 13.02 | 1.29 | 7.70 | NO | NO |
| 1996 | 203.64 | 182.22 | 21.42 | 0.22 | 12.54 | 1.24 | 7.42 | NO | NO |
| 1997 | 204.14 | 183.54 | 20.60 | 0.28 | 12.02 | 1.19 | 7.11 | NO | NO |
| 1998 | 204.63 | 184.85 | 19.78 | 0.38 | 11.48 | 1.14 | 6.79 | NO | NO |
| 1999 | 205.13 | 186.17 | 18.96 | 0.40 | 10.98 | 1.09 | 6.50 | NO | NO |
| 2000 | 205.63 | 187.49 | 18.14 | 0.55 | 10.41 | 1.03 | 6.16 | NO | NO |
| 2001 | 211.81 | 188.80 | 23.01 | 0.90 | 13.08 | 1.29 | 7.74 | NO | NO |
| 2002 | 218.00 | 190.12 | 27.88 | 1.11 | 15.83 | 1.57 | 9.37 | NO | NO |
| 2003 | 224.18 | 191.43 | 32.74 | 1.19 | 18.66 | 1.85 | 11.04 | NO | NO |
| 2004 | 230.36 | 192.75 | 37.61 | 1.49 | 21.37 | 2.11 | 12.64 | NO | NO |
| 2005 | 236.54 | 194.07 | 42.48 | 1.81 | 24.05 | 2.38 | 14.23 | NO | NO |
| 2006 | 242.73 | 195.38 | 47.34 | 2.12 | 26.75 | 2.65 | 15.83 | NO | NO |
| 2007 | 248.88 | 196.70 | 52.18 | 2.19 | 29.57 | 2.92 | 17.50 | NO | NO |
| 2008 | 255.04 | 198.02 | 57.02 | 2.46 | 32.27 | 3.19 | 19.10 | NO | NO |
| 2009 | 261.19 | 199.33 | 61.86 | 2.56 | 35.07 | 3.47 | 20.75 | NO | NO |
| 2010 | 267.34 | 200.65 | 66.70 | 2.74 | 37.83 | 3.74 | 22.38 | NO | NO |
| 2011 | 273.50 | 201.15 | 72.35 | 2.77 | 41.16 | 4.07 | 24.35 | NO | NO |
| 2012 | 279.65 | 201.64 | 78.01 | 2.91 | 44.42 | 4.39 | 26.29 | NO | NO |
| 2013 | 280.57 | 202.14 | 78.43 | 3.00 | 44.62 | 4.41 | 26.40 | NO | NO |
| 2014 | 281.50 | 202.64 | 78.86 | 2.96 | 44.89 | 4.44 | 26.56 | NO | NO |
| 2015 | 282.42 | 203.14 | 79.28 | 3.03 | 45.10 | 4.46 | 26.69 | NO | NO |
| 2016 | 283.34 | 203.64 | 79.71 | 3.05 | 45.34 | 4.48 | 26.83 | NO | NO |
| 2017 | 284.27 | 204.14 | 80.13 | 2.98 | 45.64 | 4.51 | 27.00 | NO | NO |

| Year | 4.E Total - Settlement | 4.E.1 Settlement remaining Settlement | 4.E.2 Land converted to Settlement | 4.E.2.1 Forest land converted to Settlement | 4.E.2.2A Annual Cropland to Settlement | 4.E.2.2b Perennial Cropland to Settlement | 4.E.2.3 Grassland converted to Settlement | 4.E.2.4 Wetland converted to Settlement | 4.E.2.5 Other land converted to Settlement |
|---|---|---|---|---|---|---|---|---|---|
| 2018 | 285.19 | 204.63 | 80.56 | 2.88 | 45.94 | 4.54 | 27.19 | NO | NO |
| 2019 | 286.11 | 205.13 | 80.98 | 2.88 | 46.19 | 4.57 | 27.33 | NO | NO |
| 2020 | 287.03 | 205.63 | 81.40 | 2.74 | 46.53 | 4.60 | 27.53 | NO | NO |
| 2021 | 287.96 | 211.81 | 76.14 | 2.46 | 43.59 | 4.31 | 25.79 | NO | NO |
| 2022 | 288.88 | 218.00 | 70.88 | 2.42 | 40.49 | 4.00 | 23.96 | NO | NO |

Table 6.8-2: Emissions in Settlements for period 1990-2022 in kt $CO_2$-eq

| Year | 4.E Total - Settlement | 4.E.1 Settlement remaining Settlement | 4.E.2 Land converted to Settlement | 4.E.2.1 Forest land converted to Settlement | 4.E.2.2 Cropland to Settlement | 4.E.2.3 Grassland converted to Settlement | 4.E.2.4 Wetland converted to Settlement | 4.E.2.5 Other land converted to Settlement | 4.D.2 Land converted to Settlements ($N_2O$ in $CO_2$-eq) |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 267.61 | NE | 267.61 | 2.13 | 130.19 | 103.12 | NO | NO | 32.17 |
| 1991 | 244.50 | NE | 244.50 | 2.02 | 115.47 | 95.84 | NO | NO | 31.17 |
| 1992 | 236.95 | NE | 236.95 | 1.91 | 112.01 | 92.86 | NO | NO | 30.17 |
| 1993 | 229.41 | NE | 229.41 | 1.79 | 108.55 | 89.89 | NO | NO | 29.17 |
| 1994 | 221.88 | NE | 221.88 | 3.31 | 104.02 | 86.39 | NO | NO | 28.16 |
| 1995 | 214.34 | NE | 214.34 | 2.16 | 101.31 | 83.70 | NO | NO | 27.16 |
| 1996 | 206.85 | NE | 206.85 | 2.05 | 97.89 | 80.75 | NO | NO | 26.17 |
| 1997 | 198.08 | NE | 198.08 | 2.84 | 93.01 | 77.07 | NO | NO | 25.16 |
| 1998 | 192.51 | NE | 192.51 | 6.05 | 88.74 | 73.58 | NO | NO | 24.15 |
| 1999 | 185.12 | NE | 185.12 | 4.98 | 86.13 | 70.87 | NO | NO | 23.14 |
| 2000 | 180.41 | NE | 180.41 | 11.65 | 80.08 | 66.56 | NO | NO | 22.12 |
| 2001 | 326.10 | NE | 326.10 | 10.73 | 175.14 | 112.20 | NO | NO | 28.04 |
| 2002 | 375.14 | NE | 375.14 | 14.32 | 196.86 | 130.01 | NO | NO | 33.96 |
| 2003 | 420.81 | NE | 420.81 | 13.37 | 219.21 | 148.33 | NO | NO | 39.90 |
| 2004 | 471.84 | NE | 471.84 | 25.98 | 235.96 | 164.07 | NO | NO | 45.82 |
| 2005 | 513.46 | NE | 513.46 | 25.99 | 255.07 | 180.66 | NO | NO | 51.74 |
| 2006 | 556.10 | NE | 556.10 | 26.18 | 274.77 | 197.50 | NO | NO | 57.65 |
| 2007 | 618.26 | NE | 618.26 | 40.23 | 298.25 | 216.23 | NO | NO | 63.56 |

| Year | 4.E Total - Settlement | 4.E.1 Settlement remaining Settlement | 4.E.2 Land converted to Settlement | 4.E.2.1 Forest land converted to Settlement | 4.E.2.2 Cropland to Settlement | 4.E.2.3 Grassland converted to Settlement | 4.E.2.4 Wetland converted to Settlement | 4.E.2.5 Other land converted to Settlement | 4.D.2 Land converted to Settlements ($N_2O$ in $CO_2$-eq) |
|---|---|---|---|---|---|---|---|---|---|
| 2008 | 663.32 | NE | 663.32 | 46.73 | 315.13 | 232.02 | NO | NO | 69.44 |
| 2009 | 758.43 | NE | 758.43 | 95.17 | 337.63 | 250.29 | NO | NO | 75.35 |
| 2010 | 757.66 | NE | 757.66 | 52.44 | 356.83 | 267.15 | NO | NO | 81.24 |
| 2011 | 807.55 | NE | 807.55 | 47.55 | 383.13 | 288.71 | NO | NO | 88.16 |
| 2012 | 852.11 | NE | 852.11 | 43.41 | 405.22 | 308.42 | NO | NO | 95.06 |
| 2013 | 752.68 | NE | 752.68 | 39.39 | 335.37 | 282.35 | NO | NO | 95.57 |
| 2014 | 750.56 | NE | 750.56 | 31.76 | 338.29 | 284.41 | NO | NO | 96.09 |
| 2015 | 766.88 | NE | 766.88 | 45.60 | 339.19 | 285.49 | NO | NO | 96.60 |
| 2016 | 755.09 | NE | 755.09 | 29.11 | 341.61 | 287.24 | NO | NO | 97.12 |
| 2017 | 759.10 | NE | 759.10 | 28.42 | 343.90 | 289.13 | NO | NO | 97.65 |
| 2018 | 762.87 | NE | 762.87 | 27.52 | 346.13 | 291.05 | NO | NO | 98.18 |
| 2019 | 767.35 | NE | 767.35 | 28.58 | 347.60 | 292.47 | NO | NO | 98.70 |
| 2020 | 770.85 | NE | 770.85 | 26.74 | 350.23 | 294.65 | NO | NO | 99.23 |
| 2021 | 722.27 | NE | 722.27 | 25.34 | 328.09 | 276.00 | NO | NO | 92.83 |
| 2022 | 673.39 | NE | 673.39 | 26.86 | 304.01 | 256.12 | NO | NO | 86.40 |

## 6.8.2. Methodological issues

### 6.8.2.1. Land use change to Settlements (4.E.2)

A) Biomass

The IPCC Tier 2 approach was used for the calculation of annual change in carbon stocks of living biomass of the land use categories converted to Settlements. The approach follows exactly the method in the other LUC categories. Country specific biomass data for grassland and annual plants of cropland were used. Based on expert judgment, the biomass carbon stocks of annual plants in unsealed areas of settlements were estimated to be the same as the grassland biomass (4.29 t C/ha), corrected as per the relative share of the unsealed areas of settlements in Croatia. According to the CLC database, the average share of unsealed areas in the settlements category was 4.5%. Carbon stocks of sealed areas were set to be zero.

The biomass carbon stock growth rates of perennial plants at unsealed settlement areas were determined based on the data from Cadastre of Greens of City of Zagreb. Following this Cadastre, in region of City of Zagreb there is 22,518 coniferous trees and 142,898 deciduous trees in unsealed area of City of Zagreb. Default annual carbon accumulation rate from the IPCC GPG (Table 8.2) for mixed hardwood species (0.01003 tC/ha annually) was taken to calculate total annual carbon accumulation for deciduous trees in Zagreb. Total annual carbon accumulation was calculated using IPCC Tier 2b – *Individual plant growth* method (Equation 8.3) based on number of individual woody plants by broad species class in Cadastre of Greens of City of Zagreb.

In case of coniferous species, the mean value of annual carbon accumulation rate for broad coniferous species class was taken (0.00867 tC/year) from the IPCC GPG (Table 8.2).

The resulting total annual carbon accumulation for trees in City of Zagreb was then divided by the related unsealed area of City of Zagreb to get per ha value. This resulted in an annual growth of trees at unsealed area of City of Zagreb of 0.0263 tC/ha annually. The figure was used for all unsealed Croatian settlement area.

The average annual carbon stock in annual plants of cropland before the LUC was 5.7 t C/ha. National defined value of 8.9 t C/ha for Perennial cropland was used to calculate the biomass carbon stock change in Perennial cropland converted to Settlements. In case of Grassland converted to Settlement national value of 4.3 tC/ha in Grassland before LUC was used in estimation.

For the calculation of the annual change in carbon stocks of living biomass in Forest land converted to Settlements, specific harvest data for these deforestation areas delivered by the Croatian Forests Ltd. were used.

B) Soil

The approach follows exactly the method in the other LUC categories. The calculation of emissions from soil carbon stock changes due to land use changes from other subcategories refer to a soil depth of 0-30 cm. Research on carbon stock in Croatian soils was done so that the humus layer (litter) was removed from the soil sample. The calculation of the emissions from soils as a result of the conversion of other subcategories to settlements was made using national data for carbon stocks in the soils of the land use categories involved in the LUCs (forest land, annual and perennial cropland, grassland, settlement). The soil carbon stocks in unsealed areas of settlements were assessed by this soil survey to be on average 86.91 t C/ha, corrected as per the relative share of the unsealed areas of settlements in Croatia. By expert judgment the median value of the carbon stock was used because it is less influenced by outliers (see Chapter 6.2). The used soil C stocks of the previous land uses are the same as represented in the other LUC chapters.

For this year reporting Croatia used value for the litter carbon stock that comes from the scientific investigation performed in 2017. The IPCC method as described in Chapter 6.4.2.2 was used for the estimation of carbon stock changes in litter pool in forest land that is converted to settlements.

##### 6.8.2.1.1 Forest land converted to Settlements (4.E.2.1)

The area in conversion status from Forest land to Settlements for the period of 20 years ranged from 0.23 kha to 2.42 kha in 1990-2022.

Changes in carbon stocks in biomass of Forest land converted to Settlements

Annual net carbon change rates due to loss of forest biomass and increase of biomass in the settlements area was in the range from 0.01. to -0.57 kt C in the period 1990-2022.

Changes in carbon stocks in soil, litter and dead wood pools of Forest land converted to Settlements.

The calculation of the emissions from soils because of the conversion of Forest land to Settlements was made by using national data for carbon stocks in soils in forest land (69.86 t C/ha) and carbon stocks in soils of settlements (86.91 t C/ha for the unsealed settlement area or 3.98 t C/ha for the total settlement area).

Annual net change rates due to carbon stock changes in soil ranged from -0.58 to -6.31 kt C in the period from 1990 to 2022.

Previously, the average annual carbon stock change in deadwood pool in forest land deforested in Croatia was included in the stem wood loss of deforestation areas and therefore included in the biomass results. In case of Forest land that is converted to Settlements, Croatia performs estimation of carbon stock changes in dead wood pool for the first time in this year report. A new national project regarding the determination on carbon stock in dead wood pool in deforested areas in Croatia was initiated.

The equation 2.23 from the 2006 IPCC Guidelines was used for calculating the change of carbon stock in deadwood on forest areas converted to settlements:

$\Delta C_{Dw} = A_{0N} *(C_N - C_0) / T_{0N}$

where:

$\Delta C_{DW}$ = annual change in carbon stocks in dead wood (tC/ha)

$C_N$ = dead wood/litter stock, under the new land-use category (tC/ha)

$C_0$ = dead wood/litter stock, under the old land-use category (tC/ha)

$A_{0N}$ = area undergoing conversion from old to new land-use category (ha)

$T_{0N}$ = time period of the transition from old to new land-use category, yr

National values of dead wood stock ($m^3$/ha) were determined from the available data collected through the Croatian National Forest Inventory (CRONFI) process, as follows:

Table 6.8-3: National values of dead wood stock in $m^3$/ha

| | Forest type | Standing deadwood | Lying deadwood |
|---|---|---|---|
| Deadwood stock ($m^3$/ha), mean value | Deciduous | 5.84 | 7.28 |
| | Coniferous | 5.16 | 10.32 |
| | Out of Yield (maquies and shrub) | 0.58 | 0.36 |

When determining the carbon stock in dead wood, $BEF_2$ and R/S factor were applied in case of dry, standing wood, thus ensuring the inclusion of all parts of the tree.

Table 6.8-4: Parameters from the 2006 IPCC Guidelines used in calculation

| | Wood density | $BEF_2$ | R/S | Carbon fraction | Deadwood carbon |
|---|---|---|---|---|---|
| | (t d.m./$m^3$) | | | (CF) (tC/ t d.m.) | stock (tC/ha) |
| Deciduous | 0.56 | 1.197 | 0.23 | 0.5 | 4.43 |
| Coniferous | 0.39 | 1.039 | 0.29 | 0.5 | 3.4 |
| Out of Yield | 0.68 | 1.15 | 0.46 | 0.5 | 0.46 |

Annual data on deforestation according to the type of conversion had been collected through the LULUCF 1 project and shown in Table 6.8-5. Estimation of the carbon stock change was performed using the data on deforested areas for each type of forest in particular (deciduous, coniferous, out of yield (maquies and shrub)), and the values were summarized and shown for all types of forests together depending on the type of conversion of forest land and year of the conversion.

Table 6.8-5: Dead wood CSC (kt C) on the deforested areas due to land use change from Forest land to Settlements

| Year | Area of deforestated land (kha) | Deadwood carbon stock change (kt C) |
|---|---|---|
| 1990 | 0.23 | NO |
| 1991 | 0.21 | NO |
| 1992 | 0.20 | NO |
| 1993 | 0.19 | NO |
| 1994 | 0.24 | -0.01 |
| 1995 | 0.23 | NO |
| 1996 | 0.22 | NO |
| 1997 | 0.28 | 0.00 |
| 1998 | 0.38 | -0.03 |
| 1999 | 0.40 | -0.01 |
| 2000 | 0.55 | -0.07 |
| 2001 | 0.90 | -0.02 |
| 2002 | 1.11 | -0.04 |
| 2003 | 1.19 | -0.02 |
| 2004 | 1.49 | -0.21 |
| 2005 | 1.81 | -0.15 |
| 2006 | 2.12 | -0.12 |
| 2007 | 2.19 | -0.46 |
| 2008 | 2.46 | -0.51 |
| 2009 | 2.56 | -1.71 |
| 2010 | 2.74 | -0.62 |
| 2011 | 2.77 | -0.53 |
| 2012 | 2.91 | -0.37 |
| 2013 | 3.00 | -0.23 |
| 2014 | 2.96 | -0.08 |
| 2015 | 3.03 | -0.38 |
| 2016 | 3.05 | 0.00 |
| 2017 | 2.98 | 0.00 |
| 2018 | 2.88 | 0.00 |
| 2019 | 2.88 | -0.01 |
| 2020 | 2.74 | -0.01 |
| 2021 | 2.46 | -0.02 |
| 2022 | 2.42 | -0.04 |

For the CSC estimation in litter pool the value of 4.57 tC/ha and 0.00 tC/ha were used in case of conversion form Forest land to Settlements category.

#### 6.8.2.1.2 Cropland converted to Settlements (4.E.2.2)

The area in conversion status from Cropland to settlements for the time period of 20 years ranged from 16.97 kha to 44.50 kha in the years 1990 - 2022.

Changes in carbon stocks in biomass of Cropland converted to Settlements

Annual net change due to loss of cropland biomass and increase of biomass in settlements area ranged from -3.87 to -1.33 kt C in annual cropland and -0.63 to -0.27 kt C in perennial cropland converted to settlements in the years 1990 and 2022.

Changes in carbon stocks in soil, litter and dead wood pools of Cropland converted to Settlements

The calculation of the emissions from soils as a result of the conversion of Cropland to Settlements was made by using national data for carbon stocks in soils in annual cropland (52.71 t C/ha) and perennial cropland (71.01 t C/ha), as well as carbon stocks in soils of Settlements (86.91 t C/ha for the unsealed settlement area or 3.98 t C/ha for the total settlement area).

Annual net rates due to carbon stock changes in soil ranged from -26.9 to -70.7 kt C in annual cropland converted to Settlements and from -4.1 to -10.7 kt C in perennial cropland converted to settlements in years 1990 and 2022.

Regarding this conversion type, Croatia uses Tier 1 for dead wood and litter pools. According to the 2006 IPCC Guidelines litter and dead wood pools are not present on non-forest categories of land. Consequently, notation key NO is used for these pools in case of cropland converted to settlement category.

#### 6.8.2.1.3 Grassland converted to Settlements (4.E.2.3)

The area in conversion status from Grassland to Settlements ranged from 9.14 to 23.96 kha in period 1990-2022.

Changes in carbon stocks in biomass of Grassland converted to Settlements

Annual net rates due to loss of grassland biomass and increase of biomass in settlements area ranged from -1.66 to -0.43 kt C during the period 1990-2022.

Changes in carbon stocks in soil, litter and dead wood pools of Grassland converted to Settlements

The calculation of emissions from soils because of conversion of Grassland to Settlements was made by using national data for carbon stocks in soils in Grassland (75.75 t C/ha) and carbon stocks in soils of settlements (86.91 t C/ha for the unsealed settlement area or 3.98 t C/ha for the total settlement area).

Annual net rates due to carbon stock changes in soil ranged from -26.5 to -69.4 kt C in the period 1990-2022.

Regarding this conversion type, Croatia uses Tier 1 for dead wood and litter pools. According to the 2006 IPCC Guidelines litter and deadwood pools are not present on non-forest categories of land. Consequently, notation key NO is used for these pools in case of cropland converted to settlement category.

#### 6.8.2.1.4 $N_2O$ Emissions in soils of Land converted to Settlements

The annual release of $N_2O$ due to the conversion of Forest land, Grassland and Cropland to Settlement were calculated using the IPCC default value (Tier 1) and equation 11.8 as follows:

$N_2O_{net-min} - N = EF1 \times \Delta CLC_{mineral} \times 1/(C/N\ ratio)$

where:

EF1 = the emission factor for calculating emissions of $N_2O$ from N in the soil = 0.01 kg $N_2O$- N/kg N (IPCC GPG default value)

$\Delta CLC_{mineral}$ = change in the carbon stock in mineral soils in land to cropland

C/N = ratio by mass of C to N in the soil organic matter (8 for Grassland and 9 for Cropland converted to Settlements and 11 for Forest land converted to Settlements)

### 6.8.3. Uncertainties and time-series consistency

According to the Tier 2 method relative uncertainty for the total $CO_2$-eq in category Land converted to Settlements ranges were calculated and presented in Annex II. Also, the comparison between the uncertainties calculated using Tier 1 and Tier 2 methods by categories and carbon pools is presented in Annex II.

The Settlements category has been included into the key category analysis. The analysis using Tier 1 and Tier 2 Level and Trend methods confirmed land converted to Settlement as a key category.

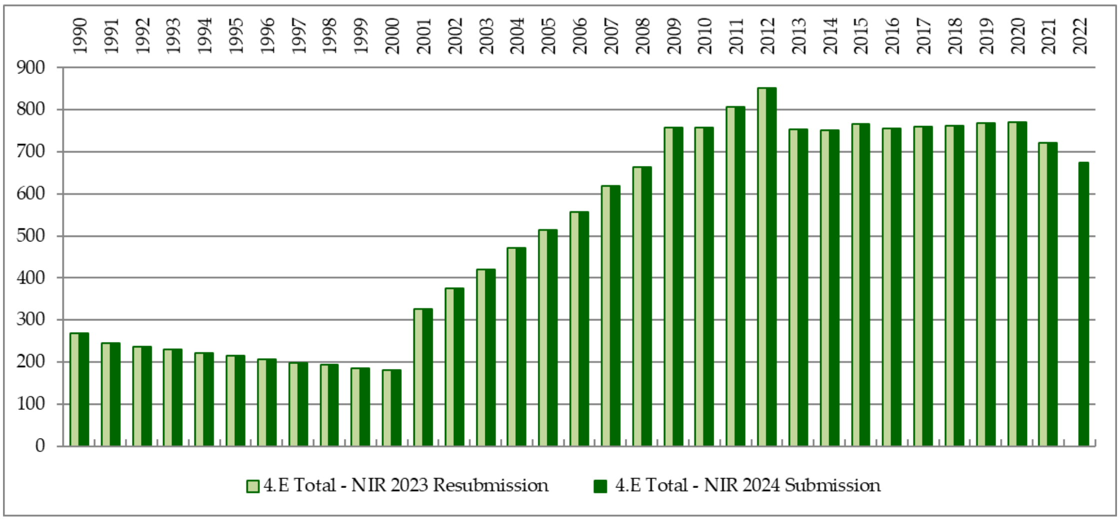
### 6.8.4. Category-specific QA/QC and verification

The calculation of the data for category 4.E was included in overall QA/QC system of the Croatian GHG inventory.

### 6.8.5. Category-specific recalculations

For this reporting there has not been recalculation in this category of land as it can been seen in Figure 6.8-1.

Figure 6.8-1: Current and previously reported emissions for category 4.E (kt $CO_2$-eq)




### 6.8.6. Category-specific planned improvements

The results of currently running CROLIS project that will enable application of Approach 3 for each LULUCF land use category are planned to be used three years from now.

## 6.9. Other land (CRF category 4.F)

In this category only the total area of land was considered. There was no conversion from Other land use categories to Other land.

### 6.9.1. Description

Table 6.9-1: Activity Data for Other land, in kha

| Year | 4.F Total - Other land | 4.F.1 Other land remaining Other land | 4.F.2 Land converted to Other land | 4.F.2.1 Forestland converted to Other land | 4.F.2.2.A Annual cropland converted to Other land | 4.F.2.2.B Perrenial cropland converted to Other land | 4.F.2.3 Grassland converted to Other land | 4.F.2.4 Wetland converted to Other land | 4.F.2.5 Settlement converted to Other land |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1991 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1992 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1993 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1994 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1995 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1996 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1997 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1998 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 1999 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2000 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2001 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2002 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2003 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2004 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2005 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2006 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2007 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2008 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2009 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2010 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2011 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2012 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2013 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2014 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2015 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2016 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |

| Year | 4.F Total - Other land | 4.F.1 Other land remaining Other land | 4.F.2 Land converted to Other land | 4.F.2.1 Foreslland converted to Other land | 4.F.2.2.A Annual cropland converted to Other land | 4.F.2.2.B Perrenial cropland converted to Other land | 4.F.2.3 Grassland converted to Other land | 4.F.2.4 Wetland converted to Other land | 4.F.2.5 Settlement converted to Other land |
|---|---|---|---|---|---|---|---|---|---|
| 2017 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2018 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2019 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2020 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2021 | 201.63 | 201.63 | NO | NO | NO | NO | NO | NO | NO |
| 2022 | 201.37 | 201.37 | NO | NO | NO | NO | NO | NO | NO |

### 6.9.2. Methodological issues

As informed in Chapter 6.3.6, area of Other land category has been always reported by Croatia as a difference between the total area of Croatia and sum of all other categories of land which is in line with the IPCC 2006 GL.

Corine Land Cover (CLC) was one of the data sources that was examined during the process of land use change matrix development. Regarding the identification of forest land category (which includes forest land that are subject of forest fires), it was conclude that CLC database is not appropriate for this category of land due its resolution and the fact that the minimum area for mapping the land cover is 25 ha and the minimum area for mapping of changes is 5 ha, while the 0,1 ha is set as the threshold for defining forest areas in Croatia. All forest areas are identified using the maps (with more precise scales than CLC) that are produced and make integral part of the Forest management plan for the Republic of Croatia and other relevant programs and plans in forest sector. Following the fact that all forest areas are identified, there is no Open spaces with less or no vegetation (Level 2 of CLC) that reaches thresholds defined for forest and emissions of which should be reported under the Other category of land due to the forest fires.

### 6.9.3. Uncertainties and time-series consistency

This category of land was not subject of uncertainty estimates in LULUCF sector.

### 6.9.4. Category-specific QA/QC and verification

The calculation of the data for category 4.F was included in overall QA/QC system of the Croatian GHG inventory.

### 6.9.5. Category-specific recalculations

In this cycle there were no recalculations in this category.

### 6.9.6. Category-specific planned improvements

In this cycle there were no recalculations in this category.

## 6.10. Harvested Wood Products (CRF category 4.G)

### 6.10.1. Category description

Since NIR 2015 submission, Parties to the UNFCCC and the KP are obliged to submit their national estimation of emissions/removals in harvested wood products (HWP), following the stipulations of Decision 2/CMP.7. Carbon stock changes in this new pool are included within the LULUCF sector as a separate category (CRF 4.G).

Estimation performed for Croatia is presented in below Table 6.10-1 and shows fluctuation of emissions/removals during the reporting period 1990-2022. The estimation has been based on of HWP production data for Croatia presented in Table 6.10-2.

Table 6.10-1: Emissions/removals (kt $CO_2$) from HWPs in the period between 1990-2022

| Year | Total - HWP | Sawn wood | Wood panels | Paper and paper board |
|---|---|---|---|---|
| 1990 | -317.85 | -338.61 | -62.53 | 83.29 |
| 1991 | 176.24 | -52.70 | -6.75 | 235.69 |
| 1992 | 252.83 | -114.62 | 1.19 | 366.27 |
| 1993 | 66.40 | -163.41 | -16.95 | 246.76 |
| 1994 | -45.49 | -70.05 | 6.57 | 17.99 |
| 1995 | -55.09 | -30.18 | 18.78 | -43.69 |
| 1996 | -12.27 | -23.36 | 22.74 | -11.65 |
| 1997 | 119.97 | -19.61 | 19.09 | 120.49 |
| 1998 | 3.68 | -88.51 | 9.98 | 82.20 |
| 1999 | -58.26 | -103.91 | 3.10 | 42.55 |
| 2000 | -69.66 | -107.05 | 9.86 | 27.53 |
| 2001 | -306.12 | -19.15 | 4.80 | -291.77 |
| 2002 | -302.33 | -84.35 | 8.10 | -226.08 |
| 2003 | -190.82 | -30.93 | -5.83 | -154.05 |
| 2004 | -180.30 | -41.72 | -14.09 | -124.50 |
| 2005 | -348.72 | -79.71 | -37.39 | -231.61 |
| 2006 | -322.96 | -121.90 | -67.81 | -133.25 |
| 2007 | -309.35 | -155.23 | -80.37 | -73.76 |
| 2008 | -325.34 | -179.91 | -85.71 | -59.72 |
| 2009 | -178.97 | -107.68 | -47.16 | -24.13 |
| 2010 | -249.16 | -131.49 | -55.62 | -62.05 |
| 2011 | -268.76 | -203.59 | -44.35 | -20.82 |

| Year | Total - HWP | Sawn wood | Wood panels | Paper and paper board |
|---|---|---|---|---|
| 2012 | -319.83 | -297.69 | -51.85 | 29.71 |
| 2013 | -426.18 | -618.90 | -109.16 | 301.89 |
| 2014 | -538.61 | -778.66 | -103.19 | 343.25 |
| 2015 | -764.15 | -859.11 | -88.27 | 183.23 |
| 2016 | -780.07 | -786.78 | -21.76 | 28.47 |
| 2017 | -1029.35 | -965.44 | -69.90 | 5.99 |
| 2018 | -761.66 | -709.89 | -62.74 | 10.97 |
| 2019 | -752.16 | -703.45 | -37.03 | -11.69 |
| 2020 | -629.54 | -559.92 | -100.28 | 30.66 |
| 2021 | -656.28 | -509.97 | -127.50 | -18.82 |
| 2022 | -393.25 | -329.76 | -87.51 | 24.02 |

Table 6.10-2: HWP produced in Croatia from 1961-2022

| Year | Sawn wood ($m^3$) | Wood panels ($m^3$) | Paper and paper board (t) |
|---|---|---|---|
| 1961 | 547,662 | 43,995 | 75,716 |
| 1962 | 581,089 | 58,586 | 93,839 |
| 1963 | 607,928 | 76,436 | 115,360 |
| 1964 | 639,705 | 96,295 | 140,116 |
| 1965 | 649,570 | 101,755 | 159,272 |
| 1966 | 690,767 | 99,462 | 168,171 |
| 1967 | 681,257 | 96,751 | 180,484 |
| 1968 | 682,891 | 82,194 | 197,438 |
| 1969 | 664,538 | 108,296 | 211,902 |
| 1970 | 649,571 | 114,011 | 235,680 |
| 1971 | 710,708 | 113,120 | 247,097 |
| 1972 | 700,546 | 102,519 | 275,697 |
| 1973 | 736,640 | 96,162 | 284,214 |
| 1974 | 800,359 | 103,495 | 300,171 |
| 1975 | 752,598 | 100,946 | 304,217 |
| 1976 | 803,409 | 106,000 | 311,437 |
| 1977 | 822,907 | 97,467 | 347,423 |
| 1978 | 842,119 | 81,555 | 361,706 |
| 1979 | 915,645 | 136,265 | 372,571 |

| Year | Sawn wood ($m^3$) | Wood panels ($m^3$) | Paper and paper board (t) |
|---|---|---|---|
| 1980 | 876,005 | 171,074 | 421,158 |
| 1981 | 879,100 | 180,225 | 444,036 |
| 1982 | 939,227 | 176,150 | 419,721 |
| 1983 | 943,097 | 196,434 | 484,205 |
| 1984 | 1,045,493 | 189,301 | 451,864 |
| 1985 | 1,067,294 | 157,962 | 488,565 |
| 1986 | 1,064,931 | 213,371 | 478,645 |
| 1987 | 1,069,834 | 198,328 | 484,849 |
| 1988 | 1,095,016 | 187,411 | 472,241 |
| 1989 | 1,098,438 | 183,865 | 462,642 |
| 1990 | 861,180 | 152,239 | 396,075 |
| 1991 | 568,633 | 95,530 | 248,268 |
| 1992 | 633,582 | 87,592 | 81,389 |
| 1993 | 689,513 | 106,534 | 91,609 |
| 1994 | 597,338 | 82,892 | 222,452 |
| 1995 | 553,486 | 69,904 | 269,610 |
| 1996 | 549,105 | 65,195 | 253,519 |
| 1997 | 548,567 | 68,145 | 145,902 |
| 1998 | 621,258 | 77,198 | 148,408 |
| 1999 | 640,827 | 84,196 | 161,424 |
| 2000 | 633,839 | 77,008 | 163,564 |
| 2001 | 553,358 | 81,943 | 423,774 |
| 2002 | 618,684 | 78,302 | 440,299 |
| 2003 | 564,107 | 92,571 | 435,440 |
| 2004 | 571,027 | 101,058 | 448,457 |
| 2005 | 610,118 | 125,152 | 568,494 |
| 2006 | 654,119 | 157,419 | 542,970 |
| 2007 | 690,910 | 172,235 | 525,862 |
| 2008 | 717,212 | 180,049 | 532,189 |
| 2009 | 651,449 | 142,660 | 517,054 |
| 2010 | 675,574 | 152,678 | 554,671 |
| 2011 | 752,374 | 142,692 | 535,390 |
| 2012 | 849,860 | 151,696 | 498,249 |
| 2013 | 1,190,787 | 212,169 | 263,421 |
| 2014 | 1,359,823 | 209,062 | 154,919 |
| 2015 | 1,463,833 | 196,589 | 204,644 |
| 2016 | 1,399,846 | 130,892 | 289,168 |

| Year | Sawn wood ($m^3$) | Wood panels ($m^3$) | Paper and paper board (t) |
|---|---|---|---|
| 2017 | 1,593,264 | 181,231 | 300,986 |
| 2018 | 1,364,898 | 176,166 | 295,355 |
| 2019 | 1,369,193 | 151,461 | 311,615 |
| 2020 | 1,243,880 | 217,425 | 279,068 |
| 2021 | 1,204,002 | 247,997 | 312,927 |
| 2022 | 1,013,709 | 210,481 | 281,719 |

### 6.10.2. Methodological issues

For the estimation of emissions/removals from harvested wood products (HWP) Croatia used Tier 2 applying the production approach (Approach B).

Input data on types of HWP production on national level were collected within the scope of the project "Upgrading the Croatian National System for the reporting of greenhouse gas emissions for the implementation of the Decision No 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities" (abbreviated: LULUCF 2 project; implemented in period 2014-2015). A separate document was produced for the purposes of the estimation and this reporting.[50]

Data that had been delivered by the Republic of Croatia to the UNECE/FAO were analysed and compared with the data available in different data sources on national level. It had been decided that data delivered by Croatia to the UNECE/FAO database for the period 1992-2014 would be used for the estimation. Since the data on total harvested volume in Croatia refers to the wood harvested on areas under the forest land remaining forest land category and areas that were subject to deforestation, in order to comply with the requirements of Decision 2/CMP.7 (Annex, Part E, point 31), the special ratio was determined. As it has been already reported, there is no harvest in category Out of yield (maquies and shrubs) forests and the exact data on harvested volume of coniferous as well as deciduous forests on deforested areas are well known. The volumes of wood harvested on deforested areas were subtracted from the total volume cut in Croatia. For this purpose, a specially determined ratio was used. The determined ratio shows that 99% of total volume harvested in Croatia belongs to the volume cut on areas that falls under the forest land remaining forest land category. Carbon stock changes in harvested wood products volume cut on this area was calculated using the first order decay method and they are reported under the CRF Table 4G.s1.

The carbon stock changes in case of volumes cut on deforested areas were estimated using the instantaneous oxidation method.

For the period from 1961 to 1991, data on harvested wood products in the Republic of Croatia were taken from a number of statistical yearbooks, statistical reports, statistical bulletins[51], that are and stored / available to the Central Bureau of Statistics (CBS).

[50] The development of the national methodology for calculating carbon stock in wood products, 2014 (originally in Croatian: „*Razvoj nacionalnih metodologija za izračun zalihe ugljika u drvnim proizvodima*“).

[51] Department of Statistics and records. Statistical Yearbook for the period 1953-1959; Industry, Report of the Executive Council of NR Croatia and Report to the Executive Council of the Parliament of NR Croatia for period 1957-1970; Industry.

For the period before 1961, equation 12.6 from 2006 IPCC Guidelines (Vol 4, Chapter 12) was used to determine harvested wood products data on production in the period between 1900-1960. For the year 1900, value of zero was used as input data on domestic production for all types of HWPs.

$$\boldsymbol{V_t = V^{1961} * e^{[(U*(t-1961)]}}$$

where:

Vt = annual production, imports/exports for a solid wood/paper product for year t [Gg C/a]

t = year

$V_{1961}$ = annual production, imports/exports for a solid wood/paper product for year 1961 [Gg C/a]

U=value of 0.0151=estimated continuous rate of increase for industrial roundwood consumption (harvest) in Europe between 1900-1961 (2006 IPCC Guidelines, Vol 4 , Tbl. 12.3);

When data were collected for all HWPs types for the period between 1961 to 2018 and after 'forecast back' data were defined for the period between 1900 to 1960 the share of domestic products in total production were determined by applying the equation 2.8.1 (Chapter 2 of the IPCC (2014) KP supplement):

$$\boldsymbol{f_{IRW}(i) = \frac{IRWp(i) - IRWex(i)}{IRWp(i) + IRWim(i) - IRWex(i)}}$$

where:

fIRW (i) = share of wood from domestic harvest for year i

IRWp (i)= production of industrial roundwood in year i, ($m^3$)

IRWim (i) = import of industrial roundwood in year i, ($m^3$)

IRWex (i) = export of industrial roundwood in year i, ($m^3$)

Since for the year 1961 data were not found for the production in case of fibreboard (HDF; MDF; Insulating boards) in the available/existing statistical reports, it was concluded that this kind of production was not presented in Croatia. Since in the FAO database for this type of HWP was reported zero for all years, consequently for the period between 1900-2015 value of zero was used in estimation.

Based on the part of existing data for paper and paperboard, the equation of a linear trend was defined for the period from 1962 to 1981:

$$y = 21582 \cdot t - 42231736$$

where:

t = year

y = value of the variable 10 tons (paper and paperboard)

Statistical Bulletins for period 1971-1989; Important products in the export and import of SR Croatia for period 1976 -1990. See References.

The correlation coefficient r = 0.99202183 and the coefficient of determination $R^2$ = 0.98410732 are extremely high suggesting that the trend equation perfectly describes the movement of the value of variable 10 in the analysed period.

Using the equation of trend, the value of variable 10 for the year 1961 was calculated:

$$y = 21582 \cdot 1961 - 42231736 = 90566$$

Determined value of 90,566 tons for y (1961) was used for calculation purposes and determination of paper production in period 1900-1960.

The nationally available data on Wood pulp production were collected and share of domestically production were defined for each year using the **equation 2.8.2.**

Annual fraction of domestically produced Wood pulp as feedstock for Paper and Paperboard production

$$(f_{PULP}) = (Pulp_{Production} - Pulp_{Export}) / (Pulp_{Production} + Pulp_{Import} - Pulp_{Export})$$

Finally, the changes in the carbon stock of HWP products in use are estimated by using equation 12.1 (2006 IPCC Guidelines, Chapter 12):

$$\boldsymbol{C(i+1) = e^{-k} * C(i) + \left[\frac{(1-e^{-k})}{k}\right] * Inflow(i+1)}$$

where:

i = year

C(i) = the carbon stock of the HWP pool in the beginning of year i [Gg C]

k = decay constant of first-order decay for each HWP category given in units, $yr^{-1}$

(k = ln(2)/HL where HL is half-life of the HWP pool in years)

Inflow (i) = the inflow to the HWP pool during year i [Gg C/yr]

Following KP supplement recommendations when applying Tier 2 in estimation (Table 2.8.2) next values were used:

- Sawn wood – 35 years
- Wood panels – 25 years
- Paper – 2 years

Then the carbon stock change is calculated as the difference of C(i+1) and C(i).

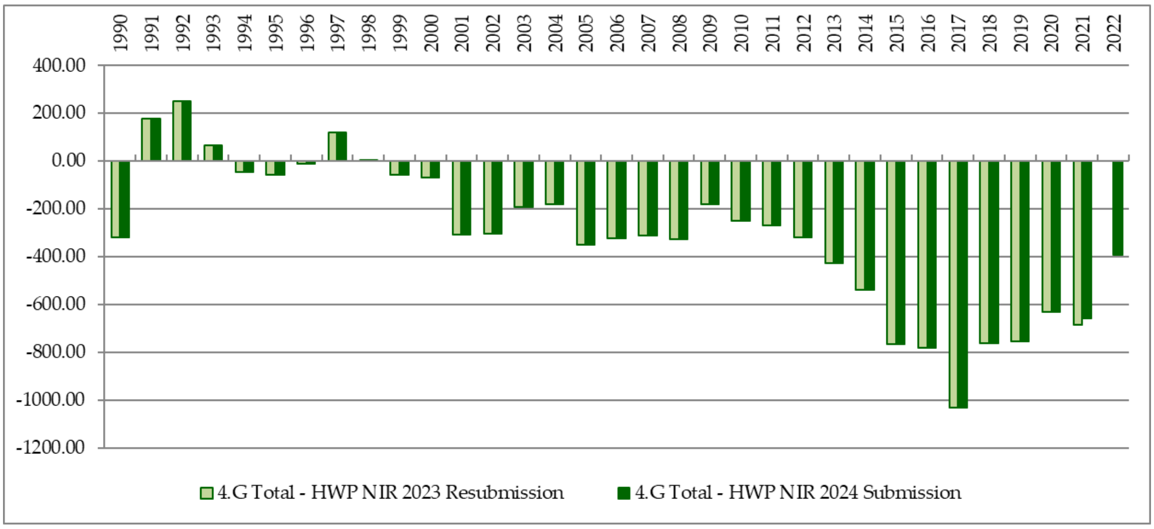
### 6.10.3. Uncertainty assessment

First uncertainty estimation for harvested wood products was conducted for NIR 2015, and the overall uncertainty for this category ranges from -87.78% to 130.36%.

### 6.10.4. Recalculations

For NIR 2024 Submission there has not been recalculation in HWP pool.

Figure 6.10-1: Current and previously reported emissions (+) and removals (-) in HWP (kt $CO_2$)




### 6.10.5. Planned Improvements

Through the new project initiated by the MESD in 2022 that deals with HWP issues the activity data will be revised and used for the NIR 2025 Submission.

## 6.11. Direct $N_2O$ emissions from N inputs to managed soils (CRF category 4. I)

$N_2O$ emissions from N fertilization of cropland and grassland are reported in the agriculture sector. No fertilizers are applied to forest land.

## 6.12. Emissions and removals from drainage and rewetting and other management of organic and mineral soils (CRF category 4. II)

Drainage of soils did not occur in Croatia in period 1990-2022 and no data are reported.

## 6.13. Direct $N_2O$ emissions from n mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (CRF category 4. III)

### 6.13.1. Description

$N_2O$ emissions from Cropland remaining Cropland (Perennial cropland converted to Annual cropland) are reported in the agriculture sector. Under this category according to the 2006 IPCC Guidelines, $N_2O$ emissions associated with disturbance of land use changes that occurs in Croatia are reported as follows:

- Forestland converted to Cropland; Forestland converted to Settlements,
- Cropland converted to Wetlands; Cropland converted to Settlements,
- Grassland converted to Cropland; Grassland converted to Wetlands; Grassland converted to Settlements.

### 6.13.2. Methodological issues

The annual release of $N_2O$ mentioned above conversions was calculated using the IPCC default value (Tier 1) and equation 11.8:

$N_2O_{net\text{-}min} - N = EF_1 \times \Delta C_{LCmineral} \times 1/(C/N\ ratio)$

where:

$EF_1$ = the emission factor for calculating emissions of $N_2O$ from N in the soil = 0.01 kg $N_2O$- N/kg N (IPCC GPG default value)

$\Delta C_{LCmineral}$ = change in the carbon stock in mineral soils in forestland converted to cropland

C/N = ratio by mass of C to N in the soil organic matter = 11 (national value for forestland) and 9 (national value for Grassland and Cropland category)

### 6.13.3. Category-specific recalculations

There was no recalculation in $N_2O$ emission estimation since NIR 2018. However, in NIR 2018 submission a mistake occurs when entering $N_2O$ data into the CRF database. This was corrected for this year submission. In NIR 2019 the same values for C/N ratios were used as in NIR 2018. In this report the mistakes in reporting about the used C/N ratios were corrected.

## 6.14. Indirect $N_2O$ emissions from managed soils (CRF category 4. IV)

There are indirect $N_2O$ emissions associated with the loss of soil organic matter resulting from a change in land use or management of mineral soils from leaching and run-offs in the Croatian context, and that those emissions are reported under the Agriculture sector, consistently with the notation keys that were used in CRF table 4 (IV).

## 6.15. Biomass burning (CRF category 4.V)

### 6.15.1. Description

Detailed analyses conducted within the LULUCF 1 project for the purposes of determining the areas affected by fires in the period 1990-2014 years included categories of forest land, grassland and cropland. Analyses comprehended data and information primarily available in the Register on forest fires. This register was established in 2009 pursuant to the *Forest Act*[52] and at that time relevant Ordinance[53]. It contains all data and information on fires that occurred in forests or land under the forest management after year 1990. Additionally, it contains data and information on fires occurred on agricultural types of land (cropland and grassland) when fires are connected with forests and/or lands under the forest management. It is estimated that more than 50% of all fires on agricultural types of land are connected with forests or land under the forest management. Although data and information available in this register concerning fires on agricultural types of land cannot be consider complete, at the moment, the Register is consider to be most reliable source of data and information about fires on agricultural lands in Croatia.

[52] Forest Act (OG 140/05), Article 40.

[53] *Ordinance on the method of data collection, conducting the Register and requirements for using data on forest fires* (OG 126/06).

This Register is currently running based on new legislative act[54] that prescribes methodology for data collection and its recording.

All data and information concerning areas affected by fires are presented as one of outcomes of LULUCF 1 project in a separate document[55].

Based on the conducted analyses it was determined that Cropland areas were not affected by fires in the period 1990-2014. Cropland areas were affected by fires in 2015 and the estimation of emissions for this category were performed for the first time in NIR 2017.

The analyses of forest land category were conducted on all types of forests (including maquies and shrub forests) regardless the ownership type. Also, by this work all areas that were converted to/from forest land and areas in which natural spreading of forests were recorded in period 1990-2014 were covered. According to the available data and information during the period 1990-2014 fires did not occur in state forests that are managed by other legal bodies. Data and information presented in this report concerning fire emissions refer to state owned forests managed by Croatian forests Ltd and private forests.

Emissions are reported in CRF tables under corresponding categories of land.

For future work on Croatian LULUCF and KP reporting update of the Register has been recognized as relevant within the LULUCF 1 project. It has been recommended this to be performed through a separate project[56]. The completeness of the Registry and its upgrade in a way that fully MESDts requirements of LULUCF and KP reporting, as well as reporting to other international and national institutions, has been envisaged as a long term objective for Croatian reporting.

### 6.15.2. Methodological issues

Data available in the Registry on forest fires can be described concerning two time periods and depending on the methods used for data collection. The first period covers time frame from 1990 to November 2006. The second period describes time from November 2006 to 2012, when the Registry was officially established based on the *Forest Act* [57]and *Ordinance*[58] provisions. In the first period, the methods of collecting data on forest fires were not legally prescribed, and Croatian forests Ltd. had been recording data and information on fires in analog paper forms as part of its internal procedures. These forms contained a variety of information (e.g. information about fire location, type of vegetations affected by fires, causes of fires, type of fires, types of intervention, participants in firefighting, burnt volume, etc.). In 2001 the internal database on forest fires was established in digital form in Croatian forests Ltd. This secured that data on fires are kept in paper and digital forms in the period from 2001 to 2008.

Recording the forest fires on maps has not been requested by national legislation so far. However, in many occasions sketches of areas affected by fires were kept. By 2005, the majority of the sketches were drawn up by hand on a topographic map presenting forest divisions into compartments and sub-compartments at scale of 1: 25,000. After 2005, the mapping of areas affected by fires has been done using also global positioning system (GPS) on the fields (Figure 6.15-1, and Figure 6.15-2).

Although it has not been officially prescribed yet, mapping of areas affected by fires (using GPS as one of possible tools for recording purposes) since 2009 makes a part of good practice in forest management in Croatia (Figure 6.15-3). This work enabled development of the map with detailed spatial information on forest fires (Figure 6.15-4).

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[54] *Ordinance on the method of data collection, conducting the Register and requirements for using data on forest fires* (OG 175/13).

[55] Janeš,D.,G.Kovač,V.Grgesina,D.Pleskalt (2014): Identifying areas affected by fires according to requirements of Article 3.3 and 3.4 of the Kyoto protocol.

[56] Ibid.

[57] Ibid.

[58] Ibid.

Figure 6.15-1: Map of areas affected by fires in 2006 (Forest district Split, Forest Office Zadar, Management unit Mustapstan (state owned forests marked in green (40.0 ha), private owned forests marked in red (10.0 ha))

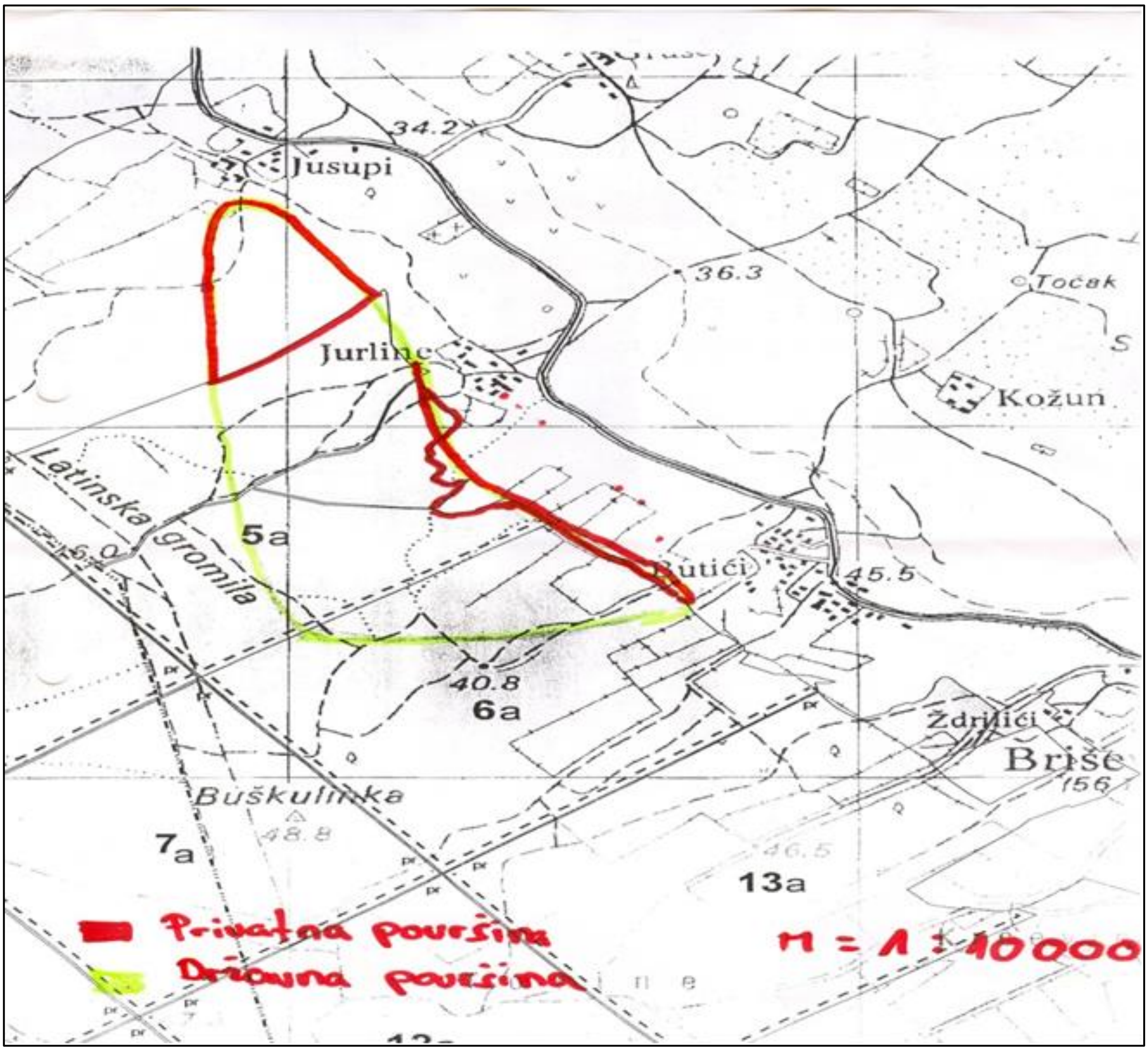


Figure 6.15-2: Map of state-owned forests affected by fires in 2007 defined using GPS (Forest district Split, Forest Office Metković, Management unit Šibovnica; total affected area 77.10 ha)

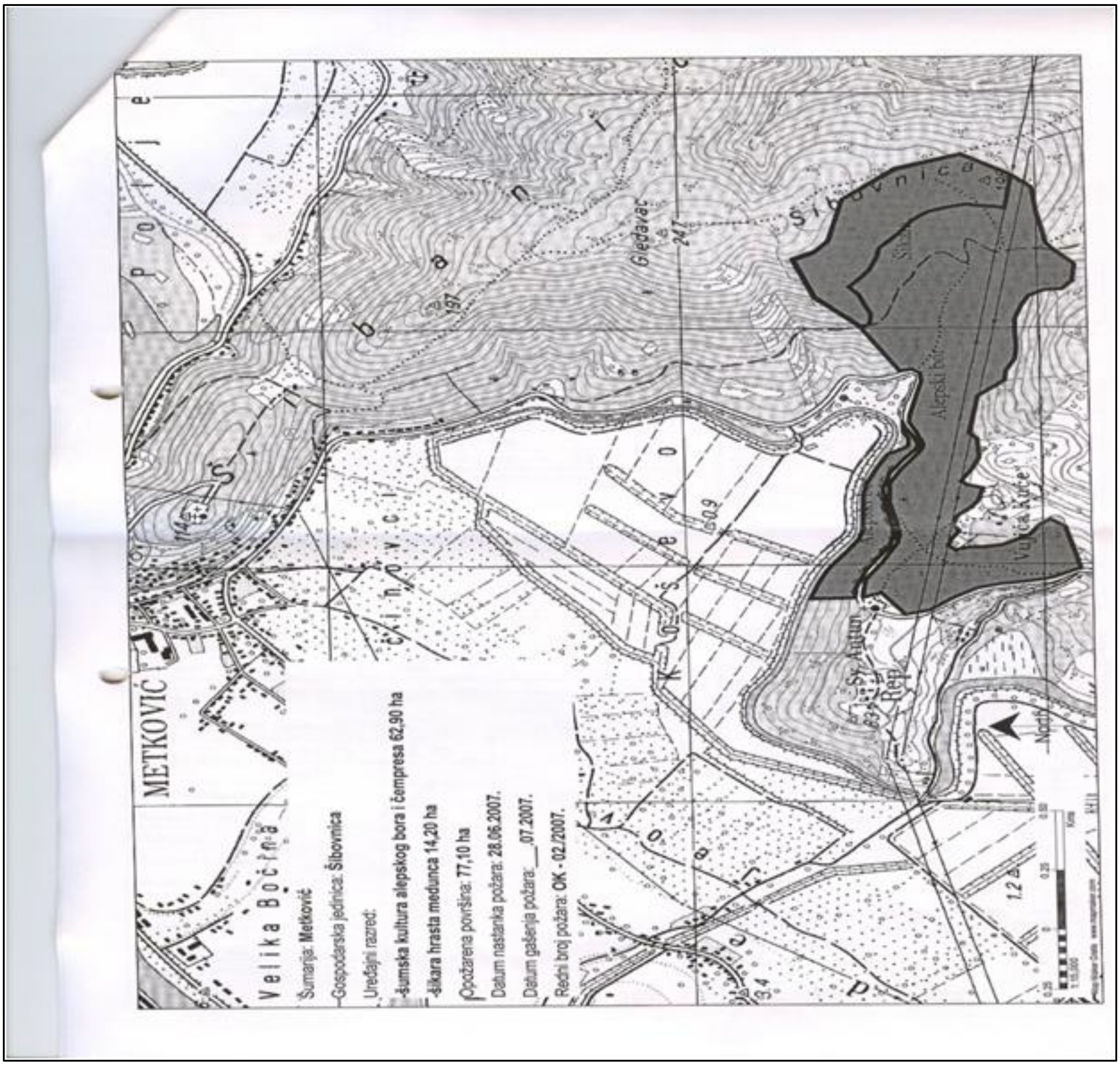


Figure 6.15-3: Map from unified GIS database on forest fires, Forest district Split, Forest Office Split, Management unit Mosor-Perun (state owned forests affected by fires (marked in pink) in 2006 and 2007; total affected area 18.43 ha)

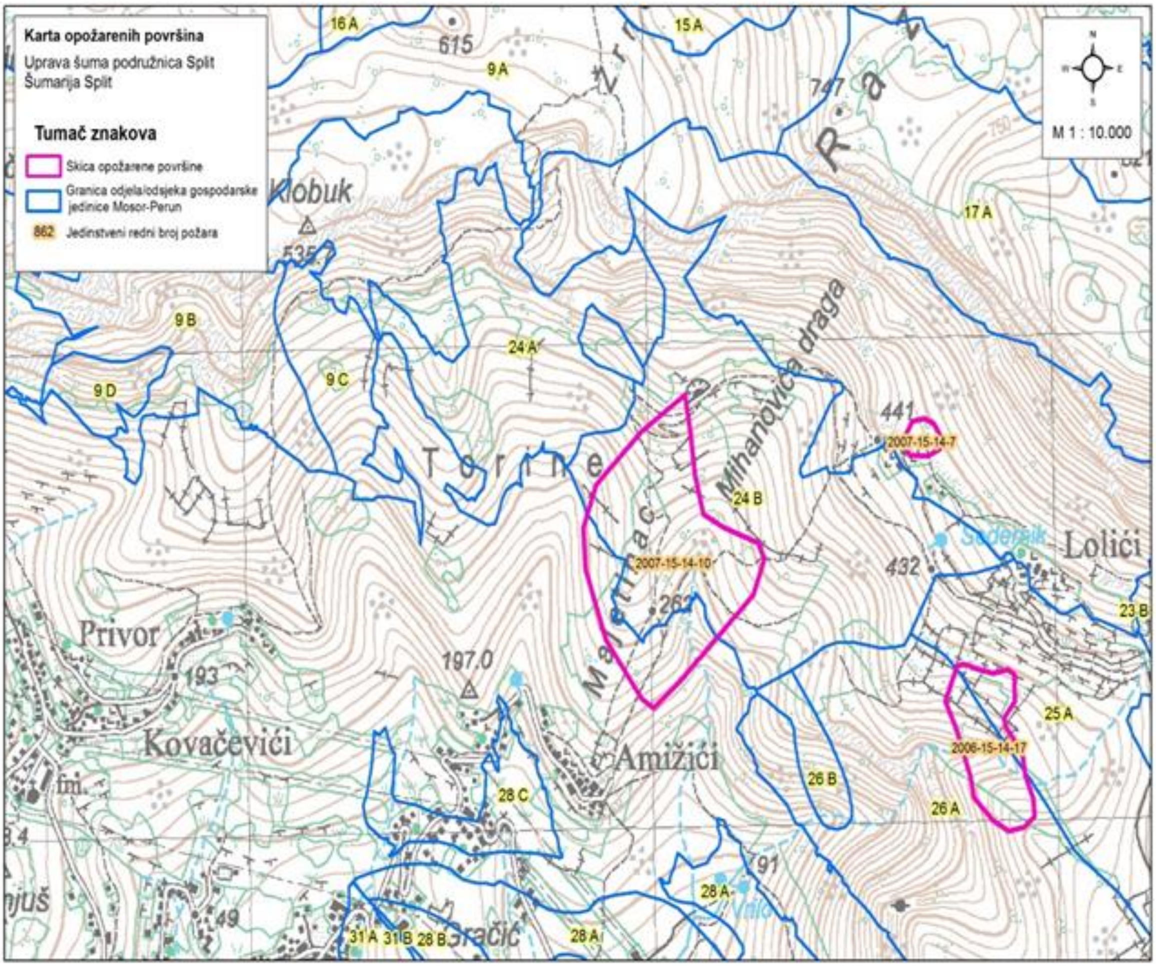
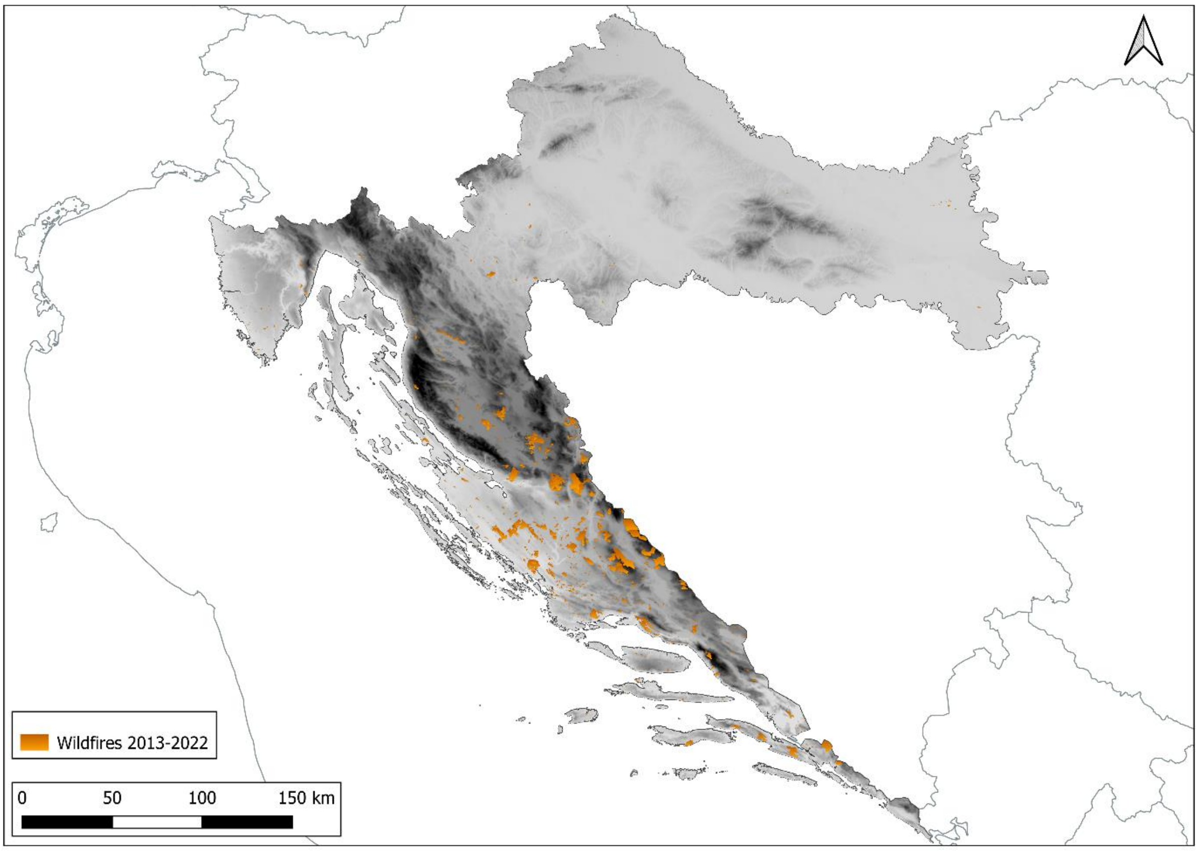


Figure 6.15-4: Spatial distribution of forest fires in Croatia for period 2013-2022




In order to secure reporting on emissions due to forest fires separately for categories Forest land remaining Forest land and Land converted to/from Forest land, each record on each single forest fire in Register in period 1990-2013 were checked. All data and information in Register were then compared with data, maps and information available in corresponding Forest management plans in order to determine whether the affected forest areas were recoded as forest or land under the forest management (in Croatian circumstances this corresponds to Grassland category comparing to IPCC definitions). If the corresponding forest management plan was developed after 1990, additional checking was done by using forest management plan that was valid in period before 1990.

In case of emissions from fires in areas that are subject of conversion from Forest land to other categories of land, Croatia used notation key NO in CRF tables. In Croatia only conversion from Forest land to Settlement and Cropland category occurs. Based on the data available in the Register, Cropland areas were affected by fires only in year 2015 during the whole reporting period. Additionally, since conversion from Forest land to Settlements in Croatia happens in general for infrastructure purposes, there are no GHG emissions due to biomass burning on these lands.

The controlled burning of managed forest is not carried out in Croatia.

The GHG emissions due to forest fires are reported in categories: Forest land remaining Forest land and Grassland converted to Forest land using equation 2.27, Tier 1 method and default values prescribed in 2006 IPCC Guidelines. In case of Forest land remaining Forest land and Land converted to Forest land, a mean value of 19.8 t/ha biomass consumption was applied (B x C) and emission factor (D) prescribed in table 2.5 for category *Extra tropical forests* as this category includes all other forest types as follows: $CO_2$ (1569), $CH_4$ (4.7) and $N_2O$ (0.26). Data on areas of forest fires are the only nationally estimated values for this estimation.

When estimating emissions in category *Annual cropland remaining annual cropland*, assumption was used that the values applicable to Grassland category are valid since the Guidelines do not provide factors for annual cropland (except for residues). In this case $CH_4$ and $N_2O$ emissions are reported in CRF tables while $CO_2$ emissions are substituted by the biomass regrowth. When estimating emissions due to the fires in perennial Cropland remaining perennial Cropland category of land, the same factors as for Forest land category are used because no separate factors are prescribed for perennial cropland by Guidelines.

When estimating emissions in category *Grassland remaining grassland*, value from Table 2.4 Savanna Grasslands (mid/late dry season burns) was used for biomass consumption, and emission factors of 1,640 ($CO_2$), 2.4 ($CH_4$) and 0.2 ($N_2O$).

Estimates of non-$CO_2$ greenhouse gas emissions (CO, $NO_x$ and NMHC) released in wildfires were estimated also according to Tier 1, equation 2.27, IPCC GPG 2006 using corresponding factors for biomass consumption and emission factors from Tables 2.4, 2.5, 2.6.

$L_{fire}$ (tGHG) = A x $M_B$ x $C_f$ x $G_{ef}$ x $10^{-3}$

where:

A = area burnt (ha)

$M_B$ = mass of fuel available for combustion (tonnes $ha^{-1}$)

$C_f$ = combustion factor, dimensionless

$G_{ef}$ = emission factor (g $kg^{-1}$ dry matter burnt)

In the category *Forest land remaining Forest land*, the amount of $CO_2$ emissions ranged between 2.45 and 1160.75 kt $CO_2$ equivalents, $CH_4$ emissions ranged between 0.21 and 97.36 kt $CO_2$ equivalent while $N_2O$ emissions ranged from 0.11 to 50.97 kt $CO_2$ equivalent in the reporting period 1990-2022. Emissions of these gases are significantly lower in category *Land converted to Forest land*.

As informed by Croatia, volume cut on areas affected by forest fires has to be separately recorded as so-called random yield and it refers also to the partially burnt and harvested wood. It makes a part of total yield in a specific year that is registered in Croatia. So, the total harvest felling and the biomass losses also include volume of the partially burnt biomass. The estimation of emissions due to the biomass burning has been performed using the Tier 1 methodology and the default values for mass available for combustion and combustion factor (MB*Cf) from the 2006 GL (Table 2.4). The area of forest fires is the only nationally determined value used for this estimation.

For this year reporting also the $CO_2$ emissions are estimated for the complete areas (instead of previously 60% of areas) that were subject of forest fires in period 1990-2022 following the ERT's request in 2020.

In addition, for this year reporting Croatia estimated emissions due to the controlled biomass burning that took place on 6.7 ha of Grassland category. The same methology and factores as for uncontrolled fires on Grassland areas were applied. This activity is undertaken under the project „*Dinara back to Life*“ (https://dinarabacktolife.eu/en/) financed through EU LIFE Programme. In the framework of this project, grassland restoration activities are being conducted. Project, amongst other, includes restoration of endangered grasslands that are habitats of rare and threatened bird species in Croatia. These grassland habitats are under threat due to the depopulation of rural areas that results with land abandonment and disappearance of traditional land management practices. All these processes lead to the vegetation succession and shrub encroachment.

One of the project's restoration activities that was piloted in 2021 is controlled/prescribed burning. This method includes prescribed burning of selected, targeted area under appropriate conditions. It is implemented in the cold part of the year, when only surface layer is being burnt, without damaging the deeper soil layers.

### 6.15.3. Uncertainties and time-series consistency

When performing uncertainty analyses in LULUCF sector, values presented in Table 6.15-1 were used in case of forest fires. Regarding forest fire emissions, the calculations of $N_2O$, $CH_4$ and $CO_2$ emissions, the values are presented in the Annex II.

Table 6.15-1: Uncertainties of the emission factors and the activity data and sources of information from emissions from forest fires

| Inputs | Uncertainty (%) | Source of information |
|---|---|---|
| Area destroyed by fire (A) | 30% | Default, IPCC 2006 |
| Quantity of wood burnt down*Burning efficiency (B*C) | 75% | Default, IPCC 2006 |
| Emission factor for $CO_2$ (D) | 75% | Default, IPCC 2006 |
| Emission factor for $CH_4$ (D) | 75% | Default, IPCC 2006 |
| Emission factor for $N_2O$ (D) | 75% | Default, IPCC 2006 |

### 6.15.4. Category-specific QA/QC and verification

Emission estimation due to fires are included in overall QA/QC system in LULUCF sector.

### 6.15.5. Category-specific recalculations

Correction of the reported $N_2O$ emissions for 2018 has been corrected.

### 6.15.6. Category-specific planned improvements

At this moment no new projects have been predicted for the emission estimation due to the forest fires.

# Chapter 7: Waste (CRF sector 5)

## 7.1. Overview of sector

Waste management activities, such as disposal and biological treatment of solid waste, incineration of waste and wastewater treatment and discharge, can produce emissions of GHG including methane ($CH_4$), carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$).

$CH_4$ and $N_2O$ emissions as a result of disposal and biological treatment of solid waste, $CO_2$ and $N_2O$ emissions resulting from incineration of waste (without energy recovery), $CH_4$ and $N_2O$ emissions from treatment of domestic and industrial wastewater are included in emissions estimates in this sector.

The methodology used to estimate emissions from waste management activities requires country-specific knowledge on waste generation, composition and management practice.

With the aim of collecting all the necessary data for the emission calculation and improving reporting on greenhouse gas emissions from the Waste sector (CRF 5), categories Solid waste disposal (CRF 5.A), Biological waste treatment (CRF 5.B) and Waste incineration and open burning of waste (CRF 5.C), the Ministry of Economy and Sustainable Development (MESD) launched the project **System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950** (hereinafter: Project)[59], whose specific goals are:

- determination of historical data from 1950 to 1990 and insufficient data for the period from 1990 onwards for municipal waste, industrial waste and sludge from wastewater treatment plants;
- classification of landfills in accordance with the IPCC classification;
- determination of methane correction factor;
- uncertainty assessment of the GHG emissions calculation;
- improvement of the quality assurance and quality control system for the purposes of reporting on GHG emissions.

An effort was made to evaluate and compile data coming from different sources and adjust them to the recommended IPCC methodology which used for $CH_4$ emission estimation. The aim of the project is improving the transparency, accuracy, completeness, comparability and consistency of GHG inventory from the Waste sector, in accordance with the recommendations/requirements of ERT.

The Project was organized into eight project activities that resulted with eight elaborates:

- Elaborate 1 Collection, analysis and determination of data on the composition of municipal waste, generation and management of municipal waste and biodegradable municipal waste, 2022
- Elaborate 2 Collection, analysis and determination of data on the generation and management of industrial waste, 2022
- Elaborate 3 Collection, analysis and determination of data on the generation and management of sludge from wastewater treatment plants, 2022
- Elaborate 4 Classification of landfills according to the IPCC classification, 2023
- Elaborate 5 Determination of Methane Correction Factor, 2023

[59] Usluga unaprjeđenja sustava i izrada podloga sa povijesnim podacima za izračun i izvješćivanje o emisijama stakleničkih plinova iz sektora Otpad uključujući podatke za povijesni niz od 1950., in Croatian (System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950), Client: Ministry of Economy and Sustainable Development, Executor: Bidders Association - EKONERG d.o.o., IPZ Uniprojekt TERRA d.o.o., 2022 – 2023

- Elaborate 6 Application of the IPCC model and comparison analysis with the previous results of the estimation, 2023
- Elaborate 7 Uncertainty assessment of the GHG emissions estimation for the Waste sector (categories 5.A, 5.B and 5.C), 2023
- Elaborate 8 Improvement of the quality assurance and quality control system for reporting on GHG emissions from the Waste sector (categories 5.A, 5.B and 5.C), 2023

**The Project defined data for the period 1950 - 2021. Data for 2022 were collected by the Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste.**

Implementation and establishment of the integral waste management system in Croatia are ensured by applying and fulfilling the objectives defined by the Waste Management Act[60] and Waste Management Plan[61]. The main act regulating waste management issues in the Republic of Croatia is the Waste Management Act. There are a number of ordinances that have been adopted according to Waste Management Act, some of them regulating certain waste management operations, some regulating management of specific waste types. Waste Framework Directive[62] is transposed in the area of waste management into the Croatian legislation by the Waste Management Act.

The following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal. Avoiding and reducing waste generation has the highest priority and results in a reduction of quantity and adversity of produced waste which enters into the next phase. Reuse/recovery of produced waste has the purpose to use material and energy potentials of waste, in the framework of technical, ecological and economic possibilities. Disposal of remaining inert waste at the managed controlled landfills has the lowest rank in the waste management hierarchy. According to the Waste Management Plan, the backbone of the system will be recycling centres with sorting of waste. Waste management system in Croatia will be organized as an integral unit of all subjects at the national, regional and local level.

Article 54 of the Waste Management Act defines specific waste types as well as procedures and objectives for the management of these waste. One of these is the construction and demolition waste. Ordinance on construction waste and asbestos-containing waste[63] stipulates the objectives of construction waste management and the manner of handling with this waste. Special attention in Ordinance is given to measures related to waste prevention, separation at construction site and re-use. A certain part of construction and demolition waste that could be deposited at landfills in the framework of industrial waste, pursuant to the Act and Ordinance should be deposited of according to procedures and practices as well as municipal waste. General conditions for landfilling are prescribed in Ordinance on the waste landfills[64] and Directive on the landfill of waste[65]. On July 4, 2018, the new EU rules came into force, with legally binding targets for waste recycling and reduction of waste disposal with fixed deadlines for Member States, within two years, to align their waste management regulation with new Directives.

Regarding ERT recommendation to provide information in the NIR on the systems and amounts of plastic waste disposed of and/or incinerated for the entire time series, including information on plastic waste that is not collected and recycled and total AD for plastic waste that is generated in the country

[60] Waste Management Act (OG 84/2021, 142/2023)
[61] Decision on the adoption of theWaste Management Plan of the Republic of Croatia for the period 2023 - 2028 (OG 84/2023)
[62] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
[63] Ordinance on construction waste and asbestos-containing waste (OG 69/2016)
[64] Ordinance on the waste landfills (OG 4/2023)
[65] Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

(W.12, 2022) (W.6, 2020) (W.11, 2018)[66], a brief overview of plastic waste management system in Croatia is provided here. A detailed overview is presented in Elaborate 2, Annex 1.

Data on plastic waste management are available in the following data sources: (1) Environmental Pollution Register (EPR), (2) Reports on packaging and packaging waste, (3) Reports on cross-border traffic of waste, (4) Reports on the state of the environment in the Republic of Croatia, (5) statistics of the Croatian Bureau of Statistics (CBS) and (6) professional and other literature.

(1) Environmental Pollution Register includes data on plastic waste generated from 2007 onwards (industrial waste) and from 2006 onwards (municipal waste). Waste, by EWC code, group 15 01 02 (plastic packaging) makes up the largest part of plastic waste. There was a significant increase in separately collected waste 15 01 02 (plastic packaging) in the system of separate collection of municipal waste since 2012, and the mass of separately collected waste 20 01 39 (plastic) is also increasing. Since 2019, there has been a noticeable increase in the mass of waste 19 12 04 (plastic and rubber), which is generated by mechanical processing of waste (e.g. from sorting, crushing, compaction, pelletizing) (Elaborate 2, Annex 1, Table P.1-2). Data on the plastic waste management that was separately collected in the municipal waste management system in the period after 2006 show that the majority of separately collected plastic waste is sent for recovery (Elaborate 2, Annex 1, Table P.1-3). Data on the used and disposed of plastic waste that the recyclers and disposers submitted to the EPR in the period after 2014 show that for most of the waste plastic, recovery was reported using the process with Recovery Code R3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes) and by the process R12 Exchange of wastes for submission to any of the operations numbered R1 - R11 (Elaborate 2, Annex 1, Table P.1-4).

(2) Reports on packaging and packaging waste: Packaging waste is classified in group 15 01 regardless of the activity in which it was generated. The establishment of the legal framework for the packaging and packaging waste management system in the Republic of Croatia began in 2005 with the adoption of the Ordinance on packaging and packaging waste[67]. The system is organized based on extended producer responsibility, which began to be applied in January 2006. The packaging waste management system is managed by the Environment Protection and Energy Efficiency Fund (EPEEF). EPEEF data represent official data for calculating recovery and recycling rates of packaging waste. The data of EPEEF are processed and published in Reports on packaging and packaging waste. The data in Elaborate 2, Annex1, Table P.1-5 – Table P.1-7, show the continuous growth of plastic packaging (polymers) that was put on the market in the Republic of Croatia in the period after 2006. The largest part of waste 15 01 02 (plastic packaging) collected in the EPEEF system is recovered - recycling (material recovery). Furthermore, a significant part of packaging waste is collected and recovered outside the EPEEF system.

3) Reports on cross-border traffic of waste: Cross-border traffic of waste in the Republic of Croatia has been systematically monitored since 2004. The import of waste subject to the notification procedure into the Republic of Croatia was completely prohibited until it became a full member of the European Union in 2013. Reports on cross-border transport of waste in the period up to 2013 contain data on the export of hazardous and non-hazardous waste and the import of non-hazardous waste. Reports on cross-border traffic of waste from 2014 onwards contain data on the export and import of waste subject to the notification procedure, the transit of waste subject to the notification procedure, and the export and import of waste that is not subject to the notification procedure. Reports on the cross-border movement of waste up to and including 2014 were prepared based on data from annual reports on the realized import or export of non-hazardous waste and data collected directly from importers/exporters of waste, while further reports on cross-border movement of waste were prepared based on data from the annual

[66] FCCC/ARR/2022/HRV Report on the individual review of the annual submission of Croatia submitted in 2022, 15 March 2023

[67] Ordinance on packaging and packaging waste (OG 97/05, 115/05, 81/08, 31/09, 156/09, 38/10, 10/11, 81/11, 126/11, 38/13, 86/13) and after it the Ordinance on packaging and waste packaging (OG 88/15, 78/16, 116/17, 14/20, 144/20)

reports of importers/exporters of waste. In the period from 2004 onwards, data on imported and exported plastic waste show a significant increase (Elaborate 2, Annex 1, Table P.1-8 and Table P.1-9).

(4) Reports on the State of the Environment of the Republic of Croatia: The first complete Report on the State of the Environment in the Republic of Croatia was prepared in 1998, which was followed by reports for the periods: 1997 - 2005, 2005 - 2008, 2009 - 2012 and 2013 - 2016. In the Report from 1998, it was stated that in 1995 a total of 13,307 tons of secondary raw materials were collected from municipal waste, of which 2 tons were plastic. Packaging from industrial facilities (metal, wood, paper, polymer...), selectively collected through collectors of secondary raw materials or through direct business relations between the owner of the packaging and the processor of secondary raw materials, is returned for processing. Household packaging, which makes up more than 50% of municipal waste (paper, plastic, glass...) is disposed of at municipal waste disposal sites. The reasons for this were the method of collecting municipal waste and the high costs of organization and implementation of separate collection of different types of packaging that would enable its recovery. For industrial waste, it is stated that 12 Wastes from shaping and physical and mechanical surface treatment of metals and plastics is partially taken over by collectors of secondary raw materials. In the Report from 2007 (for the period 1997 - 2005), it was stated that there was no accurate data on the amount of generated packaging waste, which was estimated according to the amount of packaging placed on the market in the previous year. The amount of packaging waste was increasing, especially the share of plastic packaging waste was growing rapidly. A certain amount of packaging waste was processed in the territory of the Republic of Croatia, although it could be much more, considering the installed capacities of processing companies. Regarding the separate collection of municipal waste components, it was estimated that approximately 27,000 tons of waste were collected separately in 2004, of which approximately 48% was paper, 42% was glass, and approximately 10% was other types of waste. In the Report for the period 2005 - 2008, it was pointed out that the amount of separately collected types from municipal waste has increased significantly, from 27,000 t in 2004 to 247,252 t reported in 2008. The share of plastic was 1%. The mass of packaging waste from polymer materials (plastic packaging) collected in the EPEEF system was listed in the Report for the period 2009 - 2012 (data show the continuous growth of plastic packaging, which is specified in the Elaborate 2, Annex 1, Table P.1-5). In the Report for the period 2013 - 2016, further progress in separate collection of individual components of municipal waste was highlighted.

(5) Statistics of the Croatian Bureau of Statistics (CBS): The first available data on waste in statistical yearbooks refer to waste generated in selected activities in 1993: Industry and mining, Agriculture, Construction and Health care, in which 7,053 t of waste plastic materials and rubber waste were generated. Research on waste was carried out every three years. In 1996, data was collected for the following activities: Agriculture, Mining, Manufacturing, Electricity, gas and water supply, Construction and Health care. There was no information on plastic waste in published data. The three-year Report on the production and recovery of waste (OTP-1) collected data on waste - as of December 31, 1999, the amounts of waste were shown: plastic packaging (3,960 t), small plastics (3,824 t) and other plastics (7,324 t) from the following activities: Waste from recycling, Waste from water collection, purification and distribution, Waste from retail large amount of residues and waste, Waste from transport, storage and connections, Waste from public administration and defence and Waste from wastewater removal, garbage collection, etc. Plastic waste was delivered to recovery - including recycling (2,236 t), incineration without energy utilization (12 t), waste disposal sites (12,800 t) and abroad (60 t). Data on waste in the period 2000 - 2003 were collected through the Reports on Incineration, Composting and Disposal of Waste (OTP-SKO). For the year 2002: plastic packaging (3,265 t), small plastics (2,233 t) and other plastics (20,229 t). Data on waste for the period 2004 - 2010 were collected through the Annual Reports on Waste - (OTP). Since 2011, the CBS has been taking data on waste from the EPR. Published data for plastic waste refer to waste plastic in municipal waste: 15 01 02 (plastic packaging) and KB 20 01 39 (plastic) (Elaborate 2, Annex 1, Table P.1-2 and Table P.1-3).

(6) Professional and other literature: In Mužinić (1998)[68], the outputs of the implementation of primary recycling in the city of Zagreb in the period 1990 - 1997 are given: 1.7 t of PET packaging was collected in 1995, and 81.3 t in 1997. In 1996, in addition to PET packaging, about 13.7% by mass of other plastic packaging was collected. This percentage was increased in 1998 to 26% by mass.

In Šercer and Opsenica (1998)[69], the analysis of the morphological composition of household waste carried out in 1997 in pilot communal units in the City of Zagreb was performed, with analysis of the share of certain types of plastic in household waste (Elaborate 2, Annex 1, Table P.1-9).

In Mužinić, Radović and Milanović (2000)[70], the composition of household waste in the City of Zagreb in 1992 was analysed, the share of plastic was 6%. An overview of the results of the implementation of primary recycling in the City of Zagreb in the period 1995 - 1999 was provided, data on the collected PET packaging in the primary recycling system was highlighted (Elaborate 2, Annex 1, Table P.1-10).

In Fundurulja, Mužinić and Tonković (2000)[71], the composition of municipal waste for certain areas of the Republic of Croatia was analysed by sorting municipal waste in the City of Split (1998), the City of Bjelovar for the urban and rural part (1999) and the City of Velika Gorica (four seasons in 1999/2000). In cities with more than 100,000 inhabitants, the assumed share of plastic was 11%, in cities with less than 100,000 inhabitants 8%, and in other rural settlements 18%.

In Domanovac and Orašanin (2002)[72], the composition of municipal waste in the continental and coastal parts of the Republic of Croatia was analysed by sorting representative samples from urban and rural areas. Analyses were conducted in different seasons in the period 1992 - 2000, with most analyses performed since 1997. Regarding results, plastic constitutes 11.6% by mass of municipal waste in the continental part and 12.3% by mass in the coastal part of the Republic of Croatia. These data were used as official data in the Waste Management Plan in the Republic of Croatia for the period 2007 - 2015 (OG 85/07, 126/10, 31/11) where the average proportion of plastic in municipal waste was additionally analysed, 12% by mass.

The Methodology for analysing the composition of solid waste[73] assessed the composition of mixed municipal waste and the composition of municipal waste. It was estimated that the share of plastic in mixed municipal waste is 22.87%, and in municipal waste 19.45%.

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[68] Mužinić, Mladen: Provođenje primarne reciklaže u Zagrebu i očekivani razvoj do 2000. godine, V. Međunarodni simpozij gospodarenje otpadom Zagreb '98, Zbornik radova (1998), str. 57-73, in Croatian (Implementation of primary recycling in the City of Zagreb and expected development until the year 2000, 5th International Symposium on Waste Management Zagreb '98, Proceedings (1998), p. 57-73)

[69] Šercer, Mladen i Opsenica, Dane: Plastika u kućnom otpadu Grada Zagreba, V. Međunarodni simpozij gospodarenje otpadom Zagreb '98, Zbornik radova (1998), str. 99-108, in Croatian (Plastics in the household waste of the City of Zagreb, 5th International Waste Management Symposium Zagreb '98, Proceedings (1998), p. 99-108)

[70] Mužinić, Mladen, Radović, Sanja i Milanović Zlatko: Provođenje primarne reciklaže u Zagrebu i očekivani razvoj u narednom razdoblju, VI. Međunarodni simpozij gospodarenje otpadom Zagreb 2000, Zbornik radova (2000), str. 85-103, in Croatian (Implementation of primary recycling in the City of Zagreb and expected development in the coming period, 6th International Symposium on Waste Management Zagreb 2000, Proceedings (2000), p. 85-103)

[71] Fundurulja, Danko, Mužinić, Mladen i Tonković, Vladimir: Procjena postojećeg stanja u zbrinjavanju komunalnog otpada u Republici Hrvatskoj, VI. Međunarodni simpozij gospodarenje otpadom Zagreb 2000, Zbornik radova (2000), str. 29-38, in Croatian (Assessment of the current state of municipal waste disposal in the Republic of Croatia, 6th International Symposium on Waste Management Zagreb 2000, Proceedings (2000), p. 29-38)

[72] Domanovac, Tomislav i Orašanin, Radenko: Sastav komunalnog otpada kontinentalnog i priobalnog dijela Republike Hrvatske, VII. Međunarodni simpozij gospodarenje otpadom Zagreb 2002, Zbornik radova (2002), str. 61-68, in Croatian (The composition of municipal waste in the continental and coastal part of the Republic of Croatia, 7th International Symposium on Waste Management Zagreb 2002, Proceedings (2002), p. 61-68)

[73] Hrvatska agencija za okoliš i prirodu: Metodologija za određivanje sastava i količina komunalnog odnosno miješanog komunalnog otpada s Naputkom za naručivanje i provedbu određivanja prosječnog sastava komunalnog odnosno miješanog komunalnog otpada, 2015., in Croatian (Croatian Agency for the Environment and Nature: The methodology for determining the composition and quantity of mixed municipal waste with the Instructions for ordering and implementation of determining the average composition of mixed municipal waste" in the framework of the project "Creating a uniform methodology for the analysis of the composition of solid waste, determine the average composition of solid waste in the Republic of Croatia and the projection of the amount of solid waste", 2015)

### 7.1.1. Emission trends

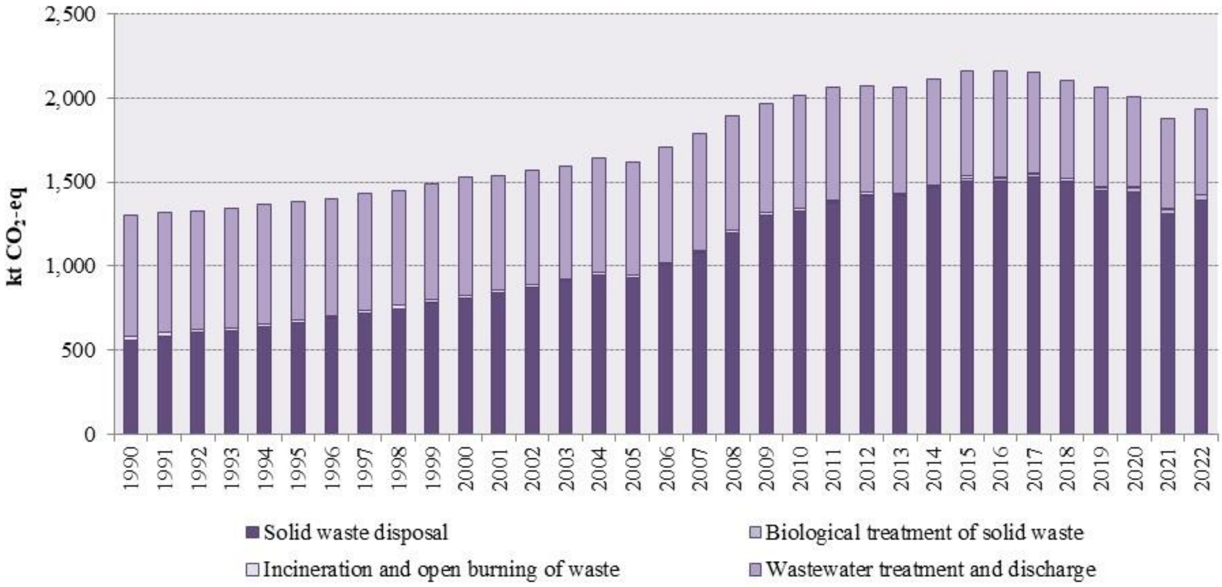
Regulation on the Greenhouse Gases Emissions Monitoring, Policy and Measures for Climate Change Mitigation in the Republic of Croatia[74] prescribes obligation and procedure for emissions monitoring, which comprise estimation and/or reporting of all anthropogenic emissions and removals. According to requirement, sources of GHG should report the required activity data for more accurate emissions estimation.

Comprehensive research in the Project regarding system improvements and the development of historical databases for the calculation and reporting of GHG emissions from categories 5.A, 5.B and 5.C resulted in data and parameters that, along with the data for category 5.D, are included in the IPCC models. The results of the emission calculations show deviation from the results of the previous emission calculations, since the data collected by the Project are more detailed and accurate, based on relevant scientific and professional literature and research. A more detailed interpretation of data deviations from previous data will be presented in the sectoral chapters.

Global warming potential (GWP) values from the IPCC Fifth Assessment Report (AR5) have been used in this submission.

The total annual emissions of GHG from Sector 5 Waste (with related IPCC categories), expressed in kt $CO_2$-eq, in the period 1990 - 2022 are presented in the Figure 7.1-1.

Figure 7.1-1: Emissions of GHGs from Waste sector (1990 - 2022)




In 2022, GHG emissions from Sector 5 Waste amounted to 1,935.29 kt $CO_2$ equivalent, compared to 1,301.50 kt in 1990. These emissions constituted 7.9% of Croatia's total GHG emissions (without LULUCF) in 2022 and 4.1% of total emissions in 1990. GHG emissions from this sector increased during the reporting period. In recent years, the increasing trend is slower compared to the previous period and starts to decrease:

- 71.9% of sectoral emissions refer to the emission from solid waste disposal in 2022, compared to 42.9% in 1990. An increase in generated and deposited of solid waste exists during the reporting period. In recent years, the increasing trend is slower in waste generation, while decreasing trend occurs in waste disposal, compared to the previous period, influenced by the

[74] Regulation on the Greenhouse Gases Emissions Monitoring, Policy and Measures for Climate Change Mitigation in the Republic of Croatia (OG 5/2017)

implementation of the measures undertaken to avoid/reduce and recycle waste, which are still not sufficiently applied;

- 26.3% of sectoral emissions refer to the emission from wastewater treatment and discharge in 2022, compared to 55.2% in 1990. Decrease in emissions during the reporting period mainly is a result of population decrease as well reduction of economic activity after 2008 and a declining fluctuating trend in the industrial production;
- biological treatment of solid waste and incineration and open burning of waste have considerably lower contribution to the sectoral emission during the reporting period.

In the Waste sector, three source categories represent key source categories regardless of LULUCF (detailed in theTable 7.1-1):

Table 7.1-1: Key categories in Waste sector based on the level and trend assessment in 2022[75]

| Table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, 2024) | | | | | | | | |
| IPCC Source Categories | GHG | Key | If Column C is Yes, Criteria for Identification | | | | Com. |
| 5.A Solid Waste Disposal | $CH_4$ | Yes | L1e, L2e | T1e, T2e | L1i, L2i | T1i, T2i | |
| 5.D Wastewater Treatment and Discharge | $CH_4$ | Yes | L1e, L2e | T1e, T2e | L1i, L2i | T1i, T2i | |
| 5.D Wastewater Treatment and Discharge | $N_2O$ | Yes | L2e | T2e | | | |

L1e - Level excluding LULUCF - Tier1 T1e - Trend excluding LULUCF - Tier1
L2e - Level excluding LULUCF - Tier2 T2e - Trend excluding LULUCF - Tier2
L1i - Level including LULUCF - Tier1 T1i - Trend including LULUCF - Tier1
L2i - Level including LULUCF - Tier2 T2i - Trend including LULUCF - Tier2

## 7.2. Solid waste disposal (CRF 5.A)

### 7.2.1. Category description

Generation of municipal solid waste (MSW) per capita has registered significant increasing trend until 2009. Starting with 2009 there is a decrease in quantities registered, caused primarily by the economic crisis but also other factors regarding to effects of measures undertaken to avoid/reduce and recycle waste. Priority is given according to avoiding and reducing waste generation and reducing its hazardous properties. If waste generation can neither be avoided nor reduced, waste must be re-used-recycled and/or recovered; reasonably unusable waste must be permanently deposited of in an environmentally friendly way.

Data on generated and deposited quantities of MSW, industrial waste (IW) and sludge from wastewater treatment were collected within the Project for the period 1950 - 2021,. updated with new data for 2022. Explanation on data sources on MSW, IW and sludge are provided in the section 7.2.2.1.

In 2022, there was 56.0% of MSW, 41.3% of IW and 2.7% of sludge in total waste that was deposited at official landfills. From total MSW deposited in 2022, 63.2% were biodegradable. From total IW deposited in 2022, 3.6% were biodegradable waste, and 3.0% were sludge from wastewater treatment.

The amounts of separately collected fractions from MSW and IW are gradually increasing in recent years. Since 2006, collection schemes have been developed for management of six special waste categories - packaging waste, waste oils, end-of-life vehicles, waste electrical and electronic equipment,

[75] Data on key categories are taken from Annex 1 Key categories (Tier 1 and Tier 2)

waste tires, batteries and accumulators. This resulted in increased quantities of collection and recovery of those waste streams.

In the annual reports, produced by the MESD, validated data on MSW and IW generation (collection by waste code) is available since 2007. The data on deposited MSW, IW and sludge (by waste code) is available since 2010 (Croatian waste catalogue is harmonized with Commission Decision 2000/532/EC, the European List of Waste). Inventory includes emissions related to the disposal of MSW, IW and sludge at solid waste disposal sites (SWDS).

Of the total amount of MSW generated in 2022, 46% (844.387 tonnes) was separately collected fractions. The largest separately collected fractions were paper and cardboard waste (32%), bulky waste (16%) and biowaste (14%), followed by plastic (11%), glass (8%), wood (7%), metal waste (4%), electrical and electronic waste (4%), textile (1%), and other waste (3%). The recovery rate of MSW in 2022 was 34%. Landfill operators report data on each waste type landfilled. Additional information on separate collection and landfilling (by waste code) is available in the 2022 Municipal Waste Report.

There has been no systematic monitoring of the composition of MSW and IW. The report "The methodology for determining the composition and quantity of mixed municipal waste with the Instructions for ordering and implementation of determining the average composition of mixed municipal waste" was done in the framework of the project "Creating a uniform methodology for the analysis of the composition of solid waste, determine the average composition of solid waste in the Republic of Croatia and the projection of the amount of solid waste" (Croatian Agency for the Environment and Nature, 2015) (hereinafter: Methodology for analyzing the composition of solid waste). This report contains data on the estimated composition of mixed municipal waste for 2015.

Apart from a certain amount of waste being separately collected, still, plenty of waste are deposited at SWDS and there is a need to improve pre-treatment of waste prior to disposal of the residual part, in accordance with the waste management hierarchy. The infrastructure currently available for the management of municipal waste and environment protection measures on some landfills are still of inadequate standard. However, efforts are being made to reduce possible adverse effects that landfills can have on environment by laying down stringent technical requirements by adopting the Ordinance on the waste landfills and Ordinance on the waste management[76], which are in line with the European Directive on the landfill of waste.

According to the Waste Management Act, the MESD is responsible for maintaining the Waste Management Information System, which contains numbers of databases, among other Database on Landfills (CSUIO). The database contains comprehensive information on waste management practices, such as information on technical measures (e.g. fence, scale, flares…) or environmental protection measures (e.g. degassing, compacting, aligning, monitoring…). The database also contains data on the status of remediation of landfills (in preparation/ongoing/finished) and status of operation (active/closed). Active MSW landfills are obligated by legislation to deliver this data to the MESD in prescribed form (Form on landfills and landfilling of waste – Form OOO), as for the rest (closed MSW landfills and IW landfills) the data forms are periodically sent to landfill operators by the MESD or the update is done upon receiving the information on individual landfill from other sources. Data on remediation status is requested by the MESD once a year from the EPEEF, which co-financed remediation of almost all official landfills to improve technical standards at landfills, in order to comply with requests of the EU Landfill Directive.

The total numbers of active and closed landfills in which all waste was deposited of by the end of 2022 are presented in the Table 7.2-1, Table 7.2-2 (MSW landfills) and Table 7.2-3 (IW landfills - active).

[76] Ordinance on the Waste Management (OG 106/2022)

Table 7.2-1: The total number of active and closed landfills (total landfilled waste) by the end of 2022

| Number of landfills | Active | Closed | Closed (waste was removed) | Total |
|---|---|---|---|---|
| Managed SWDS | 73 | 80 | 96 | 249 |
| Unmanaged deep | 14 | 23 | 0 | 31 |
| Unmanaged shallow | 1 | 30 | 0 | 37 |
| **Total** | **88** | **133** | **96** | **317** |

Table 7.2-2: The total number of active and closed MSW landfills by the end of 2022

| Number of landfills | Active | Closed | Closed (waste was removed) | Total |
|---|---|---|---|---|
| Managed SWDS | 70 | 78 | 96 | 233 |
| Unmanaged deep | 10 | 21 | 0 | 38 |
| Unmanaged shallow | 0 | 29 | 0 | 34 |
| **Total** | **80** | **128** | **96** | **305** |

Table 7.2-3: The total number of active IW landfills by the end of 2022

| Number of landfills | Active (IW) | Active (biodegradable IW) | Active (sludge) |
|---|---|---|---|
| Managed SWDS | 38 | 14 | 13 |
| Unmanaged deep | 7 | 1 | 3 |
| Unmanaged shallow | 1 | 0 | 1 |
| **Total** | **46** | **15** | **17** |

These tables do not include data for unofficial sites in which the waste is improperly discarded into environment. The tables contain data only on official landfills. Some of the official landfills still operate without all necessary permits (based on the condition at site, each landfill is categorized as managed or unmanaged), but landfilling is agreed with local self-government body. Remediation and improvements of technical standards at such landfills is co-financed by EPEEF.

In 2020, the electronic application Sustav Evidencija lokacija odbačenog otpada, ELOO, in Croatian (Discarded Waste Location Records System) was launched for registering the locations in the territory of the Republic of Croatia where waste is improperly discarded into the environment. An employee of the service responsible for communal arrangement (communal orderly) orders the removal of waste to a person who has improperly stored, left, discarded and/or disposed of waste in the local self-government unit he covers. The ELOO System contains data on locations, estimated quantities and types of waste discarded into environment. Data on locations contaminated with waste are of satisfactory quality, but data on types and quantities are not. Data from the ELOO System are available in Overviews of data from Discarded Waste Location Records System[77]. In addition to 2022, 2021 and 2020 are also covered by the overviews.

Remediation and closure of the existing landfills or their conversion into transfer stations or recycling yards will continue in parallel with the construction of the new waste management centres, complying with the requirements of the Landfill Directive. These activities combined with planned increase of primary separation will further lead to the reduction of deposited biodegradable MSW and IW.

[77] Overview of data from Discarded Waste Location Records System, Ministry of Economy and Sustainable Development, 2022

### 7.2.2. Methodological issues

A method used to calculate $CH_4$ emissions according to the 2006 IPCC Guidelines is First Order Decay (FOD) method. A calculation of $CH_4$ emissions was performed using Tier 2 method and the IPCC FOD model, with a combination of country-specific data and default parameters. The Decision Tree (Figure 3.1 in the 2006 IPCC Guidelines, Volume 5) indicates that the Croatian approach results in a Tier 2 estimate. The Project generated good-quality country-specific activity data on historical and current waste disposal. Croatia doesn't apply a CS-model or use CS-key parameters.

According 2006 IPCC Guidelines, section 3.2.1.1, the IPCC FOD model provides two options for $CH_4$ emission estimation that can be use depending on the level of available data. Until now, Croatia used single-phase model based on bulk waste. The Project defined amounts of components (food, garden, paper, wood, textile, nappies, plastics and other inert waste) of deposited MSW, required for multi-phase model based on waste composition data, which is currently in use.

Croatia included the $CH_4$ emissions for category 5.A Solid waste disposal from MSW, IW and sludge deposited at SWDS for the complete time series. The quantity of deposited MSW, IW and sludge from wastewater treatment is considered from 1950 onwards.

#### 7.2.2.1. Activity data and data sources description

The main data supplier for activity data in Waste sector is the MESD that is collecting and processing waste data, among other the data reported to EPR, Register of permits and certificates for waste management and Waste Management Information System.

By the Ordinance on the Environmental Pollution Register[78] adopted according to the Environment Protection Act[79], the MESD is collecting data on the quantities and types of waste produced, collected, recovered or deposited of. Data on quantities are available for each waste code (based on European LoW - List of Waste) and NACE activity. Data on waste are entered in: a) Form NO (Generation of waste), b) Form SO (Collection of waste), Form OZO (Recovery/disposal of waste).

The MESD collects data on waste and landfills in accordance with the Waste Management Act and the Ordinance on the Waste Management. The person who manages the landfill is obliged to submit data on the mass of biodegradable municipal waste deposited of at the landfill on the prescribed forms twice a year, within 30 days from the end of the semester. These data are needed to monitor the achievement of objectives in accordance with the obligations of the Landfill Directive, which is required to report to the European Commission.

Validation and verification of data is done first by county offices (with appropriate support from the environment protection inspectors), and then by the MESD, which cooperates with the competent offices in counties and companies collecting MSW, IW and sludge, in order to strengthen data quality. Data is checked for completeness, correctness and consistency in time-series. In cases that collected or deposited waste is not reported, quantities are determined on the basis of previous year report or calculation on the basis of average waste production per capita. Quality of MSW data is gradually improving as scales are installed at landfills.

**Activity data included in the IPCC FOD model**

In this section, the outputs of the Project related to activity data on MSW, IW and sludge are presented.

[78] Ordinance on the Environmental Pollution Register (OG 3/2022)
[79] Environment Protection Act (OG 80/2013, 78/2015, 12/2018, 118/2018)

**MSW activity data**

***Population***

According to the known data on population covered by organized MSW collection in the Republic of Croatia in the period 1995 - 2022 (Elaborate 1, Chapter 2.1.1.1., Table 2.1-3, updated with new data for 2022[80]) and estimated data for the missing years (Elaborate 1, Chapter 2.1.1.2., Table 2.1-4), data on population covered by organized MSW collection were determined (Table 7.2-4).

Table 7.2-4: Population covered by organized MSW collection in the period 1950 – 2022

| Year | Population covered by organized MSW collection | Year | Population covered by organized MSW collection |
|---|---|---|---|
| 1950 | 1,477,100 | 1987 | 2,406,840 |
| 1951 | 1,487,416 | 1988 | 2,475,859 |
| 1952 | 1,497,202 | 1989 | 2,543,091 |
| 1953 | 1,506,471 | 1990 | 2,599,938 |
| 1954 | 1,516,022 | 1991 | 2,406,624 |
| 1955 | 1,525,539 | 1992 | 2,359,857 |
| 1956 | 1,535,005 | 1993 | 2,548,139 |
| 1957 | 1,544,136 | 1994 | 2,782,259 |
| 1958 | 1,552,800 | 1995 | 2,661,330 |
| 1959 | 1,561,004 | 1996 | 2,741,265 |
| 1960 | 1,574,641 | 1997 | 2,984,469 |
| 1961 | 1,583,496 | 1998 | 3,144,220 |
| 1962 | 1,590,599 | 1999 | 3,404,395 |
| 1963 | 1,598,240 | 2000 | 3,540,800 |
| 1964 | 1,605,685 | 2001 | 3,502,470 |
| 1965 | 1,614,219 | 2002 | 3,568,471 |
| 1966 | 1,630,454 | 2003 | 3,634,611 |
| 1967 | 1,638,421 | 2004 | 3,701,956 |
| 1968 | 1,648,313 | 2005 | 3,763,325 |
| 1969 | 1,659,946 | 2006 | 3,821,688 |
| 1970 | 1,676,457 | 2007 | 3,879,195 |
| 1971 | 1,690,258 | 2008 | 3,999,406 |
| 1972 | 1,702,423 | 2009 | 4,154,500 |
| 1973 | 1,715,284 | 2010 | 4,115,019 |
| 1974 | 1,729,865 | 2011 | 4,096,555 |
| 1975 | 1,743,296 | 2012 | 4,241,953 |
| 1976 | 1,761,885 | 2013 | 4,166,320 |
| 1977 | 1,775,251 | 2014 | 4,187,528 |
| 1978 | 1,793,339 | 2015 | 4,161,568 |
| 1979 | 1,810,867 | 2016 | 4,136,780 |
| 1980 | 1,827,279 | 2017 | 4,079,161 |
| 1981 | 1,842,529 | 2018 | 4,030,613 |
| 1982 | 1,855,937 | 2019 | 4,016,470 |
| 1983 | 1,879,852 | 2020 | 4,003,156 |
| 1984 | 1,903,153 | 2021 | 3,871,223 |
| 1985 | 2,250,543 | 2022 | 3,836,363 |
| 1986 | 2,316,619 | | |

[80] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Source: 2022 Municipal Waste Report, Ministry of Economy and Sustainable Development, July 2023 (in Croatian), https://www.haop.hr/sites/default/files/uploads/inline-files/OTP_Izvje%C5%A1%C4%87e%20o%20komunalnom%20otpadu%20za%202022.%20godinu_FV.pdf

***Waste generation rate***

The waste generation rate (kg/cap/yr) was estimated based on the total mass of generated MSW and the population covered by organized MSW collection (Elaborate 1, Chapter 2.1.2.3., Table 2.1-9, updated with new data for 2022[81]). Table 7.2-5 shows estimated mass of generated MSW per population covered by organized MSW collection in the period 1950 - 2022.

Table 7.2-5: Waste generation rate (kg/cap/yr) in the period 1950 – 2022

| Year | Waste generation rate (kg/cap/yr) | Year | Waste generation rate (kg/cap/yr) |
|---|---|---|---|
| 1950 | 133 | 1987 | 228 |
| 1951 | 134 | 1988 | 238 |
| 1952 | 136 | 1989 | 249 |
| 1953 | 138 | 1990 | 262 |
| 1954 | 140 | 1991 | 305 |
| 1955 | 142 | 1992 | 334 |
| 1956 | 144 | 1993 | 332 |
| 1957 | 146 | 1994 | 327 |
| 1958 | 148 | 1995 | 368 |
| 1959 | 149 | 1996 | 364 |
| 1960 | 151 | 1997 | 340 |
| 1961 | 154 | 1998 | 339 |
| 1962 | 156 | 1999 | 328 |
| 1963 | 158 | 2000 | 331 |
| 1964 | 160 | 2001 | 344 |
| 1965 | 162 | 2002 | 347 |
| 1966 | 164 | 2003 | 351 |
| 1967 | 166 | 2004 | 354 |
| 1968 | 168 | 2005 | 385 |
| 1969 | 171 | 2006 | 433 |
| 1970 | 173 | 2007 | 443 |
| 1971 | 175 | 2008 | 447 |
| 1972 | 178 | 2009 | 420 |
| 1973 | 180 | 2010 | 396 |
| 1974 | 182 | 2011 | 402 |
| 1975 | 185 | 2012 | 394 |
| 1976 | 187 | 2013 | 413 |
| 1977 | 190 | 2014 | 391 |
| 1978 | 192 | 2015 | 397 |
| 1979 | 195 | 2016 | 406 |
| 1980 | 198 | 2017 | 421 |
| 1981 | 200 | 2018 | 439 |
| 1982 | 203 | 2019 | 451 |
| 1983 | 206 | 2020 | 423 |
| 1984 | 208 | 2021 | 456 |
| 1985 | 211 | 2022 | 481 |
| 1986 | 221 | | |

[81] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Source: 2022 Municipal Waste Report, Ministry of Economy and Sustainable Development, July 2023 (in Croatian), https://www.haop.hr/sites/default/files/uploads/inline-files/OTP_Izvje%C5%A1%C4%87e%20o%20komunalnom%20otpadu%20za%202022.%20godinu_FV.pdf

Calculation of the waste generation rate that needs to be use in the IPCC FOD model is based on the population covered by organized waste collection, which differ from the waste generation rate calculated using the total population.

***Total MSW***

For the period 1950 - 2022, data on generated MSW were calculated by multiplying population covered by organized MSW collection (Table 7.2-4) and waste generation rate (Table 7.2-5). Data on generated MSW (kt) are presented in the Table 7.2-6.

Table 7.2-6: Generated MSW (kt) in the period 1950 – 2022

| Year | Generated MSW (kt) | Year | Generated MSW (kt) |
|---|---|---|---|
| 1950 | 195.903 | 1987 | 549.124 |
| 1951 | 199.911 | 1988 | 590.247 |
| 1952 | 203.919 | 1989 | 634.450 |
| 1953 | 207.926 | 1990 | 681.964 |
| 1954 | 212.044 | 1991 | 733.035 |
| 1955 | 216.230 | 1992 | 787.932 |
| 1956 | 220.483 | 1993 | 846.939 |
| 1957 | 224.762 | 1994 | 910.366 |
| 1958 | 229.047 | 1995 | 978.542 |
| 1959 | 233.338 | 1996 | 996.771 |
| 1960 | 238.526 | 1997 | 1,015.000 |
| 1961 | 243.076 | 1998 | 1,065.007 |
| 1962 | 247.433 | 1999 | 1,117.478 |
| 1963 | 251.948 | 2000 | 1,172.534 |
| 1964 | 256.509 | 2001 | 1,205.633 |
| 1965 | 261.322 | 2002 | 1,239.667 |
| 1966 | 267.482 | 2003 | 1,274.661 |
| 1967 | 272.385 | 2004 | 1,310.643 |
| 1968 | 277.696 | 2005 | 1,449.381 |
| 1969 | 283.398 | 2006 | 1,654.105 |
| 1970 | 290.046 | 2007 | 1,718.697 |
| 1971 | 296.346 | 2008 | 1,788.311 |
| 1972 | 302.473 | 2009 | 1,743.211 |
| 1973 | 308.835 | 2010 | 1,629.915 |
| 1974 | 315.628 | 2011 | 1,645.295 |
| 1975 | 322.334 | 2012 | 1,670.005 |
| 1976 | 330.130 | 2013 | 1,720.758 |
| 1977 | 337.084 | 2014 | 1,637.371 |
| 1978 | 345.075 | 2015 | 1,653.919 |
| 1979 | 353.110 | 2016 | 1,679.765 |
| 1980 | 361.077 | 2017 | 1,716.441 |
| 1981 | 368.962 | 2018 | 1,768.411 |
| 1982 | 376.619 | 2019 | 1,811.617 |
| 1983 | 386.576 | 2020 | 1,692.966 |
| 1984 | 396.604 | 2021 | 1,766.560 |
| 1985 | 475.273 | 2022 | 1,844.382 |
| 1986 | 510.866 | | |

### *% to SWDS*

According to the known data on mass of MSW deposited at SWDS (Elaborate 1, Chapter 2.2.1.1., Table 2.2-9, updated with new data for 2022[82]) and estimated data for the missing years (Elaborate 1, Chapter 2.2.1.2., Table 2.2-24), data for the period 1950 - 2022 were determined, i.e. share of MSW deposited at SWDS (%) and mass of deposited MSW (kt). Until 1985, generated MSW was equal to deposited MSW (Elaborate 1, Chapters 2.1.2.2. and 2.2.1.2.). Data are shown in the Table 7.2-7.

Table 7.2-7: Share of deposited MSW (%) and mass of deposited MSW (kt) in the period 1950 – 2022

| Year | Share of deposited MSW (%) | Mass of deposited MSW (kt) | Year | Share of deposited MSW (%) | Mass of deposited MSW (kt) |
|---|---|---|---|---|---|
| 1950 | 100.00 | 195.904 | 1987 | 92.33 | 506.981 |
| 1951 | 100.00 | 199.911 | 1988 | 87.94 | 519.049 |
| 1952 | 100.00 | 203.919 | 1989 | 84.03 | 533.107 |
| 1953 | 100.00 | 207.926 | 1990 | 79.71 | 543.580 |
| 1954 | 100.00 | 212.044 | 1991 | 72.97 | 534.891 |
| 1955 | 100.00 | 216.230 | 1992 | 67.70 | 533.438 |
| 1956 | 100.00 | 220.483 | 1993 | 65.67 | 556.199 |
| 1957 | 100.00 | 224.762 | 1994 | 67.08 | 610.691 |
| 1958 | 100.00 | 229.047 | 1995 | 65.60 | 641.912 |
| 1959 | 100.00 | 233.338 | 1996 | 66.83 | 666.155 |
| 1960 | 100.00 | 238.526 | 1997 | 69.39 | 704.315 |
| 1961 | 100.00 | 243.076 | 1998 | 70.19 | 747.578 |
| 1962 | 100.00 | 247.433 | 1999 | 66.69 | 745.242 |
| 1963 | 100.00 | 251.948 | 2000 | 67.41 | 790.462 |
| 1964 | 100.00 | 256.509 | 2001 | 69.59 | 839.022 |
| 1965 | 100.00 | 261.322 | 2002 | 71.95 | 891.953 |
| 1966 | 100.00 | 267.482 | 2003 | 74.52 | 949.818 |
| 1967 | 100.00 | 272.385 | 2004 | 77.31 | 1,013.271 |
| 1968 | 100.00 | 277.696 | 2005 | 74.73 | 1,083.080 |
| 1969 | 100.00 | 283.398 | 2006 | 80.71 | 1,335.003 |
| 1970 | 100.00 | 290.046 | 2007 | 94.26 | 1,620.000 |
| 1971 | 100.00 | 296.346 | 2008 | 96.78 | 1,730.671 |
| 1972 | 100.00 | 302.473 | 2009 | 96.99 | 1,690.783 |
| 1973 | 100.00 | 308.835 | 2010 | 97.38 | 1,587.291 |
| 1974 | 100.00 | 315.628 | 2011 | 95.02 | 1,563.321 |
| 1975 | 100.00 | 322.334 | 2012 | 82.77 | 1,382.283 |
| 1976 | 100.00 | 330.130 | 2013 | 82.12 | 1,413.113 |
| 1977 | 100.00 | 337.084 | 2014 | 79.89 | 1,308.122 |
| 1978 | 100.00 | 345.075 | 2015 | 79.73 | 1,318.741 |
| 1979 | 100.00 | 353.110 | 2016 | 76.22 | 1,280.377 |
| 1980 | 100.00 | 361.077 | 2017 | 72.34 | 1,241.743 |
| 1981 | 100.00 | 368.962 | 2018 | 65.94 | 1,166.062 |
| 1982 | 100.00 | 376.619 | 2019 | 59.20 | 1,072.506 |
| 1983 | 100.00 | 386.576 | 2020 | 55.59 | 941.081 |
| 1984 | 100.00 | 396.604 | 2021 | 53.34 | 942.305 |
| 1985 | 100.00 | 475.273 | 2022 | 55.56 | 1,024.808 |
| 1986 | 95.48 | 487.790 | | | |

[82] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Source: 2022 Municipal Waste Report, Ministry of Economy and Sustainable Development, July 2023 (in Croatian), https://www.haop.hr/sites/default/files/uploads/inline-files/OTP_Izvje%C5%A1%C4%87e%20o%20komunalnom%20otpadu%20za%202022.%20godinu_FV.pdf

***Composition of waste going to SWDS***

According to the available and estimated data on share of different components (fractions) of deposited MSW (Elaborate 1, Chapters 2.3.1. and 2.3.2. updated with new data for 2022[83]), data on share of different components of MSW deposited at SWDS for use in multi-phase IPCC FOD in the period 1950 - 2022 were determined. Data are shown in the Table 7.2-8.

Table 7.2-8: Data on composition of MSW deposited at SWDS for use in multi-phase IPCC FOD model in the period 1950 – 2022

| Year | Food (%) | Garden (%) | Paper (%) | Wood (%) | Textile (%) | Nappies (%) | Plastics, other inert (%) |
|---|---|---|---|---|---|---|---|
| 1950 | 50.4 | 6.7 | 21.0 | 3.0 | 0.8 | 0.2 | 17.8 |
| 1951 | 50.3 | 6.7 | 21.0 | 3.0 | 0.8 | 0.3 | 17.9 |
| 1952 | 50.2 | 6.7 | 21.1 | 2.9 | 0.9 | 0.3 | 17.9 |
| 1953 | 50.0 | 6.7 | 21.1 | 2.9 | 1.0 | 0.4 | 17.9 |
| 1954 | 49.9 | 6.7 | 21.1 | 2.9 | 1.0 | 0.4 | 18.0 |
| 1955 | 49.7 | 6.7 | 21.1 | 2.9 | 1.1 | 0.5 | 18.0 |
| 1956 | 49.6 | 6.7 | 21.2 | 2.8 | 1.2 | 0.5 | 18.1 |
| 1957 | 49.4 | 6.7 | 21.2 | 2.8 | 1.2 | 0.6 | 18.1 |
| 1958 | 49.2 | 6.7 | 21.2 | 2.8 | 1.3 | 0.6 | 18.2 |
| 1959 | 49.1 | 6.7 | 21.2 | 2.7 | 1.4 | 0.7 | 18.2 |
| 1960 | 48.9 | 6.7 | 21.2 | 2.7 | 1.4 | 0.8 | 18.3 |
| 1961 | 48.7 | 6.6 | 21.2 | 2.7 | 1.5 | 0.8 | 18.4 |
| 1962 | 48.5 | 6.6 | 21.3 | 2.7 | 1.6 | 0.9 | 18.5 |
| 1963 | 48.3 | 6.6 | 21.3 | 2.6 | 1.6 | 1.0 | 18.6 |
| 1964 | 48.1 | 6.6 | 21.3 | 2.6 | 1.7 | 1.0 | 18.7 |
| 1965 | 47.9 | 6.6 | 21.3 | 2.6 | 1.8 | 1.1 | 18.8 |
| 1966 | 47.7 | 6.6 | 21.3 | 2.5 | 1.8 | 1.2 | 18.9 |
| 1967 | 47.5 | 6.6 | 21.3 | 2.5 | 1.9 | 1.2 | 19.0 |
| 1968 | 53.3 | 7.5 | 15.0 | 1.3 | 1.3 | 1.2 | 20.4 |
| 1969 | 47.1 | 6.5 | 21.3 | 2.4 | 2.0 | 1.4 | 19.2 |
| 1970 | 46.9 | 6.5 | 21.3 | 2.4 | 2.1 | 1.4 | 19.4 |
| 1971 | 46.6 | 6.5 | 21.3 | 2.4 | 2.2 | 1.5 | 19.5 |
| 1972 | 46.4 | 6.5 | 21.3 | 2.3 | 2.2 | 1.6 | 19.6 |
| 1973 | 46.2 | 6.4 | 21.3 | 2.3 | 2.3 | 1.7 | 19.8 |
| 1974 | 46.0 | 6.4 | 21.3 | 2.3 | 2.4 | 1.7 | 19.9 |
| 1975 | 45.7 | 6.4 | 21.3 | 2.2 | 2.4 | 1.8 | 20.1 |
| 1976 | 45.5 | 6.4 | 21.3 | 2.2 | 2.5 | 1.9 | 20.2 |
| 1977 | 45.2 | 6.4 | 21.3 | 2.2 | 2.6 | 2.0 | 20.4 |
| 1978 | 38.4 | 5.4 | 24.8 | 1.4 | 2.5 | 2.0 | 25.5 |
| 1979 | 44.7 | 6.3 | 21.3 | 2.1 | 2.7 | 2.1 | 20.7 |
| 1980 | 44.5 | 6.3 | 21.3 | 2.1 | 2.8 | 2.2 | 20.9 |
| 1981 | 43.6 | 5.9 | 20.1 | 2.4 | 2.3 | 2.3 | 23.5 |
| 1982 | 44.0 | 6.3 | 21.2 | 2.0 | 2.9 | 2.4 | 21.3 |
| 1983 | 43.7 | 6.2 | 21.2 | 2.0 | 3.0 | 2.4 | 21.4 |
| 1984 | 43.4 | 6.2 | 21.2 | 1.9 | 3.0 | 2.5 | 21.6 |
| 1985 | 43.2 | 6.2 | 21.2 | 1.9 | 3.1 | 2.6 | 21.8 |
| 1986 | 42.9 | 6.2 | 21.2 | 1.9 | 3.2 | 2.7 | 22.0 |
| 1987 | 42.6 | 6.1 | 21.1 | 1.8 | 3.2 | 2.8 | 22.2 |
| 1988 | 42.4 | 6.1 | 21.1 | 1.8 | 3.3 | 2.8 | 22.4 |

[83] For the year 2022, the estimate was made on the basis of known data for 2015 and 2021 (average value).

| Year | Food (%) | Garden (%) | Paper (%) | Wood (%) | Textile (%) | Nappies (%) | Plastics, other inert (%) |
|---|---|---|---|---|---|---|---|
| 1989 | 42.1 | 6.1 | 21.1 | 1.8 | 3.4 | 2.9 | 22.6 |
| 1990 | 41.8 | 6.1 | 21.1 | 1.7 | 3.4 | 3.0 | 22.9 |
| 1991 | 41.5 | 6.0 | 21.0 | 1.7 | 3.5 | 3.1 | 23.1 |
| 1992 | 39.7 | 5.6 | 21.2 | 1.2 | 3.8 | 0.0 | 28.4 |
| 1993 | 40.9 | 6.0 | 21.0 | 1.6 | 3.6 | 3.3 | 23.5 |
| 1994 | 40.7 | 6.0 | 21.0 | 1.6 | 3.7 | 3.4 | 23.8 |
| 1995 | 40.4 | 5.9 | 20.9 | 1.6 | 3.8 | 3.4 | 24.0 |
| 1996 | 40.1 | 5.9 | 20.9 | 1.5 | 3.8 | 3.5 | 24.2 |
| 1997 | 40.6 | 5.1 | 18.4 | 1.2 | 4.5 | 3.8 | 26.4 |
| 1998 | 39.5 | 5.9 | 20.8 | 1.4 | 4.0 | 3.7 | 24.7 |
| 1999 | 39.2 | 5.8 | 20.8 | 1.4 | 4.0 | 3.8 | 24.9 |
| 2000 | 38.9 | 5.8 | 20.8 | 1.4 | 4.1 | 3.9 | 25.2 |
| 2001 | 38.6 | 5.8 | 20.7 | 1.3 | 4.2 | 4.0 | 25.4 |
| 2002 | 38.3 | 6.9 | 20.0 | 1.3 | 4.3 | 3.7 | 25.5 |
| 2003 | 38.0 | 5.7 | 20.7 | 1.3 | 4.3 | 4.1 | 26.0 |
| 2004 | 37.7 | 5.7 | 20.6 | 1.2 | 4.4 | 4.2 | 26.2 |
| 2005 | 37.4 | 5.7 | 20.6 | 1.2 | 4.4 | 4.3 | 26.5 |
| 2006 | 31.8 | 5.6 | 21.8 | 1.0 | 4.2 | 4.1 | 31.5 |
| 2007 | 36.7 | 5.6 | 20.5 | 1.1 | 4.5 | 4.5 | 27.0 |
| 2008 | 36.4 | 5.6 | 20.5 | 1.1 | 4.6 | 4.6 | 27.3 |
| 2009 | 36.1 | 5.5 | 20.4 | 1.0 | 4.7 | 4.7 | 27.6 |
| 2010 | 35.8 | 5.5 | 20.4 | 1.0 | 4.7 | 4.7 | 27.8 |
| 2011 | 35.5 | 5.5 | 20.3 | 1.0 | 4.8 | 4.8 | 28.1 |
| 2012 | 35.2 | 5.4 | 20.3 | 0.9 | 4.9 | 4.9 | 28.4 |
| 2013 | 34.8 | 5.4 | 20.2 | 0.9 | 4.9 | 5.0 | 28.7 |
| 2014 | 34.5 | 5.4 | 20.2 | 0.9 | 5.0 | 5.1 | 29.0 |
| 2015 | 31.4 | 5.7 | 23.2 | 1.0 | 3.7 | 4.0 | 31.1 |
| 2016 | 33.9 | 5.3 | 20.1 | 0.8 | 5.1 | 5.3 | 29.6 |
| 2017 | 33.5 | 5.3 | 20.1 | 0.8 | 5.2 | 5.4 | 29.8 |
| 2018 | 33.2 | 5.2 | 20.0 | 0.7 | 5.2 | 5.5 | 30.1 |
| 2019 | 32.9 | 5.2 | 20.0 | 0.7 | 5.3 | 5.5 | 30.4 |
| 2020 | 32.6 | 5.2 | 19.9 | 0.7 | 5.3 | 5.6 | 30.7 |
| 2021 | 35.0 | 4.2 | 16.1 | 0.7 | 6.0 | 7.2 | 30.8 |
| 2022 | 33.2 | 4.9 | 19.7 | 0.8 | 4.8 | 5.6 | 30.9 |

Based on the mass and composition of mixed MSW in 2021 and the total separately collected mass of MSW components listed in the 2021 Municipal Waste Report[84], an average composition of MSW in the Republic of Croatia were estimated for 2021, in accordance with the Methodology for analysing the composition of solid waste[85] (Elaborate 1, Chapter 2.3.4., Table 2.3-15). Data are shown in the Table 7.2-9.

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[84] Source: 2021 Municipal Waste Report, Ministry of Economy and Sustainable Development, July 2022 (in Croatian), https://www.haop.hr/sites/default/files/uploads/dokumenti/021_otpad/Izvjesca/komunalni/OTP_Izvje%C5%A1%C4%87e%20o%20komunalnom%20otpadu%20za%202021.%20godinu_FV.pdf

[85] “The methodology for determining the composition and quantity of mixed municipal waste with the Instructions for ordering and implementation of determining the average composition of mixed municipal waste” in the framework of the project “Creating a uniform methodology for the analysis of the composition of solid waste, determine the average composition of solid waste in the Republic of Croatia and the projection of the amount of solid waste” (Croatian Agency for the Environment and Nature, 2015)

Table 7.2-9: Estimated average composition of MSW in the Republic of Croatia in 2021

| Component | Average composition of mixed MSW (%) | Mass of components of mixed MSW (t) | Separately collected MSW (t) | Generated mass of MSW (t) | Average composition of MSW (%) |
|---|---|---|---|---|---|
| Paper/cardboar | 16.12 | 161,952 | 228,265 | 390,217 | 22.09 |
| Metal | 2.85 | 28,670 | 51,225 | 79,895 | 4.52 |
| Wood | 0.69 | 6,939 | 38,450 | 45,389 | 2.57 |
| Glass | 3.44 | 34,617 | 53,210 | 87,827 | 4.97 |
| Textiles | 5.98 | 60,102 | 3,838 | 63,940 | 3.62 |
| Plastic | 16.88 | 169,610 | 73,707 | 243,317 | 13.77 |
| Rubber | 0.20 | 1,969 | | 1,969 | 0.11 |
| Organic waste | 39.23 | 394,224 | 122,175 | 516,399 | 29.23 |
| Other waste | 14.61 | 146,794 | 190,813 | 337,607 | 19.11 |
| **Total** | **100.00** | **1,004,877** | **761,683** | **1,766,560** | **100.00** |

## IW activity data

### *Gross domestic product (GDP)*

According to the known data on GDP (Elaborate 2, Chapter 2.1.1.1., Tables 2.1-2, 2.1-3 and 2.1-4, updated with new data for 2022[86]) and estimated data for the missing years (Elaborate 2, Chapter 2.1.1.2., Table 2.1-5), data on GDP in USD millions were determined (Table 7.2-10).

Table 7.2-10: GDP (USD millions) in the period 1950 – 2022

| Year | GDP (USD millions) | Year | GDP (USD millions) |
|---|---|---|---|
| 1950 | 11,238.784 | 1987 | 16,578.019 |
| 1951 | 11,362.480 | 1988 | 14,521.601 |
| 1952 | 11,486.706 | 1989 | 16,378.033 |
| 1953 | 11,617.352 | 1990 | 24,823.009 |
| 1954 | 11,745.610 | 1991 | 18,156.379 |
| 1955 | 11,883.299 | 1992 | 10,240.636 |
| 1956 | 11,997.829 | 1993 | 10,902.667 |
| 1957 | 12,112.821 | 1994 | 14,584.958 |
| 1958 | 12,213.341 | 1995 | 22,647.644 |
| 1959 | 12,326.219 | 1996 | 24,005.639 |
| 1960 | 12,436.539 | 1997 | 24,024.712 |
| 1961 | 12,559.336 | 1998 | 25,736.176 |
| 1962 | 12,688.672 | 1999 | 23,594.827 |
| 1963 | 12,821.569 | 2000 | 21,782.324 |
| 1964 | 12,900.325 | 2001 | 23,266.228 |
| 1965 | 13,018.929 | 2002 | 27,082.484 |
| 1966 | 13,137.996 | 2003 | 35,025.619 |
| 1967 | 13,254.460 | 2004 | 42,035.226 |
| 1968 | 13,374.442 | 2005 | 45,829.540 |
| 1969 | 13,491.805 | 2006 | 50,973.937 |
| 1970 | 13,612.703 | 2007 | 60,775.332 |
| 1971 | 13,724.769 | 2008 | 71,136.092 |
| 1972 | 13,815.498 | 2009 | 63,514.893 |

[86] Source: Croatian Bureau of Statistics (CBS): Gross Domestic Product, annual calculation, 1995 - 2022 (ESA 2010), 19 October 2023, Tab. 12.1.2.1. https://podaci.dzs.hr/hr/statistika-u-nizu/

| Year | GDP (USD millions) | Year | GDP (USD millions) |
|---|---|---|---|
| 1973 | 13,909.634 | 2010 | 60,779.995 |
| 1974 | 14,000.954 | 2011 | 63,550.842 |
| 1975 | 14,095.697 | 2012 | 57,487.155 |
| 1976 | 14,187.608 | 2013 | 59,148.897 |
| 1977 | 14,282.959 | 2014 | 58,538.398 |
| 1978 | 14,378.618 | 2015 | 50,327.870 |
| 1979 | 14,471.419 | 2016 | 52,536.998 |
| 1980 | 17,764.228 | 2017 | 56,461.109 |
| 1981 | 16,265.318 | 2018 | 62,476.254 |
| 1982 | 14,774.526 | 2019 | 62,473.178 |
| 1983 | 13,256.719 | 2020 | 57,635.509 |
| 1984 | 11,714.976 | 2021 | 69,155.171 |
| 1985 | 10,158.672 | 2022 | 71,516.540 |
| 1986 | 14,087.071 | | |

***Waste generation rate***

The waste generation rate (kt/USDm GDP/yr) was estimated based on the known data on mass of generated IW (data from CBS Statistics / Environmental Pollution Register (EPR) Reports / Reports on the State of the Environment of the Republic of Croatia; Elaborate 2, Chapter 2.1.2.1.; Table 2.1-7, updated with new data for 2022[87]) and estimated data for the missing years (Elaborate 2, Chapter 2.1.2.2.; Table 2.1-12). Table 7.2-11 shows estimated mass of generated IW per USDm GDP in the period 1950 - 2022.

Table 7.2-11: Waste generation rate (kt/USDm GDP/yr) in the period 1950 – 2022

| Year | Waste generation rate (kt/USDm GDP/yr) | Year | Waste generation rate (kt/USDm GDP/yr) |
|---|---|---|---|
| 1950 | 0.183 | 1987 | 0.149 |
| 1951 | 0.181 | 1988 | 0.148 |
| 1952 | 0.180 | 1989 | 0.148 |
| 1953 | 0.179 | 1990 | 0.147 |
| 1954 | 0.177 | 1991 | 0.156 |
| 1955 | 0.176 | 1992 | 0.158 |
| 1956 | 0.174 | 1993 | 0.152 |
| 1957 | 0.173 | 1994 | 0.122 |
| 1958 | 0.172 | 1995 | 0.083 |
| 1959 | 0.171 | 1996 | 0.084 |
| 1960 | 0.170 | 1997 | 0.111 |
| 1961 | 0.169 | 1998 | 0.129 |
| 1962 | 0.168 | 1999 | 0.168 |
| 1963 | 0.166 | 2000 | 0.128 |
| 1964 | 0.166 | 2001 | 0.109 |
| 1965 | 0.165 | 2002 | 0.084 |
| 1966 | 0.164 | 2003 | 0.038 |
| 1967 | 0.163 | 2004 | 0.037 |
| 1968 | 0.162 | 2005 | 0.033 |

[87] For 2022, the waste generation rate from 2021 has been applied. At the time of drafting the inventory, the report on data from the Environmental Pollution Register for 2022, as the source of total mass of generated industrial waste, had not yet been published.

| Year | Waste generation rate (kt/USDm GDP/yr) | Year | Waste generation rate (kt/USDm GDP/yr) |
|---|---|---|---|
| 1969 | 0.161 | 2006 | 0.035 |
| 1970 | 0.160 | 2007 | 0.033 |
| 1971 | 0.159 | 2008 | 0.021 |
| 1972 | 0.158 | 2009 | 0.020 |
| 1973 | 0.158 | 2010 | 0.026 |
| 1974 | 0.157 | 2011 | 0.024 |
| 1975 | 0.157 | 2012 | 0.024 |
| 1976 | 0.156 | 2013 | 0.024 |
| 1977 | 0.155 | 2014 | 0.027 |
| 1978 | 0.155 | 2015 | 0.039 |
| 1979 | 0.154 | 2016 | 0.040 |
| 1980 | 0.154 | 2017 | 0.033 |
| 1981 | 0.153 | 2018 | 0.029 |
| 1982 | 0.152 | 2019 | 0.033 |
| 1983 | 0.151 | 2020 | 0.041 |
| 1984 | 0.151 | 2021 | 0.041 |
| 1985 | 0.150 | 2022 | 0.041 |
| 1986 | 0.149 | | |

***Total IW***

For the period 1950 - 2022, data on generated IW were calculated by multiplying GDP (Table 7.2-8) and waste generation rate (Table 7.2-9). Data on generated IW (kt) are presented in the Table 7.2-12.

Table 7.2-12: Generated IW (kt) in the period 1950 – 2022

| Year | Generated IW (kt) | Year | Generated IW (kt) |
|---|---|---|---|
| 1950 | 2,056.166 | 1987 | 2,463.815 |
| 1951 | 2,062.196 | 1988 | 2,150.994 |
| 1952 | 2,068.226 | 1989 | 2,420.837 |
| 1953 | 2,074.256 | 1990 | 3,660.353 |
| 1954 | 2,080.287 | 1991 | 2,834.479 |
| 1955 | 2,086.317 | 1992 | 1,614.126 |
| 1956 | 2,092.347 | 1993 | 1,655.131 |
| 1957 | 2,098.377 | 1994 | 1,772.208 |
| 1958 | 2,104.407 | 1995 | 1,889.286 |
| 1959 | 2,110.437 | 1996 | 2,006.363 |
| 1960 | 2,116.467 | 1997 | 2,659.267 |
| 1961 | 2,122.497 | 1998 | 3,312.170 |
| 1962 | 2,128.528 | 1999 | 3,965.074 |
| 1963 | 2,134.558 | 2000 | 2,782.746 |
| 1964 | 2,140.588 | 2001 | 2,535.010 |
| 1965 | 2,146.618 | 2002 | 2,287.273 |
| 1966 | 2,152.648 | 2003 | 1,336.112 |
| 1967 | 2,158.678 | 2004 | 1,552.673 |
| 1968 | 2,164.708 | 2005 | 1,512.991 |
| 1969 | 2,170.738 | 2006 | 1,796.488 |
| 1970 | 2,176.769 | 2007 | 2,004.059 |
| 1971 | 2,182.799 | 2008 | 1,501.531 |
| 1972 | 2,188.829 | 2009 | 1,257.802 |
| 1973 | 2,194.859 | 2010 | 1,592.609 |

| Year | Generated IW (kt) | Year | Generated IW (kt) |
|---|---|---|---|
| 1974 | 2,200.889 | 2011 | 1,536.607 |
| 1975 | 2,206.919 | 2012 | 1,376.114 |
| 1976 | 2,212.949 | 2013 | 1,441.213 |
| 1977 | 2,218.979 | 2014 | 1,607.450 |
| 1978 | 2,225.010 | 2015 | 1,939.376 |
| 1979 | 2,231.040 | 2016 | 2,107.017 |
| 1980 | 2,728.021 | 2017 | 1,869.789 |
| 1981 | 2,486.924 | 2018 | 1,805.773 |
| 1982 | 2,245.826 | 2019 | 2,072.329 |
| 1983 | 2,004.729 | 2020 | 2,371.977 |
| 1984 | 1,763.632 | 2021 | 2,853.250 |
| 1985 | 1,522.535 | 2022 | 2,950.677 |
| 1986 | 2,101.675 | | |

***% to SWDS***

According to the known data on mass of IW deposited at SWDS (Elaborate 2, Chapter 2.2.1.1., Table 2.2-6, updated with new data for 2022[88]) and the estimated data for the missing years (Elaborate 2, Chapter 2.2.1.2., Table 2.2-33 - 2.2-47), the data for the period 1950 - 2022 were determined, i.e. share of IW deposited at SWDS (%) and mass of deposited IW (kt). Data are shown in the Table 7.2-13.

Table 7.2-13: Share of deposited IW (%) and mass of deposited IW (kt) in the period 1950 – 2022

| Year | Share of deposited IW (%) | Mass of deposited IW (kt) | Year | Share of deposited IW (%) | Mass of deposited IW (kt) |
|---|---|---|---|---|---|
| 1950 | 2,27 | 46.775 | 1987 | 18,27 | 450.204 |
| 1951 | 2,33 | 47.954 | 1988 | 21,08 | 453.377 |
| 1952 | 2,38 | 49.134 | 1989 | 18,85 | 456.388 |
| 1953 | 2,43 | 50.313 | 1990 | 12,65 | 463.162 |
| 1954 | 2,48 | 51.513 | 1991 | 16,51 | 467.997 |
| 1955 | 2,53 | 52.722 | 1992 | 29,31 | 473.023 |
| 1956 | 2,58 | 53.940 | 1993 | 28,89 | 478.249 |
| 1957 | 2,63 | 55.162 | 1994 | 27,29 | 483.681 |
| 1958 | 2,68 | 56.385 | 1995 | 25,90 | 489.328 |
| 1959 | 2,73 | 57.609 | 1996 | 26,05 | 522.698 |
| 1960 | 2,78 | 58.832 | 1997 | 19,89 | 528.800 |
| 1961 | 2,83 | 60.115 | 1998 | 16,17 | 535.611 |
| 1962 | 2,88 | 61.359 | 1999 | 14,17 | 561.933 |
| 1963 | 2,93 | 62.641 | 2000 | 20,72 | 576.534 |
| 1964 | 2,98 | 63.890 | 2001 | 23,33 | 591.487 |
| 1965 | 3,04 | 65.164 | 2002 | 27,30 | 624.403 |
| 1966 | 3,09 | 66.422 | 2003 | 47,60 | 636.014 |
| 1967 | 3,14 | 67.691 | 2004 | 40,78 | 633.195 |
| 1968 | 3,20 | 69.177 | 2005 | 42,96 | 649.955 |
| 1969 | 3,25 | 70.621 | 2006 | 36,61 | 657.778 |
| 1970 | 3,80 | 82.700 | 2007 | 33,48 | 670.937 |
| 1971 | 3,86 | 84.300 | 2008 | 52,78 | 792.467 |

[88] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Ministry of Economy and Sustainable Development (the web format of the document is not available at the time the NIR report is being created)

| Year | Share of deposited IW (%) | Mass of deposited IW (kt) | Year | Share of deposited IW (%) | Mass of deposited IW (kt) |
|---|---|---|---|---|---|
| 1972 | 3,92 | 85.885 | 2009 | 41,60 | 523.308 |
| 1973 | 3,99 | 87.509 | 2010 | 24,83 | 395.389 |
| 1974 | 4,06 | 89.328 | 2011 | 29,54 | 453.953 |
| 1975 | 4,13 | 91.150 | 2012 | 40,14 | 552.401 |
| 1976 | 4,20 | 92.997 | 2013 | 38,20 | 550.527 |
| 1977 | 4,27 | 94.844 | 2014 | 30,75 | 494.316 |
| 1978 | 4,35 | 96.720 | 2015 | 29,41 | 570.460 |
| 1979 | 4,42 | 98.572 | 2016 | 22,51 | 474.287 |
| 1980 | 3,69 | 100.541 | 2017 | 22,48 | 420.387 |
| 1981 | 4,12 | 102.401 | 2018 | 22,82 | 412.145 |
| 1982 | 4,64 | 104.253 | 2019 | 24,26 | 502.694 |
| 1983 | 13,09 | 262.438 | 2020 | 20,54 | 487.160 |
| 1984 | 24,69 | 435.457 | 2021 | 21,99 | 627.457 |
| 1985 | 28,98 | 441.254 | 2022 | 25.63 | 756.240 |
| 1986 | 21.13 | 444.121 | | | |

**Sludge activity data**

According to the known and estimated data on deposited sludge (Elaborate 3, Chapter 2.2.1. Table 2.2-2, updated with new data for 2022[89]) the data on the mass of deposited sludge for the period 1950 - 2022 were determined for use in the IPCC FOD model. Data are shown in the Table 7.2-14.

Table 7.2-14: Mass of deposited sludge (kt) in the period 1950 – 2022

| Year | Mass of deposited sludge (kt) | Year | Mass of deposited sludge (kt) |
|---|---|---|---|
| 1950 | NO | 1987 | 19.454 |
| 1951 | NO | 1988 | 19.661 |
| 1952 | NO | 1989 | 19.862 |
| 1953 | NO | 1990 | 20.228 |
| 1954 | NO | 1991 | 20.511 |
| 1955 | NO | 1992 | 20.804 |
| 1956 | NO | 1993 | 21.108 |
| 1957 | NO | 1994 | 21.422 |
| 1958 | NO | 1995 | 21.747 |
| 1959 | NO | 1996 | 23.311 |
| 1960 | NO | 1997 | 23.664 |
| 1961 | NO | 1998 | 24.051 |
| 1962 | NO | 1999 | 25.320 |
| 1963 | NO | 2000 | 26.067 |
| 1964 | NO | 2001 | 26.834 |
| 1965 | NO | 2002 | 28.423 |
| 1966 | NO | 2003 | 29.049 |
| 1967 | NO | 2004 | 29.018 |
| 1968 | NO | 2005 | 29.886 |
| 1969 | NO | 2006 | 30.347 |
| 1970 | NO | 2007 | 31.057 |

[89] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Ministry of Economy and Sustainable Development (the web format of the document is not available at the time the NIR report is being created)

| Year | Mass of deposited sludge (kt) | Year | Mass of deposited sludge (kt) |
|---|---|---|---|
| 1971 | NO | 2008 | 36.805 |
| 1972 | NO | 2009 | 24.385 |
| 1973 | NO | 2010 | 18.485 |
| 1974 | NO | 2011 | 21.293 |
| 1975 | 3.770 | 2012 | 25.996 |
| 1976 | 3.861 | 2013 | 29.191 |
| 1977 | 3.952 | 2014 | 28.060 |
| 1978 | 4.046 | 2015 | 29.458 |
| 1979 | 4.138 | 2016 | 14.908 |
| 1980 | 4.236 | 2017 | 21.509 |
| 1981 | 4.330 | 2018 | 23.395 |
| 1982 | 4.425 | 2019 | 18.203 |
| 1983 | 11.179 | 2020 | 31.665 |
| 1984 | 18.616 | 2021 | 23.667 |
| 1985 | 18.932 | 2022 | 48.705 |
| 1986 | 19.123 | | |

NO - not occuring

Total annual deposited MSW, IW and sludge at SWDS in the period 1950 - 2022 are presented in the Table 7.2-15.

Table 7.2-15: Total annual deposited MSW, IW and sludge at SWDS in the period 1950 – 2022

| Year | Deposited MSW (kt) | Deposited IW (kt) | Deposited sludge (kt) | **TOTAL DEPOSITED WASTE (kt)** |
|---|---|---|---|---|
| 1950 | 195.904 | 46.775 | NO | **242.679** |
| 1951 | 199.911 | 47.954 | NO | **247.865** |
| 1952 | 203.919 | 49.134 | NO | **253.052** |
| 1953 | 207.926 | 50.313 | NO | **258.239** |
| 1954 | 212.044 | 51.513 | NO | **263.557** |
| 1955 | 216.230 | 52.722 | NO | **268.952** |
| 1956 | 220.483 | 53.940 | NO | **274.423** |
| 1957 | 224.762 | 55.162 | NO | **279.924** |
| 1958 | 229.047 | 56.385 | NO | **285.432** |
| 1959 | 233.338 | 57.609 | NO | **290.947** |
| 1960 | 238.526 | 58.832 | NO | **297.358** |
| 1961 | 243.076 | 60.115 | NO | **303.191** |
| 1962 | 247.433 | 61.359 | NO | **308.792** |
| 1963 | 251.948 | 62.641 | NO | **314.589** |
| 1964 | 256.509 | 63.890 | NO | **320.399** |
| 1965 | 261.322 | 65.164 | NO | **326.486** |
| 1966 | 267.482 | 66.422 | NO | **333.904** |
| 1967 | 272.385 | 67.691 | NO | **340.076** |
| 1968 | 277.696 | 69.177 | NO | **346.873** |
| 1969 | 283.398 | 70.621 | NO | **354.019** |
| 1970 | 290.046 | 82.700 | NO | **372.746** |
| 1971 | 296.346 | 84.300 | NO | **380.646** |
| 1972 | 302.473 | 85.885 | NO | **388.358** |
| 1973 | 308.835 | 87.509 | NO | **396.344** |
| 1974 | 315.628 | 89.328 | NO | **404.956** |

| Year | Deposited MSW (kt) | Deposited IW (kt) | Deposited sludge (kt) | **TOTAL DEPOSITED WASTE (kt)** |
|---|---|---|---|---|
| 1975 | 322.334 | 91.150 | 3.770 | **417.254** |
| 1976 | 330.130 | 92.997 | 3.861 | **426.988** |
| 1977 | 337.084 | 94.844 | 3.952 | **435.881** |
| 1978 | 345.075 | 96.720 | 4.046 | **445.841** |
| 1979 | 353.110 | 98.572 | 4.138 | **455.820** |
| 1980 | 361.077 | 100.541 | 4.236 | **465.854** |
| 1981 | 368.962 | 102.401 | 4.330 | **475.694** |
| 1982 | 376.619 | 104.253 | 4.425 | **485.297** |
| 1983 | 386.576 | 262.438 | 11.179 | **660.193** |
| 1984 | 396.604 | 435.457 | 18.616 | **850.677** |
| 1985 | 475.273 | 441.254 | 18.932 | **935.459** |
| 1986 | 487.790 | 444.121 | 19.123 | **951.034** |
| 1987 | 506.981 | 450.204 | 19.454 | **976.639** |
| 1988 | 519.049 | 453.377 | 19.661 | **992.087** |
| 1989 | 533.107 | 456.388 | 19.862 | **1,009.357** |
| 1990 | 543.580 | 463.162 | 20.228 | **1,026.970** |
| 1991 | 534.891 | 467.997 | 20.511 | **1,023.399** |
| 1992 | 533.438 | 473.023 | 20.804 | **1,027.266** |
| 1993 | 556.199 | 478.249 | 21.108 | **1,055.555** |
| 1994 | 610.691 | 483.681 | 21.422 | **1,115.794** |
| 1995 | 641.912 | 489.328 | 21.747 | **1,152.987** |
| 1996 | 666.155 | 522.698 | 23.311 | **1,212.164** |
| 1997 | 704.315 | 528.800 | 23.664 | **1,256.779** |
| 1998 | 747.578 | 535.611 | 24.051 | **1,307.240** |
| 1999 | 745.242 | 561.933 | 25.320 | **1,332.495** |
| 2000 | 790.462 | 576.534 | 26.067 | **1,393.062** |
| 2001 | 839.022 | 591.487 | 26.834 | **1,457.342** |
| 2002 | 891.953 | 624.403 | 28.423 | **1,544.779** |
| 2003 | 949.818 | 636.014 | 29.049 | **1,614.881** |
| 2004 | 1,013.271 | 633.195 | 29.018 | **1,675.484** |
| 2005 | 1,083.080 | 649.955 | 29.886 | **1,762.921** |
| 2006 | 1,335.003 | 657.778 | 30.347 | **2,023.129** |
| 2007 | 1,620.000 | 670.937 | 31.057 | **2,321.994** |
| 2008 | 1,730.671 | 792.467 | 36.805 | **2,559.943** |
| 2009 | 1,690.783 | 523.308 | 24.385 | **2,238.476** |
| 2010 | 1,587.291 | 395.389 | 18.485 | **2,001.165** |
| 2011 | 1,563.321 | 453.953 | 21.293 | **2,038.567** |
| 2012 | 1,382.283 | 552.401 | 25.996 | **1,960.680** |
| 2013 | 1,413.113 | 550.527 | 29.191 | **1,992.832** |
| 2014 | 1,308.122 | 494.316 | 28.060 | **1,830.499** |
| 2015 | 1,318.741 | 570.460 | 29.458 | **1,918.659** |
| 2016 | 1,280.377 | 474.287 | 14.908 | **1,769.572** |
| 2017 | 1,241.743 | 420.387 | 21.509 | **1,683.640** |
| 2018 | 1,166.062 | 412.145 | 23.395 | **1,601.602** |
| 2019 | 1,072.506 | 502.694 | 18.203 | **1,593.402** |
| 2020 | 941.081 | 487.160 | 31.665 | **1,459.906** |
| 2021 | 942.305 | 627.457 | 23.667 | **1,593.429** |
| 2022 | 1,024.808 | 756.240 | 48.705 | **1,829.753** |

More than half of the total deposited waste is MSW, throughout the entire reporting period. In historical years, this share was higher, starting from 1950 when it was 81%, while in the later period it decreases with a fluctuating trend, to reach 56% in 2022. Deposited IW contributes to the total deposited waste in 1950 with 19%, while in the later period it increases with a fluctuating trend, to reach 41% in 2022. Sludge began to be deposited at SWDS in 1975, with only 1% of the total deposited waste, and with a fluctuating trend throughout the period it contributes to the total deposited waste in 2022 with 3%.

A fluctuating trend for solid waste disposal by type at SWDS during reporting time series was due to multiple factors, such as the fact as the influence of the economic crisis and measures undertaken to avoid or reduce solid waste disposal. Further, a number of new legislative acts have been adopted with the purpose to increase separate collection, recycling and recovery of different waste types. National schemes based on „extended producer responsibility“ have been introduced for the collection and recovery of different waste categories.

#### 7.2.2.2. Parameters description

**Methane correction factor (MCF)**

The classification of SWDS in the Republic of Croatia according to categories defined by the IPCC methodology is presented in Elaborate 4. The criteria defined by 2006 IPCC Guidelines were applied to official SWDS to assess the distribution of disposed waste into managed - anaerobic, umanaged deep (≥ 5m) and unmanaged shallow (< 5m) SWDS.

MSW and IW (including sludge) are disposed of at two types of SWDS:

- MSW SWDS - MSW and IW are deposited;
- IW SWDS - only IW is deposited.

Following the specified distribution of SWDS and detailed assumptions described in Elaborate 4, Chapters 2.2 and 2.3, the mass of MSW and IW (including sludge) disposed of in each category of SWDS in the period 1950 - 2021 was determined (Elaborate 5), updated with new data for 2022[90].

**MSW**

Mass of deposited MSW by categories of SWDS in the period 1950 - 2022 are shown in the Table 7.2-16.

Table 7.2-16: Mass of MSW disposed of by categories of SWDS in the period 1950 – 2022

| Year | Mass of MSW (kt) - unmanaged shallow SWDS | Mass of MSW (kt) - unmanaged deep SWDS | Mass of MSW (kt) - managed SWDS | TOTAL DEPOSITED MSW (kt) |
|---|---|---|---|---|
| 1950 | 195.904 | 0.000 | 0.000 | 195.904 |
| 1951 | 199.911 | 0.000 | 0.000 | 199.911 |
| 1952 | 203.919 | 0.000 | 0.000 | 203.919 |
| 1953 | 207.926 | 0.000 | 0.000 | 207.926 |
| 1954 | 212.044 | 0.000 | 0.000 | 212.044 |
| 1955 | 215.410 | 0.000 | 0.820 | 216.230 |
| 1956 | 219.648 | 0.000 | 0.835 | 220.483 |
| 1957 | 223.791 | 0.000 | 0.971 | 224.762 |
| 1958 | 227.989 | 0.000 | 1.058 | 229.047 |
| 1959 | 232.192 | 0.000 | 1.146 | 233.338 |
| 1960 | 236.503 | 0.000 | 2.023 | 238.526 |
| 1961 | 240.676 | 0.000 | 2.400 | 243.076 |

[90] For 2022, estimates have been made according to the previous trend.

| Year | Mass of MSW (kt) - unmanaged shallow SWDS | Mass of MSW (kt) - unmanaged deep SWDS | Mass of MSW (kt) - managed SWDS | TOTAL DEPOSITED MSW (kt) |
|---|---|---|---|---|
| 1962 | 244.757 | 0.000 | 2.676 | 247.433 |
| 1963 | 221.965 | 0.000 | 29.984 | 251.948 |
| 1964 | 90.298 | 0.000 | 166.210 | 256.509 |
| 1965 | 91.117 | 0.360 | 169.845 | 261.322 |
| 1966 | 92.461 | 0.360 | 174.661 | 267.482 |
| 1967 | 93.946 | 0.360 | 178.079 | 272.385 |
| 1968 | 94.585 | 0.361 | 182.750 | 277.696 |
| 1969 | 96.227 | 0.361 | 186.810 | 283.398 |
| 1970 | 85.143 | 5.880 | 199.023 | 290.046 |
| 1971 | 86.646 | 5.895 | 203.805 | 296.346 |
| 1972 | 79.287 | 5.911 | 217.275 | 302.473 |
| 1973 | 80.789 | 5.927 | 222.119 | 308.835 |
| 1974 | 82.479 | 5.944 | 227.205 | 315.628 |
| 1975 | 80.240 | 5.966 | 236.128 | 322.334 |
| 1976 | 80.399 | 5.976 | 243.754 | 330.130 |
| 1977 | 70.303 | 7.953 | 258.829 | 337.084 |
| 1978 | 69.812 | 7.991 | 267.272 | 345.075 |
| 1979 | 70.603 | 8.040 | 274.466 | 353.110 |
| 1980 | 67.742 | 8.082 | 285.253 | 361.077 |
| 1981 | 66.069 | 8.121 | 294.773 | 368.962 |
| 1982 | 40.156 | 34.298 | 302.165 | 376.619 |
| 1983 | 41.264 | 34.284 | 311.028 | 386.576 |
| 1984 | 29.986 | 34.272 | 332.347 | 396.604 |
| 1985 | 44.702 | 34.298 | 396.273 | 475.273 |
| 1986 | 46.275 | 34.885 | 406.630 | 487.790 |
| 1987 | 47.357 | 35.129 | 424.495 | 506.981 |
| 1988 | 48.923 | 35.171 | 434.955 | 519.049 |
| 1989 | 49.535 | 35.045 | 448.527 | 533.107 |
| 1990 | 48.789 | 30.973 | 463.818 | 543.580 |
| 1991 | 43.052 | 22.377 | 469.462 | 534.891 |
| 1992 | 44.896 | 22.074 | 466.468 | 533.438 |
| 1993 | 47.833 | 24.397 | 483.969 | 556.199 |
| 1994 | 52.690 | 27.896 | 530.105 | 610.691 |
| 1995 | 53.773 | 30.263 | 557.876 | 641.912 |
| 1996 | 57.437 | 31.411 | 577.307 | 666.155 |
| 1997 | 62.591 | 33.177 | 608.547 | 704.315 |
| 1998 | 66.000 | 34.756 | 646.822 | 747.578 |
| 1999 | 67.924 | 34.298 | 643.020 | 745.242 |
| 2000 | 74.481 | 36.002 | 679.979 | 790.462 |
| 2001 | 81.916 | 37.916 | 719.190 | 839.022 |
| 2002 | 90.370 | 39.981 | 761.602 | 891.953 |
| 2003 | 100.018 | 42.211 | 807.589 | 949.818 |
| 2004 | 111.067 | 44.623 | 857.581 | 1,013.271 |
| 2005 | 123.768 | 47.236 | 912.077 | 1,083.080 |
| 2006 | 151.383 | 57.845 | 1,125.775 | 1,335.003 |
| 2007 | 182.313 | 69.804 | 1,367.882 | 1,620.000 |
| 2008 | 203.658 | 75.320 | 1,451.693 | 1,730.671 |
| 2009 | 195.242 | 73.349 | 1,422.192 | 1,690.783 |
| 2010 | 0.000 | 0.000 | 1,587.291 | 1,587.291 |
| 2011 | 0.000 | 0.000 | 1,563.321 | 1,563.321 |
| 2012 | 0.000 | 0.000 | 1,382.283 | 1,382.283 |

| Year | Mass of MSW (kt) - unmanaged shallow SWDS | Mass of MSW (kt) - unmanaged deep SWDS | Mass of MSW (kt) - managed SWDS | TOTAL DEPOSITED MSW (kt) |
|---|---|---|---|---|
| 2013 | 0.000 | 0.000 | 1,413.113 | 1,413.113 |
| 2014 | 0.000 | 0.000 | 1,308.122 | 1,308.122 |
| 2015 | 0.000 | 0.000 | 1,318.741 | 1,318.741 |
| 2016 | 0.000 | 0.000 | 1,280.377 | 1,280.377 |
| 2017 | 0.000 | 0.000 | 1,241.743 | 1,241.743 |
| 2018 | 0.000 | 0.000 | 1,166.062 | 1,166.062 |
| 2019 | 0.000 | 0.000 | 1,072.506 | 1,072.506 |
| 2020 | 0.000 | 0.000 | 941.081 | 941.081 |
| 2021 | 0.000 | 0.000 | 942.305 | 942.305 |
| 2022 | 0.000 | 0.000 | 1,024.808 | 1,024.808 |

A fluctuating trend for MSW disposed of by categories of SWDS during reporting time series was due to multiple factors, such as the coverage of the population by organized waste collection, the impact of the economic crisis, as well as factors related to waste avoidance/reduction and recycling measures. Significant changes in the share of MSW disposed of in managed and unmanaged shallow SWDS between 1963 and 1964 are related to the start of operation of the Prudinec - Jakuševec landfill in the City of Zagreb, the largest landfill in the Republic of Croatia. According to IPZ (1984)[91], since the beginning of the operation of the Prudinec - Jakuševec landfill, the disposed waste was leveled, partially compacted and covered with inert material (soil and other).

Distribution of MSW by waste management type at SWDS in the period 1950 - 2022 is shown in the Table 7.2-17.

Table 7.2-17: Distribution of MSW by waste management type at SWDS in the period 1950 – 2022

| Year | Unmanaged shallow SWDS (%) | Unmanaged deep SWDS (%) | Managed SWDS (%) |
|---|---|---|---|
| 1950 | 100.00 | 0.00 | 0.00 |
| 1951 | 100.00 | 0.00 | 0.00 |
| 1952 | 100.00 | 0.00 | 0.00 |
| 1953 | 100.00 | 0.00 | 0.00 |
| 1954 | 100.00 | 0.00 | 0.00 |
| 1955 | 99.62 | 0.00 | 0.38 |
| 1956 | 99.62 | 0.00 | 0.38 |
| 1957 | 99.57 | 0.00 | 0.43 |
| 1958 | 99.54 | 0.00 | 0.46 |
| 1959 | 99.51 | 0.00 | 0.49 |
| 1960 | 99.15 | 0.00 | 0.85 |
| 1961 | 99.01 | 0.00 | 0.99 |
| 1962 | 98.92 | 0.00 | 1.08 |
| 1963 | 88.10 | 0.00 | 11.90 |
| 1964 | 35.20 | 0.00 | 64.80 |
| 1965 | 34.87 | 0.14 | 64.99 |
| 1966 | 34.57 | 0.13 | 65.30 |
| 1967 | 34.49 | 0.13 | 65.38 |

[91] IPZ - Industrijski projektni zavod: Projekt sanacije deponije „Jakuševac“ za daljnju privremenu upotrebu, 1984. (arhiva IPZ Uniprojekt TERRA d.o.o.), in Croatian (IPZ - Industrial Design Institute: Project for rehabilitation of the landfill "Jakuševac" for further temporary use, 1984 (archive IPZ Uniprojekt TERRA d.o.o.))

| Year | Unmanaged shallow SWDS (%) | Unmanaged deep SWDS (%) | Managed SWDS (%) |
|---|---|---|---|
| 1968 | 34.06 | 0.13 | 65.81 |
| 1969 | 33.95 | 0.13 | 65.92 |
| 1970 | 29.36 | 2.03 | 68.62 |
| 1971 | 29.24 | 1.99 | 68.77 |
| 1972 | 26.21 | 1.95 | 71.83 |
| 1973 | 26.16 | 1.92 | 71.92 |
| 1974 | 26.13 | 1.88 | 71.99 |
| 1975 | 24.89 | 1.85 | 73.26 |
| 1976 | 24.35 | 1.81 | 73.84 |
| 1977 | 20.86 | 2.36 | 76.78 |
| 1978 | 20.23 | 2.32 | 77.45 |
| 1979 | 19.99 | 2.28 | 77.73 |
| 1980 | 18.76 | 2.24 | 79.00 |
| 1981 | 17.91 | 2.20 | 79.89 |
| 1982 | 10.66 | 9.11 | 80.23 |
| 1983 | 10.67 | 8.87 | 80.46 |
| 1984 | 7.56 | 8.64 | 83.80 |
| 1985 | 9.41 | 7.22 | 83.38 |
| 1986 | 9.49 | 7.15 | 83.36 |
| 1987 | 9.34 | 6.93 | 83.73 |
| 1988 | 9.43 | 6.78 | 83.80 |
| 1989 | 9.29 | 6.57 | 84.13 |
| 1990 | 8.98 | 5.70 | 85.33 |
| 1991 | 8.05 | 4.18 | 87.77 |
| 1992 | 8.42 | 4.14 | 87.45 |
| 1993 | 8.60 | 4.39 | 87.01 |
| 1994 | 8.63 | 4.57 | 86.80 |
| 1995 | 8.38 | 4.71 | 86.91 |
| 1996 | 8.62 | 4.72 | 86.66 |
| 1997 | 8.89 | 4.71 | 86.40 |
| 1998 | 8.83 | 4.65 | 86.52 |
| 1999 | 9.11 | 4.60 | 86.28 |
| 2000 | 9.42 | 4.55 | 86.02 |
| 2001 | 9.76 | 4.52 | 85.72 |
| 2002 | 10.13 | 4.48 | 85.39 |
| 2003 | 10.53 | 4.44 | 85.03 |
| 2004 | 10.96 | 4.40 | 84.63 |
| 2005 | 11.43 | 4.36 | 84.21 |
| 2006 | 11.34 | 4.33 | 84.33 |
| 2007 | 11.25 | 4.31 | 84.44 |
| 2008 | 11.77 | 4.35 | 83.88 |
| 2009 | 11.55 | 4.34 | 84.11 |
| 2010 | 0.00 | 0.00 | 100.00 |
| 2011 | 0.00 | 0.00 | 100.00 |
| 2012 | 0.00 | 0.00 | 100.00 |
| 2013 | 0.00 | 0.00 | 100.00 |
| 2014 | 0.00 | 0.00 | 100.00 |
| 2015 | 0.00 | 0.00 | 100.00 |
| 2016 | 0.00 | 0.00 | 100.00 |
| 2017 | 0.00 | 0.00 | 100.00 |
| 2018 | 0.00 | 0.00 | 100.00 |

| Year | Unmanaged shallow SWDS (%) | Unmanaged deep SWDS (%) | Managed SWDS (%) |
|---|---|---|---|
| 2019 | 0.00 | 0.00 | 100.00 |
| 2020 | 0.00 | 0.00 | 100.00 |
| 2021 | 0.00 | 0.00 | 100.00 |
| 2022 | 0.00 | 0.00 | 100.00 |

The mass fraction of the waste deposited on each type of SWDS (unmanaged shallow, unmanaged deep and managed) in the total mass of deposited waste has been calculated by dividing the mass of deposited waste at each type of SWDS (unmanaged shallow, unmanaged deep and managed) by the total mass of deposited waste. These calculated mass fractions have been multiplied by corresponding default MCF proposed by the 2006 IPCC Guidelines, Volume 5, Table 3.1.:

- mass fraction for unmanaged shallow * 0.4;
- mass fraction for unmanaged deep SWDS * 0.8;
- mass fraction for managed SWDS * 1.0.

Like that, weighted average MCF for each type of SWDS (unmanaged shallow, unmanaged deep and managed) has been calculated. The total weighted average MCF has been obtained by summing of weighted average MCF for each type of SWDS (unmanaged shallow, unmanaged deep and managed), for each year in the reporting period.

The total weighted average MCF for MSW in the period 1950 - 2022 are reported in the Table 7.2-18.

Table 7.2-18: The total weighted average MCF for MSW in the period 1950 – 2022

| Year | MCF (fraction) | Year | MCF (fraction) |
|---|---|---|---|
| 1950 | 0.40 | 1987 | 0.93 |
| 1951 | 0.40 | 1988 | 0.93 |
| 1952 | 0.40 | 1989 | 0.93 |
| 1953 | 0.40 | 1990 | 0.93 |
| 1954 | 0.40 | 1991 | 0.94 |
| 1955 | 0.40 | 1992 | 0.94 |
| 1956 | 0.40 | 1993 | 0.94 |
| 1957 | 0.40 | 1994 | 0.94 |
| 1958 | 0.40 | 1995 | 0.94 |
| 1959 | 0.40 | 1996 | 0.94 |
| 1960 | 0.41 | 1997 | 0.94 |
| 1961 | 0.41 | 1998 | 0.94 |
| 1962 | 0.41 | 1999 | 0.94 |
| 1963 | 0.47 | 2000 | 0.93 |
| 1964 | 0.79 | 2001 | 0.93 |
| 1965 | 0.79 | 2002 | 0.93 |
| 1966 | 0.79 | 2003 | 0.93 |
| 1967 | 0.79 | 2004 | 0.93 |
| 1968 | 0.80 | 2005 | 0.92 |
| 1969 | 0.80 | 2006 | 0.92 |
| 1970 | 0.82 | 2007 | 0.92 |
| 1971 | 0.82 | 2008 | 0.92 |
| 1972 | 0.84 | 2009 | 0.92 |
| 1973 | 0.84 | 2010 | 1.00 |

| Year | MCF (fraction) | Year | MCF (fraction) |
|---|---|---|---|
| 1974 | 0.84 | 2011 | 1.00 |
| 1975 | 0.85 | 2012 | 1.00 |
| 1976 | 0.85 | 2013 | 1.00 |
| 1977 | 0.87 | 2014 | 1.00 |
| 1978 | 0.87 | 2015 | 1.00 |
| 1979 | 0.88 | 2016 | 1.00 |
| 1980 | 0.88 | 2017 | 1.00 |
| 1981 | 0.89 | 2018 | 1.00 |
| 1982 | 0.92 | 2019 | 1.00 |
| 1983 | 0.92 | 2020 | 1.00 |
| 1984 | 0.94 | 2021 | 1.00 |
| 1985 | 0.93 | 2022 | 1.00 |
| 1986 | 0.93 | | |

**IW**

Mass of deposited IW by categories of SWDS in the period 1950 - 2022 are shown in the Table 7.2-19.

Table 7.2-19: Mass of IW disposed of by categories of SWDS in the period 1950 – 2022

| Year | Mass of IW (kt) - unmanaged shallow SWDS | Mass of IW (kt) - unmanaged deep SWDS | Mass of IW (kt) - managed SWDS | TOTAL DEPOSITED IW (kt) |
|---|---|---|---|---|
| 1950 | 46.775 | 0.000 | 0.000 | 46.775 |
| 1951 | 47.954 | 0.000 | 0.000 | 47.954 |
| 1952 | 49.134 | 0.000 | 0.000 | 49.134 |
| 1953 | 50.313 | 0.000 | 0.000 | 50.313 |
| 1954 | 51.513 | 0.000 | 0.000 | 51.513 |
| 1955 | 52.722 | 0.000 | 0.000 | 52.722 |
| 1956 | 53.940 | 0.000 | 0.000 | 53.940 |
| 1957 | 55.149 | 0.000 | 0.013 | 55.162 |
| 1958 | 56.364 | 0.000 | 0.021 | 56.385 |
| 1959 | 57.580 | 0.000 | 0.028 | 57.609 |
| 1960 | 58.797 | 0.000 | 0.036 | 58.832 |
| 1961 | 60.027 | 0.000 | 0.088 | 60.115 |
| 1962 | 61.359 | 0.000 | 0.000 | 61.359 |
| 1963 | 62.641 | 0.000 | 0.000 | 62.641 |
| 1964 | 8.006 | 0.000 | 55.884 | 63.890 |
| 1965 | 7.412 | 0.926 | 56.826 | 65.164 |
| 1966 | 7.513 | 1.062 | 57.847 | 66.422 |
| 1967 | 7.625 | 1.197 | 58.868 | 67.691 |
| 1968 | 7.941 | 1.333 | 59.903 | 69.177 |
| 1969 | 8.100 | 1.463 | 61.059 | 70.621 |
| 1970 | 10.389 | 1.437 | 70.874 | 82.700 |
| 1971 | 10.668 | 1.560 | 72.072 | 84.300 |
| 1972 | 10.959 | 1.682 | 73.245 | 85.885 |
| 1973 | 11.283 | 1.805 | 74.421 | 87.509 |
| 1974 | 10.597 | 1.928 | 76.804 | 89.328 |
| 1975 | 10.463 | 2.047 | 78.640 | 91.150 |
| 1976 | 10.213 | 2.170 | 80.614 | 92.997 |
| 1977 | 8.145 | 2.293 | 84.406 | 94.844 |
| 1978 | 8.464 | 2.416 | 85.841 | 96.720 |

| Year | Mass of IW (kt) - unmanaged shallow SWDS | Mass of IW (kt) - unmanaged deep SWDS | Mass of IW (kt) - managed SWDS | TOTAL DEPOSITED IW (kt) |
|---|---|---|---|---|
| 1979 | 8.774 | 2.529 | 87.268 | 98.572 |
| 1980 | 8.302 | 2.653 | 89.586 | 100.541 |
| 1981 | 8.601 | 2.776 | 91.025 | 102.401 |
| 1982 | 7.166 | 2.988 | 94.099 | 104.253 |
| 1983 | 7.296 | 3.101 | 252.041 | 262.438 |
| 1984 | 6.681 | 3.214 | 425.562 | 435.457 |
| 1985 | 15.000 | 3.566 | 422.688 | 441.254 |
| 1986 | 15.265 | 3.685 | 425.171 | 444.121 |
| 1987 | 15.689 | 3.751 | 430.763 | 450.204 |
| 1988 | 15.915 | 3.849 | 433.613 | 453.377 |
| 1989 | 15.823 | 4.096 | 436.469 | 456.388 |
| 1990 | 9.385 | 5.220 | 448.557 | 463.162 |
| 1991 | 9.425 | 5.091 | 453.481 | 467.997 |
| 1992 | 9.734 | 5.245 | 458.044 | 473.023 |
| 1993 | 9.907 | 5.330 | 463.011 | 478.249 |
| 1994 | 9.535 | 5.396 | 468.750 | 483.681 |
| 1995 | 9.015 | 2.056 | 478.256 | 489.328 |
| 1996 | 9.607 | 29.710 | 483.381 | 522.698 |
| 1997 | 10.259 | 29.881 | 488.660 | 528.800 |
| 1998 | 10.450 | 30.066 | 495.095 | 535.611 |
| 1999 | 11.233 | 30.280 | 520.420 | 561.933 |
| 2000 | 12.056 | 30.505 | 533.972 | 576.534 |
| 2001 | 12.897 | 30.757 | 547.833 | 591.487 |
| 2002 | 14.148 | 31.033 | 579.222 | 624.403 |
| 2003 | 15.030 | 31.338 | 589.647 | 636.014 |
| 2004 | 16.179 | 31.671 | 585.345 | 633.195 |
| 2005 | 17.228 | 32.038 | 600.635 | 649.250 |
| 2006 | 18.291 | 32.185 | 607.189 | 656.304 |
| 2007 | 18.564 | 32.342 | 619.855 | 668.623 |
| 2008 | 23.359 | 35.502 | 733.366 | 789.240 |
| 2009 | 42.127 | 44.353 | 436.125 | 519.088 |
| 2010 | 18.013 | 36.050 | 341.326 | 395.389 |
| 2011 | 17.185 | 29.039 | 407.730 | 453.953 |
| 2012 | 16.729 | 43.998 | 491.674 | 552.401 |
| 2013 | 17.676 | 59.593 | 473.259 | 550.527 |
| 2014 | 65.224 | 51.105 | 377.988 | 494.316 |
| 2015 | 103.414 | 106.810 | 360.237 | 570.460 |
| 2016 | 43.041 | 92.515 | 338.731 | 474.287 |
| 2017 | 13.972 | 17.013 | 389.403 | 420.387 |
| 2018 | 0.255 | 39.547 | 372.344 | 412.145 |
| 2019 | 0.000 | 57.144 | 445.550 | 502.694 |
| 2020 | 16.648 | 17.403 | 453.109 | 487.160 |
| 2021 | 0.000 | 2.439 | 625.018 | 627.457 |
| 2022 | 0.000 | 0.000 | 756.240 | 756.240 |

A fluctuating trend for IW disposed of by categories of SWDS during reporting time series was due to multiple factors, such as the impact of the economic crisis, as well as factors related to waste avoidance/reduction and recycling measures. Significant changes in the share of IW disposed of in managed and unmanaged shallow SWDS between 1963 and 1964 are related to the start of operation of the Prudinec - Jakuševec landfill in the City of Zagreb (the same as for MSW).

Distribution of IW by waste management type at SWDS in the period 1950 - 2022 is shown in the Table 7.2-20.

Table 7.2-20: Distribution of IW by waste management type at SWDS in the period 1950 – 2022

| Year | Unmanaged shallow SWDS (%) | Unmanaged deep SWDS (%) | Managed SWDS (%) |
|---|---|---|---|
| 1950 | 100.00 | 0.00 | 0.00 |
| 1951 | 100.00 | 0.00 | 0.00 |
| 1952 | 100.00 | 0.00 | 0.00 |
| 1953 | 100.00 | 0.00 | 0.00 |
| 1954 | 100.00 | 0.00 | 0.00 |
| 1955 | 100.00 | 0.00 | 0.00 |
| 1956 | 100.00 | 0.00 | 0.00 |
| 1957 | 99.98 | 0.00 | 0.02 |
| 1958 | 99.96 | 0.00 | 0.04 |
| 1959 | 99.95 | 0.00 | 0.05 |
| 1960 | 99.94 | 0.00 | 0.06 |
| 1961 | 99.85 | 0.00 | 0.15 |
| 1962 | 100.00 | 0.00 | 0.00 |
| 1963 | 100.00 | 0.00 | 0.00 |
| 1964 | 12.53 | 0.00 | 87.47 |
| 1965 | 11.37 | 1.42 | 87.21 |
| 1966 | 11.31 | 1.60 | 87.09 |
| 1967 | 11.26 | 1.77 | 86.97 |
| 1968 | 11.48 | 1.93 | 86.59 |
| 1969 | 11.47 | 2.07 | 86.46 |
| 1970 | 12.56 | 1.74 | 85.70 |
| 1971 | 12.65 | 1.85 | 85.50 |
| 1972 | 12.76 | 1.96 | 85.28 |
| 1973 | 12.89 | 2.06 | 85.04 |
| 1974 | 11.86 | 2.16 | 85.98 |
| 1975 | 11.48 | 2.25 | 86.28 |
| 1976 | 10.98 | 2.33 | 86.68 |
| 1977 | 8.59 | 2.42 | 88.99 |
| 1978 | 8.75 | 2.50 | 88.75 |
| 1979 | 8.90 | 2.57 | 88.53 |
| 1980 | 8.26 | 2.64 | 89.10 |
| 1981 | 8.40 | 2.71 | 88.89 |
| 1982 | 6.87 | 2.87 | 90.26 |
| 1983 | 2.78 | 1.18 | 96.04 |
| 1984 | 1.53 | 0.74 | 97.73 |
| 1985 | 3.40 | 0.81 | 95.79 |
| 1986 | 3.44 | 0.83 | 95.73 |
| 1987 | 3.48 | 0.83 | 95.68 |
| 1988 | 3.51 | 0.85 | 95.64 |
| 1989 | 3.47 | 0.90 | 95.64 |
| 1990 | 2.03 | 1.13 | 96.85 |
| 1991 | 2.01 | 1.09 | 96.90 |
| 1992 | 2.06 | 1.11 | 96.83 |
| 1993 | 2.07 | 1.11 | 96.81 |
| 1994 | 1.97 | 1.12 | 96.91 |
| 1995 | 1.84 | 0.42 | 97.74 |

| Year | Unmanaged shallow SWDS (%) | Unmanaged deep SWDS (%) | Managed SWDS (%) |
|---|---|---|---|
| 1996 | 1.84 | 5.68 | 92.48 |
| 1997 | 1.94 | 5.65 | 92.41 |
| 1998 | 1.95 | 5.61 | 92.44 |
| 1999 | 2.00 | 5.39 | 92.61 |
| 2000 | 2.09 | 5.29 | 92.62 |
| 2001 | 2.18 | 5.20 | 92.62 |
| 2002 | 2.27 | 4.97 | 92.76 |
| 2003 | 2.36 | 4.93 | 92.71 |
| 2004 | 2.56 | 5.00 | 92.44 |
| 2005 | 2.65 | 4.93 | 92.41 |
| 2006 | 2.79 | 4.90 | 92.31 |
| 2007 | 2.78 | 4.84 | 92.39 |
| 2008 | 2.96 | 4.50 | 92.54 |
| 2009 | 8.12 | 8.54 | 83.34 |
| 2010 | 4.56 | 9.12 | 86.33 |
| 2011 | 3.79 | 6.40 | 89.82 |
| 2012 | 3.03 | 7.96 | 89.01 |
| 2013 | 3.21 | 10.82 | 85.96 |
| 2014 | 13.19 | 10.34 | 76.47 |
| 2015 | 18.13 | 18.72 | 63.15 |
| 2016 | 9.07 | 19.51 | 71.42 |
| 2017 | 3.32 | 4.05 | 92.63 |
| 2018 | 0.06 | 9.60 | 90.34 |
| 2019 | 0.00 | 11.37 | 88.63 |
| 2020 | 3.42 | 3.57 | 93.01 |
| 2021 | 0.00 | 0.39 | 99.61 |
| 2022 | 0.00 | 0.00 | 100.00 |

The total weighted average MCF for IW in the period 1950 - 2022 is calculated the same as for MSW and are reported in the Table 7.2-21.

Table 7.2-21: The total weighted average MCF for IW in the period 1950 – 2022

| Year | MCF (fraction) | Year | MCF (fraction) |
|---|---|---|---|
| 1950 | 0.40 | 1987 | 0.98 |
| 1951 | 0.40 | 1988 | 0.98 |
| 1952 | 0.40 | 1989 | 0.98 |
| 1953 | 0.40 | 1990 | 0.99 |
| 1954 | 0.40 | 1991 | 0.99 |
| 1955 | 0.40 | 1992 | 0.99 |
| 1956 | 0.40 | 1993 | 0.99 |
| 1957 | 0.40 | 1994 | 0.99 |
| 1958 | 0.40 | 1995 | 0.99 |
| 1959 | 0.40 | 1996 | 0.98 |
| 1960 | 0.40 | 1997 | 0.98 |
| 1961 | 0.40 | 1998 | 0.98 |
| 1962 | 0.40 | 1999 | 0.98 |
| 1963 | 0.40 | 2000 | 0.98 |
| 1964 | 0.92 | 2001 | 0.98 |

| Year | MCF (fraction) | Year | MCF (fraction) |
|---|---|---|---|
| 1965 | 0.93 | 2002 | 0.98 |
| 1966 | 0.93 | 2003 | 0.98 |
| 1967 | 0.93 | 2004 | 0.97 |
| 1968 | 0.93 | 2005 | 0.97 |
| 1969 | 0.93 | 2006 | 0.97 |
| 1970 | 0.92 | 2007 | 0.97 |
| 1971 | 0.92 | 2008 | 0.97 |
| 1972 | 0.92 | 2009 | 0.93 |
| 1973 | 0.92 | 2010 | 0.95 |
| 1974 | 0.92 | 2011 | 0.96 |
| 1975 | 0.93 | 2012 | 0.97 |
| 1976 | 0.93 | 2013 | 0.96 |
| 1977 | 0.94 | 2014 | 0.90 |
| 1978 | 0.94 | 2015 | 0.85 |
| 1979 | 0.94 | 2016 | 0.91 |
| 1980 | 0.95 | 2017 | 0.97 |
| 1981 | 0.94 | 2018 | 0.98 |
| 1982 | 0.95 | 2019 | 0.98 |
| 1983 | 0.98 | 2020 | 0.97 |
| 1984 | 0.99 | 2021 | 1.00 |
| 1985 | 0.98 | 2022 | 1.00 |
| 1986 | 0.98 | | |

**Degradable organic carbon (DOC)**

**<u>MSW</u>**

The DOC is defined as the organic carbon in waste that is accessible to biochemical decomposition. The DOC is estimated based on the composition of waste and is calculated from a weighted average of the degradable carbon content of various components (type) of the waste, using the following equation:

$$DOC = \sum_i (DOC_i \cdot W_i)$$

Where:

DOC = fraction of degradable organic carbon in waste, Gg C/Gg waste

$DOC_i$ = fraction of degradable organic carbon in waste type *i*

$W_i$ = fraction of waste type *i* by waste category

The Project defined amounts of components (food, garden, paper, wood, textile, nappies, plastics and other inert waste) of deposited MSW, required for multi-phase model based on waste composition data. Data on composition of MSW deposited at SWDS for use in the IPCC FOD model in the period 1950 - 2022 are presented in previously mentioned Table 7.2-8.

Default values for DOC content (in % of wet waste) for MSW components is taken from the 2006 IPCC Guidelines, Volume 5, Table 2.4. These values are used in the IPCC FOD model in worksheet 'Parameters'. Data are shown in the Table 7.2-22. Inert waste are wastes that do not contain degradable organic carbon (i.e. DOC = 0) e.g. plastic, glass, metal etc.

Table 7.2-22: DOC content of degradable waste components (fraction of wet waste)

| MSW component | DOC content (fraction) |
|---|---|
| Food | 0.15 |
| Garden | 0.20 |
| Paper | 0.40 |
| Wood | 0.43 |
| Textile | 0.24 |
| Nappies | 0.24 |

**IW**

The largest contribution in landfilled IW is originating from construction sector and waste treatment sector. DOC for IW has been calculated by using country-specific data on mining waste (List of Waste (LoW, Group 01), construction and demolition waste (LoW, Group 17), and waste from waste management facilities and wastewater treatment plants (LoW, Group 19).

Data on mining waste (t), construction and demolition waste (t), and waste from waste management facilities and wastewater treatment plants (t) for the period 2010 - 2022 are taken from the Waste Management Information System and the Environmental Pollution Register. Quantity of landfilled mining waste (LoW, Group 01), construction and demolition waste (LoW, Group 17) and waste from waste management facilities and wastewater treatment plants (LoW, Group 19) for the period 2010 - 2022 are presented in the Table 7.2-23.

Table 7.2-23: Quantity of landfilled mining waste (LoW, Group 01), construction and demolition waste (LoW, Group 17) and waste from waste management facilities and wastewater treatment plants (LoW, Group 19) for the period 2010 – 2022

| Year | LoW, Group 01 (t) | LoW, Group 17 (t) | LoW, Group 19 (t) | TOTAL (t) |
|---|---|---|---|---|
| 2010 | 19,374 | 259,608 | 32,030 | 311,013 |
| 2011 | 4,853 | 322,158 | 36,511 | 363,523 |
| 2012 | 16,811 | 297,574 | 27,697 | 342,082 |
| 2013 | 15,825 | 280,744 | 172,366 | 468,935 |
| 2014 | 12,218 | 299,090 | 107,392 | 418,700 |
| 2015 | 33,622 | 349,013 | 108,157 | 490,792 |
| 2016 | 14,079 | 331,134 | 91,400 | 436,613 |
| 2017 | 11,577 | 235,602 | 132,970 | 380,149 |
| 2018 | 6,979 | 199,163 | 175,521 | 381,664 |
| 2019 | 2,749 | 303,221 | 167,726 | 473,695 |
| 2020 | 5,275 | 277,078 | 190,958 | 473,311 |
| 2021 | 4,117 | 440,441 | 169,639 | 614,197 |
| 2022 | 1,425 | 545,633 | 209,183 | 756,240 |

Mining waste (LoW, Group 01) consists entirely of inert materials. Footnote 4 of Table 2.5 in the 2006 IPCC Guidelines, Volume 5 becomes relevant: "Waste from mining and quarrying should be excluded from the calculations as the amounts can be large and the DOC and fossil carbon contents are likely to be negligible."

For construction and demolition waste (LoW, Group 17) a DOC is attributed to each fraction and average DOC is calculated. Default values for DOC content (as percentage in wet waste produced) in IW components are taken from the 2006 IPCC Guidelines, Volume 5, Table 2.5. (wood - 43 percent; mixed construction and demolition waste - 4 percent).

For waste from waste management facilities and wastewater treatment plants (LoW, Group 19) a DOC is attributed to each fraction and average DOC is calculated. Default values for DOC content (as percentage in wet waste produced) in IW components are taken from the 2006 IPCC Guidelines, Volume 5, Table 2.5 (textile - 24 percent; wood - 43 percent; pulp and paper - 40 percent; rubber - 39 percent). Regarding the wastes from wastewater treatment plants, the DOC content in sludge vary depending on the wastewater treatment method producing the sludge and is different for domestic and industrial sludge (2006 IPCC Guidelines, Volume 5, Chapter 2.3.2). For domestic sludge, the default DOC value (as percentage of wet waste assuming a default dry matter content of 10 percent) is 5 percent (range 4 - 5 percent, which means that the DOC content would be 40-50 percent of dry matter). A rough default value of 9 percent DOC (assuming the dry matter content to be 35 percent) is used for industrial sludge.

DOC for mining waste (LoW, Group 01), construction and demolition waste (LoW, Group 17) and waste from waste management facilities and wastewater treatment plants (LoW, Group 19) for the period 2010 - 2022 are presented in the Table 7.2-24.

Table 7.2-24: DOC for mining waste (LoW, Group 01), construction and demolition waste (LoW, Group 17) and waste from waste management facilities and wastewater treatment plants (LoW, Group 19) and average DOC for the period 2010 – 2022

| Year | Group 01 (%) | Group 17 (%) | Group 19 (%) | Average DOC(%) |
|---|---|---|---|---|
| 2010 | 0.00 | 2.35 | 3.31 | 2.31 |
| 2011 | 0.00 | 0.88 | 2.32 | 1.01 |
| 2012 | 0.00 | 1.12 | 3.94 | 1.29 |
| 2013 | 0.00 | 0.29 | 2.18 | 0.98 |
| 2014 | 0.00 | 0.80 | 3.20 | 1.39 |
| 2015 | 0.00 | 0.91 | 3.48 | 1.42 |
| 2016 | 0.00 | 0.31 | 2.70 | 0.80 |
| 2017 | 0.00 | 0.41 | 3.02 | 1.31 |
| 2018 | 0.00 | 0.77 | 5.11 | 2.75 |
| 2019 | 0.00 | 0.33 | 7.21 | 2.76 |
| 2020 | 0.00 | 0.46 | 5.44 | 2.47 |
| 2021 | 0.00 | 0.12 | 5.70 | 1.66 |
| 2022 | 0.00 | 0.19 | 5.35 | 1.70 |

The total average DOC for the entire reporting period has been calculated from the average DOC values for the period 2010 - 2022. This value amounts 0.017 and is used in the IPCC FOD model as country specific DOC for IW in Cell E21 in worksheet 'Parameters'.

The value of 0.017 is used in both IPCC FOD models - for managed and unmanaged landfills (see explanation under paragraph Oxidation factor, OX).

Regarding ERT comment W.6, 2022[92], the total average DOC was calculated using detailed data on mass of disposed IW from different sub-groups of groups 01, 17 and 19, which account for an average of about 90% of disposed IW during the observed period. Default values for DOC content are taken from the 2006 IPCC Guidelines, as previously explained. In this way, it is assumed that all degradable components in IW are covered for the DOC calculation.

[92] FCCC/ARR/2022/HRV Report on the individual review of the annual submission of Croatia submitted in 2022, 15 March 2023

**Sludge**

DOC value of 0.05, proposed by the IPCC FOD model for sewage sludge in Cell E19 in worksheet 'Parameters', is used to calculate $CH_4$ emissions from sludge.

**Fraction of DOC which decomposes ($DOC_f$)**

The decomposition of DOC does not occur completely and some of the potentially degradable materials always remain in the site over a long period of time. According to the 2006 IPCC Guidelines, the recommended default values for $DOC_f$ = 0.5 (which means that approximately 50% of total DOC actually degrades and converts to landfill gas) has been used.

**Fraction of $CH_4$ in generated landfill gas (F)**

Collection of data on F was done based on request from the MESD sent by letter to operators of landfills which reported values to Waste Management Information System. F values range from 0.23 - 0.59 in 2022, depending on the landfills. For landfills that reported very low F values, which deviate significantly from the proposed value by the 2006 IPCC Guidelines (0.5), it was suggested to check and correct the data as needed. Explanations on the collection, verification and correction of F values are included in the Annual Data Collection Plan.

**Oxidation factor (OX)**

In 2006 IPCC Guidelines, Vol. 5, Table 3.2, default values for OX are defined as:

OX = 0 for managed (not covered with aerated material), unmanaged and uncategorised SWDS.

OX = 0.1 for managed SWDS covered with $CH_4$ oxidising material, which can refer to soil.

Covers at managed landfills in Croatia are regulated by the Ordinance on the waste landfills. Article 14 prescribes the obligation to apply best available techniques during regular operations at landfills - for disposing, covering and other preventive measures to reduce to a minimum: scattering of light fractions by wind, emission of dust and odours, gathering of vermin, birds and rodents, possibility of fire and other possible impacts on environment and human health.

In remediation plans for closed landfills, usually for finishing cover use of natural soil is recommended.

MESD does not collect data on characteristics of material used for daily cover because it is usually not classified as waste. From different documentation it could be assumed that most landfills use natural soil from various excavation activities (mostly construction works) or use inert types of mineral construction waste for this purpose. Certain amount of mineral construction waste used as daily cover is reported by some landfills as backfilling.

During the 2020 ESD review the TERT recommended Croatia to operate two separate IPCC FOD models: one for unmanaged landfills (OX=0) and one for managed landfills (OX=0.1), like the most countries that have both managed and unmanaged landfills. Both emissions are summed up to obtain total emissions. This assumption improves the comparability of the HR inventory.

**Methane generation rate constant (*k*)**

IPCC default values for *k* for Climate zone Boreal and Temperate/Wet, proposed by 2006 IPCC Guidelines (Volume 5, Chapter 3, Table 3.3) have been used. These values are used in the IPCC FOD model in worksheet 'Parameters'. Data are shown in the Table 7.2-25.

Table 7.2-25: Methane generation rate constant *k*

| MSW component | *k*, boreal and temperate/wet climate zone |
|---|---|
| Food | 0.185 |
| Garden | 0.10 |
| Paper | 0.06 |
| Wood | 0.03 |
| Textile | 0.06 |
| Nappies | 0.10 |
| Sewage sludge | 0.185 |
| Industrial waste | 0.09 |

### Half-life time($t_{1/2}$)

The value $t_{1/2}$ is the time taken for the mass of decomposable DOC in waste to decay to half of initials mass. The relationship between *k* and $t_{1/2}$ is: $k = \ln(2)/t_{1/2}$. The $t_{1/2}$ is affected by a wide variety of factors related to the composition of the waste, climatic conditions, characteristics of the SWDS, waste disposal practices and others.

In the IPCC FOD model, default values for $t_{1/2}$ have been used (Table 7.2-26).

Table 7.2-26: Half-life time $t_{1/2}$ (years)

| MSW component | Half-life time $t_{1/2}$ (years) |
|---|---|
| Food | 3.7 |
| Garden | 6.9 |
| Paper | 11.6 |
| Wood | 23.1 |
| Textile | 11.6 |
| Nappies | 6.9 |
| Sewage sludge | 3.7 |
| Industrial waste | 7.7 |

### Methane recovery (R)

Collection of data on the quantity of landfill gas captured/flared/recovered was done on the basis of request from the MESD sent by letter to operators of landfills which reported values to Waste Management Information System.

In the period 2004 – 2010 there is one landfill (Jakusevac – the largest landfill in Croatia) where flaring and electricity generation were conducted, but it is not exactly defined the amount of flared gas and the amount of gas used for electricity generation (the total amount of gas was submitted in aggregated form). Because of that, the total used landfill gas is presented as flared gas and included in the calculation for the period 2004 – 2010 for this landfill. In this period, flaring was carried out at some other landfills, which is included in the calculation. There was no electricity generation at landfill Jakusevac in 2011 and 2012 because of reconstruction the gas engine, only flaring was carried out. The data for flared $CH_4$ for all landfills in Croatia were included in the calculation for 2011 and 2012. Electricity generation was started again at landfill Jakusevac in 2013, and the data for flared and recovered gas were submitted and included in the calculation until 2022. In addition, the electricity generation was performed at the second largest landfill (Visevac) in 2016, and the data for flared and recovered gas were submitted and included in the calculation until 2022. The data for flared gas for the other landfills were submitted for the period 2013 - 2022 and included in the calculation.

The data for flared and recovered landfill gas (in m$^3$ or tonnes) and the fraction of $CH_4$ in generated landfill gas were used to calculate the mass of flared and recovered $CH_4$ (kt). When volume of landfill gas was submitted in m$^3$, a value of 0.7168 kg/m$^3$ was used for methane density and included in the $CH_4$ mass calculation.

Hence, $CH_4$ that is burned on flares (without energy recovery) in the period 2004 - 2022 has been included in emission estimation. The net $CH_4$ emissions from waste disposal were calculated by subtracting the flared $CH_4$. Data on flared $CH_4$ for the period 2004 - 2022 are presented in the CRF 5.A.1.a (Amount of $CH_4$ flared).

Emissions from the use of $CH_4$ for electricity generation are included in the Energy sector, which is in line with the 2006 IPCC Guidelines. Notation key IE is used in the CRF 5.A.1.a for the Amount of $CH_4$ for energy, for the periods 2004 - 2010 and 2013 - 2022. Allocation in the Energy sector (1.A.1.a) and NK explanation are included in the cell comments, and this information should be visible in the Reporting Table 5.A Sectoral Background Data for Waste.

The flared and recovered $CH_4$ are presented in the Table 7.2-27.

Table 7.2-27: Flared and recovered $CH_4$ (2004 - 2022)

| Year | Flared $CH_4$ (kt) | Recovered $CH_4$ for energy use (kt) |
|---|---|---|
| 2004 | 0.242 | NO |
| 2005 | 2.723 | NO |
| 2006 | 1.615 | NO |
| 2007 | 1.370 | NO |
| 2008 | 1.144 | NO |
| 2009 | 1.239 | NO |
| 2010 | 3.818 | NO |
| 2011 | 4.851 | NO |
| 2012 | 5.817 | NO |
| 2013 | 6.920 | 0.408 |
| 2014 | 4.057 | 2.872 |
| 2015 | 1.650 | 4.157 |
| 2016 | 1.871 | 4.563 |
| 2017 | 0.835 | 5.046 |
| 2018 | 1.027 | 6.306 |
| 2019 | 1.328 | 7.675 |
| 2020 | 2.159 | 6.407 |
| 2021 | 2.545 | 9.813 |
| 2022 | 1.561 | 6.704 |

NO – not occurring

A fluctuating trend for flared $CH_4$ during the period 2004 - 2022 was due to remediation of the landfills, which is explained in Chapter 7.2.1. It should be noted that all landfills are not equipped with the system for the collection and treatment of landfill gas. Reduction of flared $CH_4$ since 2015 is due to the use of $CH_4$ for electricity generation (emissions are included in the Energy sector) - more methane was energy recovered and less flared.

**Delay time**

Default value of six months for delay time, provided by the IPCC FOD model, has been used. This is equivalent to a reaction of $CH_4$ production start time of 1$^{st}$ January after deposition of waste when the average residence time of waste in the SWDS has been six months.

The resulting annual emissions of $CH_4$ from 5.A Solid Waste disposal in the period 1990 - 2022 are presented in the Figure 7.2-1.

Figure 7.2-1: Emissions of $CH_4$ from 5.A Solid waste disposal (1990 - 2022)


An increase in generated and deposited of solid waste exists during the reporting period. In recent years, the increasing trend is slower compared to the previous period and starts to decrease influenced by the implementation of the measures undertaken to avoid/reduce and recycle waste, which are still not sufficiently applied. Emissions have started to decline in 2018.

Emissions of NMVOC for the period 1990 - 2022 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution'.

### 7.2.3. Uncertainties and time-series consistency

The uncertainties contained in $CH_4$ emissions estimates are related primarily to assessment of historical data for quantity of solid waste deposited at different types of SWDS and the main characteristic of SWDS as well as the usage of default IPCC parameters.

SWDS in Croatia are classified into several categories, according to applied waste management activities, legality, volume and status. In the process of defining managed and unmanaged landfills for the entire time series, assessments have been performed using the data available in relevant databases, the Waste Management Information System and the Environmental Emission Register as well as on the basis of expert judgement based on scientific and professional literature and research. Adjustment the country-specific to IPCC SWDS classification represents uncertainty in the estimation of country-specific MCF.

Uncertainty is related to the estimation of DOC for MSW, IW and sludge. For $CH_4$ emission estimation from MSW for all years in the reporting period, a transition was made from a simpler single-phase model based on bulk waste to a more complex multi-phase model based on waste composition data. Accordingly, a smaller uncertainty was estimated than in the previous calculation, in accordance with the 2006 IPCC Guidelines. The calculated average DOC value for IW and the default DOC value for sludge affect the uncertainty estimates.

A detailed explanation of the uncertainty assessment is presented in Elaborate 7, Chapter 2.2. (uncertainty estimate associated with activity data) and Chapter 2.3. (uncertainty estimate associated with emission factor).

Accordingly collected detailed information on activity data (based on scientific and professional literature and research), the team of experts involved in the Project estimated uncertainty of activity data using values recommended in the 2006 IPCC Guidelines, which are included in the tables in the uncertainty assessment chapters for individual categories. Uncertainty estimation based on expert judgment follows the 2006 IPCC Guidelines, Volume 1, Chapter 3. Uncertainties of activity data are given in the Table 7.2-28.

Uncertainties of emission factor were estimated using values recommended in the 2006 IPCC Guidelines. Uncertainties of emission factor are given in the Table 7.2-29.

Table 7.2-28: Uncertainty range of activity data for category 5.A

| IPCC category | Gas | Uncertainty of emission factor | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.A Solid waste disposal** | **$CH_4$** | | |
| 5.A.1 Managed Waste Disposal Sites / 5.A.1.a Anaerobic | $CH_4$ | -10 | 10 |
| 5.A.2 Unmanaged Waste Disposal Sites | $CH_4$ | -10 | 10 |

Table 7.2-29: Uncertainty range of emission factor for category 5.A

| IPCC category | Gas | Uncertainty of emission factor | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.A Solid waste disposal** | **$CH_4$** | | |
| 5.A.1 Managed Waste Disposal Sites / 5.A.1.a Anaerobic | $CH_4$ | -20 | 20 |
| 5.A.2 Unmanaged Waste Disposal Sites | $CH_4$ | -20 | 20 |

More detailed information on uncertainty assessment are presented in Annex 2.

Emissions from 5.A Solid waste disposal have been calculated using the same method for every year in the time series. Different sources of information were used for data sets.

### 7.2.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and correct transformation/transcription into CRF tables as well proper use of notation keys, according to QA/QC plan.

During the data collection and administration, data were checked in terms of completeness and plausibility. To clarify any discrepancies, the institution responsible for providing the data was contacted. All steps of data verification and validation are documented.

During the inventory preparation, the correctness of all data and parameters in the estimate files were checked. Plausibility of the results of estimations and their trends were checked and documented. All assumptions, expert judgements and recalculations were explained. Transformation/transcription of activity data and calculated emissions into CRF were checked to compare with information in background calculation tables.

$CH_4$ emissions from 5.A Solid waste disposal were estimated using the Tier 2 methodology that is a good practice. The uncertainty of activity data is low due to detailed information on activity data based on scientific and professional literature and research. Basic country-specific data and parameters for $CH_4$ emission calculation were compared with data set from similar countries.

All input data and information relevant for the emissions calculation have been documented and archived.

### 7.2.5. Category-specific recalculations

With the aim of collecting all the necessary data for the emission calculation and improving reporting on GHG emissions from category 5.A, the Ministry of Economy and Sustainable Development launched the project **System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950**. Comprehensive research in the Project regarding system improvements and the development of historical databases resulted in data and parameters that are included in the IPCC FOD model. The results of the emission calculations show deviation from the results of the previous emission calculations, since the data collected by the Project are more detailed and accurate, based on scientific and professional literature and research. Until now, Croatia used single-phase model based on bulk waste. The Project defined amounts of components (food, garden, paper, wood, textile, nappies, plastics and other inert waste) of deposited MSW, required for multi-phase model based on waste composition data, which is currently in use. Therefore, recalculations of $CH_4$ emissions were made for the period 1990 - 2021.

The difference in $CO_2$-eq emission from category 5.A Solid waste disposal calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 - 2021 are presented in the Table 7.2-30.

Table 7.2-30: The difference in $CO_2$-eq emission from category 5.A Solid waste disposal calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 – 2021

| Year | The mass difference in emissions $CO_2$-eq (kt) | The percentage difference in emissions $CO_2$-eq (%) |
|---|---|---|
| 1990 | 187.686 | 50.60 |
| 1991 | 190.606 | 48.62 |
| 1992 | 191.323 | 46.42 |
| 1993 | 185.152 | 42.90 |
| 1994 | 184.966 | 40.93 |
| 1995 | 188.554 | 39.78 |
| 1996 | 189.783 | 37.94 |
| 1997 | 189.269 | 35.80 |
| 1998 | 184.949 | 32.99 |
| 1999 | 184.628 | 31.09 |
| 2000 | 175.557 | 27.78 |
| 2001 | 169.730 | 25.34 |
| 2002 | 161.251 | 22.61 |
| 2003 | 150.816 | 19.79 |
| 2004 | 138.886 | 17.16 |
| 2005 | 125.972 | 15.65 |
| 2006 | 119.524 | 13.45 |
| 2007 | 115.308 | 11.97 |
| 2008 | 138.812 | 13.17 |
| 2009 | 156.403 | 13.66 |
| 2010 | 152.095 | 12.97 |
| 2011 | 165.856 | 13.70 |
| 2012 | 174.705 | 14.05 |
| 2013 | 177.202 | 14.31 |

| Year | The mass difference in emissions $CO_2$-eq (kt) | The percentage difference in emissions $CO_2$-eq (%) |
|---|---|---|
| 2014 | 175.238 | 13.63 |
| 2015 | 168.853 | 12.63 |
| 2016 | 138.189 | 10.12 |
| 2017 | 113.238 | 8.01 |
| 2018 | 89.668 | 6.38 |
| 2019 | 69.034 | 5.01 |
| 2020 | 47.836 | 3.43 |
| 2021 | 48.214 | 3.81 |

### 7.2.6. Category-specific planned improvements

The aim of the project is improving the transparency, accuracy, completeness, comparability and consistency of GHG inventory from the category 5.A Solid waste disposal, in accordance with the recommendations/requirements of ERT. An effort was made to evaluate and compile data coming from different sources and adjust them to the recommended IPCC methodology which used for $CH_4$ emission estimation.

Data sources defined by the Project will be used to collect of national data and information in future inventories, as well as methodologies to adjust country-specific circumstances to the IPCC methodological guidelines.

## 7.3. Biological treatment of solid waste (CRF 5.B)

### 7.3.1. Category description

According to the 2006 IPCC Guidelines, $CH_4$ and $N_2O$ emissions resulting from 5.B.1 Composting and $CH_4$ emission resulting from 5.B.2 Anaerobic digestion at biogas facilities are included in 5.B Biological treatment of solid waste.

Emissions from biogas combustion are included in the Energy sector, which is in line with the 2006 IPCC Guidelines.

Data on mass of feedstock treated by composting and anaerobic digestion at biogas facilities and dry matter content in composted and digested waste were collected and analysed for entire reporting period from 1990 to 2022, as outputs of the Project.

According to the analyses made in the Project, the outputs of the project for improving the pollutant inventory for the sector composting[93] and the project for improving the pollutant inventory for the sector anaerobic digestion at biogas facilities[94] were used for historical data, while for the more recent period verified data from the EPR database were used.

Detailed explanation are provided in Elaborate 1, Chapter 2.2.1.3.; Elaborate 2, Chapter 2.2.1.3. and Elaborate 3, Chapter 2.2.2.

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[93] Izvješće o unapređenju proračuna za sektor kompostiranje (NFR 5.B.1), in Croatian (Report on inventory improvement for sector composting (NFR 5.B.1)), Client: Ministry of Economy and Sustainable Development, Executor: EKONERG d.o.o., 2021

[94] Izvješće o unapređenju proračuna za sektor anaerobna digestija u bioplinskim postrojenjima (NFR 5.B.2), in Croatian (Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)), Client: Ministry of Economy and Sustainable Development, Executor: EKONERG d.o.o., 2022

### 7.3.2. Methodological issues

#### 7.3.2.1. Composting

Category 5.B.1 Composting is not a key source. The $CH_4$ emissions from composting of organic waste have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total composted waste (tonnes, dry weight) with default values for $CH_4$ emission factor (10 kg $CH_4$/t waste treated, on a dry weight basis).

$N_2O$ emissions from composting of organic waste have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total composted waste (tonnes, dry weight) with default values for $N_2O$ emission factor (0.60 kg $N_2O$/t waste treated, on a dry weight basis).

Relevant activity data is the annual quantity of composted waste. The sources of activity data are:

- eleven legal entities that own the composting facilities, with two branches within one legal entity (a total of twelve composting facilities) - data were collected for the period 1999 - 2006;
- EPR database - verified data were collected for the period 2007 - 2022.

The composting process has been applied in the Republic of Croatia since 1994. Data from one composting facility, which first started operating in 1994, are not available for the period from 1994 to 1999, so they were estimated by the method of linear extrapolation. Data for the period from 1994 to 1999 were calculated considering the trend of the mass of composted waste for the period from 2000 to 2002, since in that period the data do not differ significantly, so the calculated values show a similar trend.

Data on mass of composted waste (on a wet weight basis, t) and dry matter content of waste (kg $kg^{-1}$) were collected. Data on mass of composted waste include data on different categories of waste according to the European List of Waste (LoW) and by-products.

The total annual mass of composted waste (on a wet weight basis) includes the mass of municipal waste, industrial waste, sludge and other organic waste (slurry and manure):

- municipal solid waste (groups 15 01 and 20)
  - for the period 1994 - 2006, the outputs of the project for improving the pollutant inventory for the sector composting were used (Elaborate 1, Chapter 2.2.1.1.; Table 2.2-12);
  - for the period 2007 - 2022, verified data from the EPR database were used (Elaborate 1, Chapter 2.2.1.1. Table 2.2-14, updated with new data for 2022[95]);
- industrial waste (groups 02, 03, 04, 10, 17)
  - for the period 2013 - 2022, verified data from the EPR database were used (Elaborate 2, Chapter 2.2.1.1., Table 2.2-25 updated with new data for 2022);
- sludge (group 19) and other organic waste (slurry and manure)
  - for the period 2013 - 2022, verified data from the EPR database were used (Elaborate 3, Chapter 2.2.1., Table 2.2-5, updated with new data for 2022).

For waste according to the European List of Waste (LoW), dry matter content varies depending on the waste category. To estimate dry matter content, the average percentages of dry matter in composted waste were collected by the EPR database (verified data) for groups 15 01, 19 and 20 (Elaborate 1, Chapter 2.2.1.1., Table 2.2-15, updated with new data for 2022) and by the project for improving the

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[95] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Ministry of Economy and Sustainable Development (the web format of the document is not available at the time the NIR report is being created)

pollutant inventory for the sector composting for groups 02, 03, 04, 10 and 17 (Elaborate 2, Chapter 2.2.1.1.; Table 2.2-24).

Data on different types of waste (dry weight) treated by composting are calculated (Elaborate 1, Chapter 2.2.1.3, Table 2.2-26; Elaborate 2, Chapter 2.2.1.3, Table 2.2-49; Elaborate 3, Chapter 2.2.2., Table 2.2-10, updated with new data for 2022). Data on dry weight of different types of waste are shown in the Table 7.3-1. Data on dry matter in composted waste are shown in the Table 7.3-2.

Table 7.3-1: Data on dry weight of different types of waste treated by composting for the period 1990 – 2022

| Year | Municipal solid waste - groups 15 01, 20 (kt) | Industrial waste - groups 02, 03, 04, 10, 17 (kt) | Sludge - group 19 (kt) | Other organic waste -slurry and manure (kt) | **TOTAL composted waste (kt)** |
|---|---|---|---|---|---|
| 1990 | NO | NO | NO | NO | **NO** |
| 1991 | NO | NO | NO | NO | **NO** |
| 1992 | NO | NO | NO | NO | **NO** |
| 1993 | NO | NO | NO | NO | **NO** |
| 1994 | 2.177 | NO | NO | NO | **2.177** |
| 1995 | 2.304 | NO | NO | NO | **2.304** |
| 1996 | 2.431 | NO | NO | NO | **2.431** |
| 1997 | 2.558 | NO | NO | NO | **2.558** |
| 1998 | 2.685 | NO | NO | NO | **2.685** |
| 1999 | 2.811 | NO | NO | NO | **2.811** |
| 2000 | 3.185 | NO | NO | NO | **3.185** |
| 2001 | 2.571 | NO | NO | NO | **2.571** |
| 2002 | 3.439 | NO | NO | NO | **3.439** |
| 2003 | 2.460 | NO | NO | NO | **2.460** |
| 2004 | 2.909 | NO | NO | NO | **2.909** |
| 2005 | 5.268 | NO | NO | NO | **5.268** |
| 2006 | 4.078 | NO | NO | NO | **4.078** |
| 2007 | 8.984 | NO | NO | NO | **8.984** |
| 2008 | 8.766 | NO | NO | NO | **8.766** |
| 2009 | 7.368 | NO | NO | NO | **7.368** |
| 2010 | 7.952 | NO | NO | NO | **7.952** |
| 2011 | 8.270 | NO | NO | NO | **8.270** |
| 2012 | 15.314 | NO | NO | NO | **15.314** |
| 2013 | 17.337 | 2.734 | 1.179 | 0.086 | **21.336** |
| 2014 | 19.745 | 1.758 | 0.421 | 0.062 | **21.986** |
| 2015 | 16.182 | 18.429 | 0.314 | 0.043 | **34.968** |
| 2016 | 17.690 | 2.190 | 0.336 | 0.190 | **20.407** |
| 2017 | 20.582 | 1.352 | 0.172 | 0.914 | **23.019** |
| 2018 | 24.428 | 1.251 | 0.325 | 0.470 | **26.474** |
| 2019 | 26.503 | 1.364 | 0.260 | 0.071 | **28.198** |
| 2020 | 37.760 | 1.103 | 1.078 | 0.088 | **40.029** |
| 2021 | 42.190 | 1.589 | 2.540 | 0.045 | **46.364** |
| 2022 | 47.769 | 0.842 | 7.236 | 0.047 | **55.894** |

NO - not occuring

Table 7.3-2: Dry matter content of composted waste (kg kg$^{-1}$)

| LoW | Dry matter content (kg kg$^{-1}$) |
|---|---|
| Group 02 | 0.40 |
| Group 03 | 0.55 |

| LoW | Dry matter content (kg kg$^{-1}$) |
|---|---|
| Group 04 | 0.55 |
| Group 10 | 0.60 |
| Group 15 | 0.878 |
| Group 17 | 0.50 |
| Group 19 | 0.26 |
| Group 20 | 0.50 |

The resulting emissions of $CH_4$ and $N_2O$ from 5.B.1 Composting in the period 1990 - 2022 are presented in the Table 7.3-3.

Table 7.3-3: Emissions of $CH_4$ and $N_2O$ from 5.B.1 Composting (1990 - 2022)

| Year | $CH_4$ emission (kt) | $N_2O$ emission (kt) |
|---|---|---|
| 1990 | NO | NO |
| 1991 | NO | NO |
| 1992 | NO | NO |
| 1993 | NO | NO |
| 1994 | 0.022 | 0.001 |
| 1995 | 0.023 | 0.001 |
| 1996 | 0.024 | 0.001 |
| 1997 | 0.026 | 0.002 |
| 1998 | 0.027 | 0.002 |
| 1999 | 0.028 | 0.002 |
| 2000 | 0.032 | 0.002 |
| 2001 | 0.026 | 0.002 |
| 2002 | 0.034 | 0.002 |
| 2003 | 0.025 | 0.001 |
| 2004 | 0.029 | 0.002 |
| 2005 | 0.053 | 0.003 |
| 2006 | 0.041 | 0.002 |
| 2007 | 0.090 | 0.005 |
| 2008 | 0.088 | 0.005 |
| 2009 | 0.074 | 0.004 |
| 2010 | 0.080 | 0.005 |
| 2011 | 0.083 | 0.005 |
| 2012 | 0.153 | 0.009 |
| 2013 | 0.213 | 0.013 |
| 2014 | 0.220 | 0.013 |
| 2015 | 0.350 | 0.021 |
| 2016 | 0.204 | 0.012 |
| 2017 | 0.230 | 0.014 |
| 2018 | 0.265 | 0.016 |
| 2019 | 0.282 | 0.017 |
| 2020 | 0.400 | 0.024 |
| 2021 | 0.464 | 0.028 |
| 2022 | 0.559 | 0.034 |

NO – not occurring

Notation key IE is used in the CRF 5.B.1.b for entire period 1990 - 2022. Allocation in the CRF 5.B.1.a and NK explanation are included in the cell comments, and this information should be visible in the Reporting Table 5.B Sectoral Background Data for Waste.

Emissions of $NH_3$ for the period 1994 - 2022 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution'.

#### 7.3.2.2. Anaerobic Digestion at Biogas Facilities

Category 5.B.2 Anaerobic digestion at biogas facilities is not a key source. The $CO_2$ emissions from anaerobic digestion at biogas facilities are of biogen origin and are reported as an information item in the Energy sector, ($CO_2$bio).

Generated $CH_4$ is used to produce electricity, wherefore reporting of emissions from the process is done in the Energy sector. $CH_4$ emissions from biogas facilities due to unintentional leakages during process disturbances or other unexpected events are generally between 0 and 10 percent of the amount of $CH_4$ generated (5 percent as a default value could be used for the $CH_4$ emission calculation).

$CH_4$ emissions from anaerobic digestion of organic waste at biogas facilities have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total digested waste (tonnes, dry weight) with default values for $CH_4$ emission factor (2 kg $CH_4$/t waste treated, on a dry weight basis).

According to the TERT recommendation during the 2022 ESD review, Step 1, HR-5B-2022-0001, $N_2O$ emissions from anaerobic digestion of organic waste at biogas facilities are reported as NE, according to the explanation in the Table 4.1 of the Vol 5, Chap 4 of the 2006 IPCC GL - default emission factor for $N_2O$ emissions from anaerobic digestion at bigas facilities is assumed as negligible.

Relevant activity data is the annual quantity of digested waste. The sources of activity data are:

- twenty legal entities that own the biogas facilities, with four legal entities having several branches - a total of twenty-eight biogas facilities - data were collected for the period 2009 - 2012;
- EPR database - verified data were collected for the period 2013 - 2022.

The anaerobic digestion at biogas facilities has been applied in the Republic of Croatia since 2009.

Data on mass of digested waste (on a wet weight basis, t) and dry matter content of waste (kg $kg^{-1}$) were collected. Data on mass of digested waste include data on different categories of waste according to the European List of Waste (LoW) and by-products.

The total annual mass of digested waste (on a wet weight basis) includes the mass of municipal waste, industrial waste, sludge and other organic waste (slurry and manure):

- municipal solid waste (groups 15 01 and 20)
    - for the period 2009 - 2012, the outputs of the project for improving the pollutant inventory for the sector anaerobic digestion at biogas facilities were used (Elaborate 1, Chapter 2.2.1.1.; Table 2.2-16);
    - for the period 2013 - 2022, verified data from the EPR database were used (Elaborate 1, Chapter 2.2.1.1. Table 2.2-18, updated with new data for 2022[96]);
- industrial waste (group 02)

[96] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Ministry of Economy and Sustainable Development (the web format of the document is not available at the time the NIR report is being created)

- for the period 2013 - 2022, verified data from the EPR database were used (Elaborate 2, Chapter 2.2.1.1., Table 2.2-28 updated with new data for 2022);

- sludge (groups 02, 03 and 19) and other organic waste (slurry and manure)
  - for the period 2013 - 2022, verified data from the EPR database were used (Elaborate 3, Chapter 2.2.1., Table 2.2-8, updated with new data for 2022).

For waste according to the European List of Waste (LoW), dry matter content varies depending on the waste category. To estimate dry matter content, the average percentages of dry matter in digested waste were collected by the project for improving the pollutant inventory for the sector anaerobic digestion at biogas facilities. The values of dry matter content of waste and by-products were estimated using collected data and recommended values from EMEP/EEA GB2023 (Table 3.4, GB2023, 5.B.2 Biological treatment of waste - anaerobic digestion at biogas facilities 2023).

Data on different types of waste (dry weight) treated by anaerobic digestion at biogas facilities are calculated (Elaborate 1, Chapter 2.2.1.3, Table 2.2-27; Elaborate 2, Chapter 2.2.1.3, Table 2.2-50; Elaborate 3, Chapter 2.2.2., Table 2.2-11, updated with new data for 2022). Data on dry weight of different types of waste are shown in the Table 7.3-4. Data on dry matter content in digested waste are shown in the Table 7.3-5.

Table 7.3-4: Data on dry weight of different types of waste treated by anaerobic digestion at biogas facilities for the period 1990 – 2022

| Year | Municipal solid waste - groups 15 01, 20 (kt) | Industrial waste - group 02 (kt) | Sludge - groups 02, 03, 19 (kt) | Other organic waste -slurry and manure (kt) | **TOTAL digested waste (kt)** |
|---|---|---|---|---|---|
| 1990 | NO | NO | NO | NO | **NO** |
| 1991 | NO | NO | NO | NO | **NO** |
| 1992 | NO | NO | NO | NO | **NO** |
| 1993 | NO | NO | NO | NO | **NO** |
| 1994 | NO | NO | NO | NO | **NO** |
| 1995 | NO | NO | NO | NO | **NO** |
| 1996 | NO | NO | NO | NO | **NO** |
| 1997 | NO | NO | NO | NO | **NO** |
| 1998 | NO | NO | NO | NO | **NO** |
| 1999 | NO | NO | NO | NO | **NO** |
| 2000 | NO | NO | NO | NO | **NO** |
| 2001 | NO | NO | NO | NO | **NO** |
| 2002 | NO | NO | NO | NO | **NO** |
| 2003 | NO | NO | NO | NO | **NO** |
| 2004 | NO | NO | NO | NO | **NO** |
| 2005 | NO | NO | NO | NO | **NO** |
| 2006 | NO | NO | NO | NO | **NO** |
| 2007 | NO | NO | NO | NO | **NO** |
| 2008 | NO | NO | NO | NO | **NO** |
| 2009 | NO | NO | NO | 1.215 | **1.215** |
| 2010 | NO | NO | NO | 3.285 | **3.285** |
| 2011 | NO | NO | NO | 4.635 | **4.635** |
| 2012 | NO | NO | NO | 9.410 | **9.410** |
| 2013 | 0.008 | 0.752 | 0.753 | 1.092 | **2.605** |
| 2014 | 0.021 | 24.833 | 2.514 | 4.488 | **31.855** |
| 2015 | 0.053 | 44.142 | 0.588 | 5.256 | **50.039** |
| 2016 | 0.386 | 58.004 | 2.399 | 44.648 | **105.437** |
| 2017 | 1.461 | 36.235 | 2.505 | 26.978 | **67.178** |
| 2018 | 2.896 | 14.465 | 2.610 | 9.308 | **29.279** |

| Year | Municipal solid waste - groups 15 01, 20 (kt) | Industrial waste - group 02 (kt) | Sludge - groups 02, 03, 19 (kt) | Other organic waste -slurry and manure (kt) | **TOTAL digested waste (kt)** |
|---|---|---|---|---|---|
| 2019 | 7.151 | 11.073 | 5.274 | 11.001 | **34.499** |
| 2020 | 11.765 | 15.532 | 7.632 | 10.354 | **45.282** |
| 2021 | 6.918 | 20.069 | 9.023 | 11.702 | **47.711** |
| 2022 | 4.916 | 24.188 | 13.676 | 23.019 | **65.799** |

NO - not occuring

Table 7.3-5: Dry matter content of digested waste (kg $kg^{-1}$)

| LoW/by-product code | | Dry matter content (kg $kg^{-1}$) |
|---|---|---|
| 02, 03, 15, 19, 20 | | 0.40 |
| K3 | food waste | 0.40 |
| K3 | milk | 0.12 |
| K3 | whey | 0.07 |
| K2 | poultry manure | 0.50 |
| K2 | pig solid manure | - |
| K2 | pig slurry | 0.04 |
| K2 | cattle slurry | 0.03 - 0.04 |
| K2 | catle solid manure | 0.24 - 0.25 |
| | silage | 0.32 - 0.35 |
| | beer trope | 0.35 |

Note:

- for groups 02, 03, 15, 19, 20, the recommended value for municipal waste from Table 3.4, EMEP/EEA GB2023, 5.B.2 was estimated
- for K3 food waste and beer trope, the recommended values from Table 3.4, EMEP/EEA GB2023 (estimates for certain types of waste/by-products) were estimated
- for K3 milk, whey and K2 poultry manure, pig and cattle manure, cattle solid manure and silage, the estimated and submitted values from the questionnaire were used

The resulting emissions of $CH_4$ from 5.B.2 Anaerobic digestion at biogas facilities in the period 1990 - 2022 are presented in the Table 7.3-6.

Table 7.3-6: Emissions of $CH_4$ and $N_2O$ from 5.B.2 Anaerobic digestion at biogas facilities (1990 - 2022)

| Year | $CH_4$ emission (kt) | $N_2O$ emission (kt) |
|---|---|---|
| 1990 | NO | NO |
| 1991 | NO | NO |
| 1992 | NO | NO |
| 1993 | NO | NO |
| 1994 | NO | NO |
| 1995 | NO | NO |
| 1996 | NO | NO |
| 1997 | NO | NO |
| 1998 | NO | NO |
| 1999 | NO | NO |
| 2000 | NO | NO |
| 2001 | NO | NO |
| 2002 | NO | NO |
| 2003 | NO | NO |
| 2004 | NO | NO |

| Year | $CH_4$ emission (kt) | $N_2O$ emission (kt) |
|---|---|---|
| 2005 | NO | NO |
| 2006 | NO | NO |
| 2007 | NO | NO |
| 2008 | NO | NO |
| 2009 | 0.002 | NE |
| 2010 | 0.007 | NE |
| 2011 | 0.009 | NE |
| 2012 | 0.019 | NE |
| 2013 | 0.005 | NE |
| 2014 | 0.064 | NE |
| 2015 | 0.100 | NE |
| 2016 | 0.211 | NE |
| 2017 | 0.134 | NE |
| 2018 | 0.059 | NE |
| 2019 | 0.069 | NE |
| 2020 | 0.091 | NE |
| 2021 | 0.095 | NE |
| 2022 | 0.132 | NE |

NO – not occurring
NE – not estimated

According to the TERT recommendation during the 2022 ESD review, Step 1, HR-5B-2022-0001, $N_2O$ emissions from anaerobic digestion of organic waste at biogas facilities are reported as NE. Notation key NE is used in the CRF 5.B.2.a for the period 2009 - 2022. NK explanation is included in the cell comments: Table 4.1 of the Vol 5, Chap 4 of the 2006 IPCC GL - default emission factor for $N_2O$ emissions from anaerobic digestion at bigas facilities is assumed as negligible. This information should be visible in the Reporting Table 5.B Sectoral Background Data for Waste.

Generated $CH_4$ is used to produce electricity, wherefore reporting of emissions from the process is done in the Energy sector. Notation key IE is used in the CRF 5.B.2.a and CRF 5.B.2.b for the entire period in which electricity was generated (2009 - 2022). Allocation in the Energy sector (1.A.1, 1.A.4) and NK explanation are included in the cell comments, and this information should be visible in the Reporting Table 5.B Sectoral Background Data for Waste.

Notation key IE is used in the CRF 5.B.2.b for the period 2009 - 2022. Allocation in the CRF 5.B.2.a and NK explanation are included in the cell comments, and this information should be visible in the Reporting Table 5.B Sectoral Background Data for Waste.

Emissions of $NH_3$ for the period 2009 - 2022 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution'.

### 7.3.3. Uncertainties and time-series consistency

The uncertainties contained in $CH_4$ and $N_2O$ emissions estimates from composting and $CH_4$ emission from anaerobic digestion at biogas facilities are related primarily to applied default emission factors.

A detailed explanation of the uncertainty assessment is presented in Elaborate 7, Chapter 2.2. (uncertainty estimate associated with activity data) and Chapter 2.3. (uncertainty estimate associated with emission factor).

Accordingly collected detailed information on activity data (based on professional literature and research), the team of experts involved in the Project estimated uncertainty of activity data using values recommended in the 2006 IPCC Guidelines, which are included in the tables in the uncertainty assessment chapters for individual categories. Uncertainty estimation based on expert judgment follows the 2006 IPCC Guidelines, Volume 1, Chapter 3. Uncertainties of activity data are given in the Table 7.3-7.

Uncertainties of emission factor were estimated using values recommended in the 2006 IPCC Guidelines. Uncertainties of emission factor are given in the Table 7.3-8.

Table 7.3-7: Uncertainty range of activity data for category 5.B

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.B Biological treatment of solid waste** | **$CH_4$** | | |
| 5.B.1 Composting | $CH_4$ | -10 | 10 |
| 5.B.2 Anaerobic digestion at biogas facilities | $CH_4$ | -10 | 10 |
| **5.B Biological treatment of solid waste** | **$N_2O$** | | |
| 5.B.1 Composting | $N_2O$ | -10 | 10 |

Table 7.3-8: Uncertainty range of emission factor for category 5.B

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.B Biological treatment of solid waste** | **$CH_4$** | | |
| 5.B.1 Composting | $CH_4$ | -100 | 100 |
| 5.B.2 Anaerobic digestion at biogas facilities | $CH_4$ | -100 | 100 |
| **5.B Biological treatment of solid waste** | **$N_2O$** | | |
| 5.B.1 Composting | $N_2O$ | -110 | 110 |

More detailed information on uncertainty assessment is presented in Annex 2.

Emissions from 5.B Biological treatment of solid waste have been calculated using the same method for every year in the time series. Different sources of information were used for data sets.

### 7.3.4. Category-specific QA/QC and verification

During the preparation of the inventory submission, activities related to quality control were mainly focused on completeness and consistency of emission estimates and correct transformation/transcription into CRF tables as well proper use of notation keys, according to QA/QC plan.

During the data collection and administration, data were checked in terms of completeness and plausibility. To clarify any discrepancies, the institution responsible for providing the data was contacted. All steps of data verification and validation are documented.

During the inventory preparation, the correctness of all data and parameters in the estimate files were checked. Plausibility of the results of estimations and their trends were checked and documented. All assumptions, expert judgements and recalculations were explained. Transformation/transcription of activity data and calculated emissions into CRF were checked to compare with information in background calculation tables.

The $CH_4$ and $N_2O$ emissions from 5.B.1 Composting and 5.B.2 Anaerobic digestion at biogas facilities were estimated using the Tier 1 methodology. Detailed information on activity data are based on professional literature and research.

All input data and information relevant for the emissions calculation have been documented and archived.

### 7.3.5. Category-specific recalculations

With the aim of collecting all the necessary data for the emission calculation and improving reporting on GHG emissions from category 5.B Biological treatment of solid waste, the Ministry of Economy and Sustainable Development launched the project **System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950**. Comprehensive research in the Project regarding system improvements and the development of historical databases resulted in data that are included in the IPCC models. The results of the emission calculations show deviation from the results of the previous emission calculations, since the data collected by the Project are more detailed and accurate, based on professional literature and research. Therefore, recalculations of $CH_4$ emissions were made for the period 1990 - 2021, and recalculations of $N_2O$ emissions were made for the period 2013 - 2021.

The difference in $CO_2$-eq emission from category 5.B Biological treatment of solid waste calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 - 2021 are presented in the Table 7.3-9.

Table 7.3-9: The difference in $CO_2$-eq emission from category 5.B Biological treatment of solid waste calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 – 2021

| Year | The mass difference in emissions $CO_2$-eq (kt) | The percentage difference in emissions $CO_2$-eq (%) |
|---|---|---|
| 1990 | NO | NO |
| 1991 | NO | NO |
| 1992 | NO | NO |
| 1993 | NO | NO |
| 1994 | 0.028 | 3.01 |
| 1995 | 0.030 | 3.01 |
| 1996 | 0.031 | 3.01 |
| 1997 | 0.033 | 3.01 |
| 1998 | 0.034 | 3.01 |
| 1999 | 0.036 | 3.01 |
| 2000 | 0.041 | 3.01 |
| 2001 | 0.033 | 3.01 |
| 2002 | 0.044 | 3.01 |
| 2003 | 0.032 | 3.01 |
| 2004 | 0.037 | 3.01 |
| 2005 | 0.068 | 3.01 |
| 2006 | 0.052 | 3.01 |
| 2007 | 0.042 | 1.07 |
| 2008 | -0.517 | -11.85 |
| 2009 | -1.248 | -27.42 |
| 2010 | -1.215 | -24.84 |
| 2011 | -1.527 | -28.18 |
| 2012 | -1.998 | -21.61 |
| 2013 | -0.066 | -0.69 |
| 2014 | -0.931 | -7.53 |
| 2015 | -1.180 | -6.10 |
| 2016 | -8.385 | -36.07 |
| 2017 | -10.491 | -43.07 |
| 2018 | -1.061 | -7.41 |
| 2019 | -1.097 | -7.12 |
| 2020 | -0.192 | -0.95 |
| 2021 | -3.662 | -13.72 |

NO – not occurring

### 7.3.6. Category-specific planned improvements

The aim of the project is improving the transparency, accuracy, completeness, comparability and consistency of GHG inventory from the category 5.B Biological treatment of solid waste, in accordance with the recommendations/requirements of ERT. An effort was made to evaluate and compile data coming from different sources and adjust them to the recommended IPCC methodology which used for $CH_4$ and $N_2O$ emission estimation.

Data sources defined by the Project will be used to collect of national data and information in future inventories, as well as methodologies to adjust country-specific circumstances to the IPCC methodological guidelines.

## 7.4. Incineration and open burning of waste (CRF 5.C)

### 7.4.1. Category description

According to the 2006 IPCC Guidelines, $CO_2$, $CH_4$ and $N_2O$ emissions resulting from incineration of waste without energy recovery should be included in emissions estimates from the Waste sector. Emissions from incineration with energy recovery should be reported in the Energy sector.

The official source of activity data for waste incineration (CRF 5.C.1) is MESD that collects data from emission point sources in the EPR database. According to the Ordinance on the Environmental Pollution Register[97], the completed forms should be submitted for the previous calendar year not later than March 1 of the current year. The competent authority (administrative department of the county and the City of Zagreb) ensures the checking of data submitted in terms of their completeness, consistency and credibility. The MESD coordinates activities relating to data quality assurance and control.

Data for the period 2008 - 2022 on the total amount of incinerated waste by operation D10 (Incineration on land) and R1 (Use principally as a fuel or other means to generate energy) has been based on validated PL-OPKO forms - Registration form for entities carrying out the municipal and/or industrial waste recovery/disposal (for the period 2008 - 2016), and OZO forms - Waste recovery/disposal (for the period 2017 - 2022).

$CO_2$ and $N_2O$ emissions from incineration of IW are included in emission estimates for the period 1990 - 2008. After 2008, incineration of IW was performed with energy recovery and emissions are included in the Energy sector.

$CO_2$ emissions from the incineration of clinical waste are included in emission estimates for the period 1990 - 2016. There was no incineration of clinical waste without energy recovery in the period 2017 - 2022.

No other types of waste are reported for incineration without energy recovery.

Regarding comparison between activity data for clinical waste and the Eurostat data, which was discussed during the centralized review 2022, it was emphasized that data source for Eurostat data 2012 - 2016 was Institute for Environment and Nature within the MESD (previously Croatian Environment Agency and Croatian Agency for Environment and Nature). Data source for Eurostat data 2004 - 2010 was Croatian Bureau of Statistics. Those data were sent to Eurostat on voluntary basis. Data collection was performed by Croatian Bureau of Statistics (CBS) by biannual survey, requesting data from companies registered for waste treatment by NACE classification. Those data were not used for Croatia’s report.

On the other hand, in the same period, Croatian Environment Agency had established the Croatian Environmental Pollution Register (EPR) to which the waste operators with issued waste management

[97] Ordinance on the Environmental Pollution Register (OG 3/2022)

permit have delivered annual data based on the obligation set in Waste Act and Ordinance on Environmental Pollution Register. Those data were used for Croatia's report.

That's means the Croatia had two parallel waste data collection procedures until 2011 which differed in methodology (differences in coverage/sources/classifications), therefore the results were different. Croatia solved this problem by the Agreement between Croatian Bureau of Statistics and Croatian Environment Agency, by which the Agency became the official and only source for waste data since 2011.

The data which we prefer to be used for NIR were always administrative data, which means the data collection is based on obligation set in Waste Management Act, where the companies having waste management permit are obliged to send data to EPR. Also, environmental protection inspection is participating in validation process and control.

Until 2011, the CBS used surveys as a method of data collection. Data were processed according to statistical classification of waste (ESTAT). Validation was done by statistical officers in county offices of CBS. At that time CBS was the only institution communication with Eurostat – data was delivered on voluntary basis.

Until 2011, the Agency was not in a possession of data prepared in format requested by Eurostat. Data were based on European List of Waste but were not processed according to ESTAT classification. This administrative data were used for national purposes and reports.

Only after entering EU (2013) the Croatia become obligated to deliver the data according to Waste Statistics Regulation – and the Agency became official data source of waste data for Eurostat.

Open burning of waste (CRF 5.C.2) includes activities of incineration of agricultural waste (excluding chaff, harvest residues) outdoors carried out on land, in incinerators, in pits in the ground, in open barrels, wire mesh, containers/baskets. EMEP/EEA GB2023 provides examples of agricultural wastes that might be burned: crop residues (e.g. cereal crops, peas, beans, soya, sugar beet, oil seed rape, etc.), wood, prunings, slash, leaves, plastics and other general wastes. Prunings and slash are residues from thinning and pruning of forests, orchards and vineyards. Straw and wood are often used as the fuel for the open burning of agricultural wastes. It is assumed that the open burning of agricultural waste is mainly done in forestry, fruit growing, vineyard and farming, while the rest is negligible.

Data on mass of open-burned agricultural residue (pruning residues from orchards, olive groves and vineyards) are used to calculate $CH_4$ and $N_2O$ emissions. There is no practice of open burning pruning residues from forests in the Republic of Croatia.

## 7.4.2. Methodological issues

### 7.4.2.1. Waste incineration

Category 5.C.1 Waste incineration is not a key source. Default emission factors are used for emissions calculation from category 5.C.1 Waste incineration because of insufficient data to use higher tier.

$CO_2$ emissions from incineration of IW and clinical waste have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total incinerated waste with default values for fraction of carbon content, fraction of fossil carbon and oxidation factor proposed by 2006 IPCC Guidelines, Volume 5, Chapter 5.4, Table 5.2.

Default parameters have been used to estimate $CO_2$ emissions from IW: fraction of carbon content (0.5), fraction of fossil carbon (0.9) and oxidation factor (1.0).

Default parameters have been used to estimate $CO_2$ emissions from clinical waste: fraction of carbon content (0.6), fraction of fossil carbon (0.4) and oxidation factor (1.0).

$N_2O$ emissions from incineration of IW have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total incinerated waste with default emission factor. Default value of 100 g $N_2O$/t waste of IW, all types of incineration, proposed by 2006 IPCC Guidelines, Volume 5, Chapter 5.4, Table 5.6, has been used.

2006 IPCC Guidelines, Volume 5, not define default emission factor for $CH_4$ emission from incineration of clinical waste. In 2006 IPCC Guidelines, under Section 5.4.2 is explained that for continuous incineration of MSW and IW it is good practice to apply the $CH_4$ emission factors provided in Volume 2, Chapter 2, Stationary combustion. For the other type of incineration (semi-continuous and batch, which is the case in Croatia) only default $CH_4$ emission factors for incineration of MSW is presented (Table 5.3, Page 5.20). Because MSW and clinical waste have different contents, it is assumed that $CH_4$ emission factors for MSW and clinical waste are different. In addition, under Section 5.4.1, page 5.11 in 2006 IPCC Guidelines is explained that methane can also be generated in the waste bunker of incinerators if there are low oxygen levels and subsequent anaerobic processes in the waste bunker. This is only the case where wastes are wet, stored for long periods and not well agitated (which is the case of Croatia). Where the storage area gases are fed into the air supply of the incineration chamber, they will be incinerated and emissions will be reduced to insignificant levels. Regarding to this, $CH_4$ emission for incineration of clinical waste for the entire period 1990 - 2022 is defined as NA.

2006 IPCC Guidelines, Volume 5, not define default emission factor for $N_2O$ emission from incineration of clinical waste. In 2006 IPCC Guidelines, under Section 5.4.3 is explained that nitrous oxide emissions from waste incineration are determined by a function of the type of technology and combustion conditions, the technology applied for emission reduction as well as the contents of the waste stream. Only default $N_2O$ emission factors for incineration of MSW, IW, sludge and sewage sludge is presented (Table 5.6, Page 5.22). Regarding to this, $N_2O$ emission for incineration of clinical waste for the entire period 1990 - 2022 is defined as NA.

Above mentioned approach has been accepted by the TERT during the 2017 ESD review – the TERT confirmed that this is also the way that they interpret the 2006 IPCC Guidelines. Accordingly, Croatia did not calculate $N_2O$ emission from clinical waste. Given that TERT and the EU Member States apply the above mentioned approach, we believe that we need to follow it in order to ensure that these emissions are monitored in a harmonized way in the EU.

Data on incineration of IW for the period 1990 - 2008 have been provided by the MESD. There was no incineration of IW without energy recovery in the period 2009 - 2022. Submitted data include hazardous waste and plastics. Data have been submitted in the aggregate form.

The ERT concluded (W.11, 2022)[98] that this source is not a key category and using aggregated AD is sufficient when using a 2006 IPCC Guidelines Tier 1 estimation methodology (Vol. 5, Chap. 5.2.1.1, pp. 5.7-5.8). The ERT considers the estimates to be complete.

Data for quantity of incinerated clinical waste for the period 1990 - 2016 were obtained by the MESD. There was no incineration of clinical waste without energy recovery in the period 2017 - 2022.

Data on incinerated waste (without energy recovery) for $CO_2$ and $N_2O$ emissions calculation for the period 1990 - 2022 are presented in the Table 7.4-1.

Table 7.4-1: Incinerated waste (without energy recovery) (1990 - 2022)

| Year | Incinerated waste (t) | |
|---|---|---|
| | IW (t) | Clinical waste (t) |
| 1990 | 250.00 | 140.00 |
| 1991 | 250.00 | 140.00 |
| 1992 | 250.00 | 140.00 |
| 1993 | 250.00 | 140.00 |
| 1994 | 250.00 | 140.00 |
| 1995 | 250.00 | 140.00 |
| 1996 | 250.00 | 140.00 |
| 1997 | 1031.00 | 140.00 |
| 1998 | 2167.74 | 140.00 |
| 1999 | 2580.45 | 140.00 |
| 2000 | 3652.49 | 141.50 |
| 2001 | 3967.23 | 155.58 |
| 2002 | 2205.96 | 158.45 |
| 2003 | 400.00 | 162.64 |
| 2004 | 120.00 | 173.20 |
| 2005 | 4.50 | 175.70 |
| 2006 | 350.00 | 187.56 |
| 2007 | 285.00 | 204.89 |
| 2008 | 315.78 | 165.00 |
| 2009 | NO | 185.17 |
| 2010 | NO | 54.40 |
| 2011 | NO | 57.45 |
| 2012 | NO | 93.10 |
| 2013 | NO | 48.00 |
| 2014 | NO | 51.08 |
| 2015 | NO | 51.79 |
| 2016 | NO | 55.68 |
| 2017 | NO | NO |
| 2018 | NO | NO |
| 2019 | NO | NO |
| 2020 | NO | NO |
| 2021 | NO | NO |
| 2022 | NO | NO |

NO – not occurring

[98] FCCC/ARR/2022/HRV Report on the individual review of the annual submission of Croatia submitted in 2022, 15 March 2023

The resulting annual emissions of $CO_2$ from 5.C.1 Waste incineration in the period 1990 - 2016 are presented in the Figure 7.4-1. There were no emissions of $CO_2$ in the period 2017 - 2022.

The resulting annual emissions of $N_2O$ from 5.C.1 Waste incineration in the period 1990 - 2008 are presented in the Figure 7.4-2. There were no emissions of $N_2O$ in the period 2009 - 2022.

Figure 7.4-1: Emissions of $CO_2$ from 5.C.1 Waste incineration (1990 - 2016)

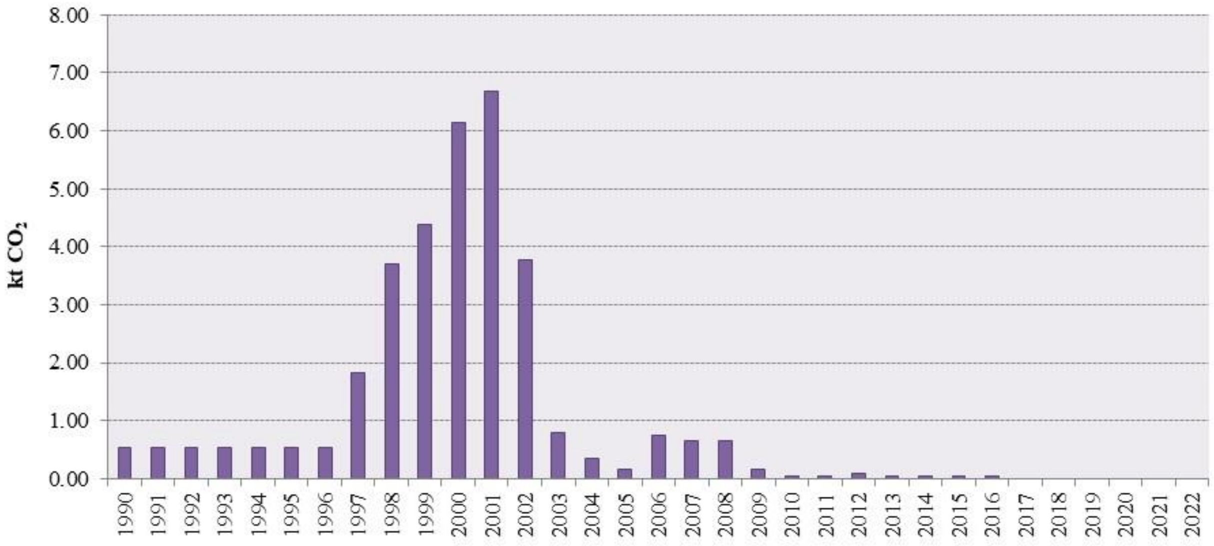
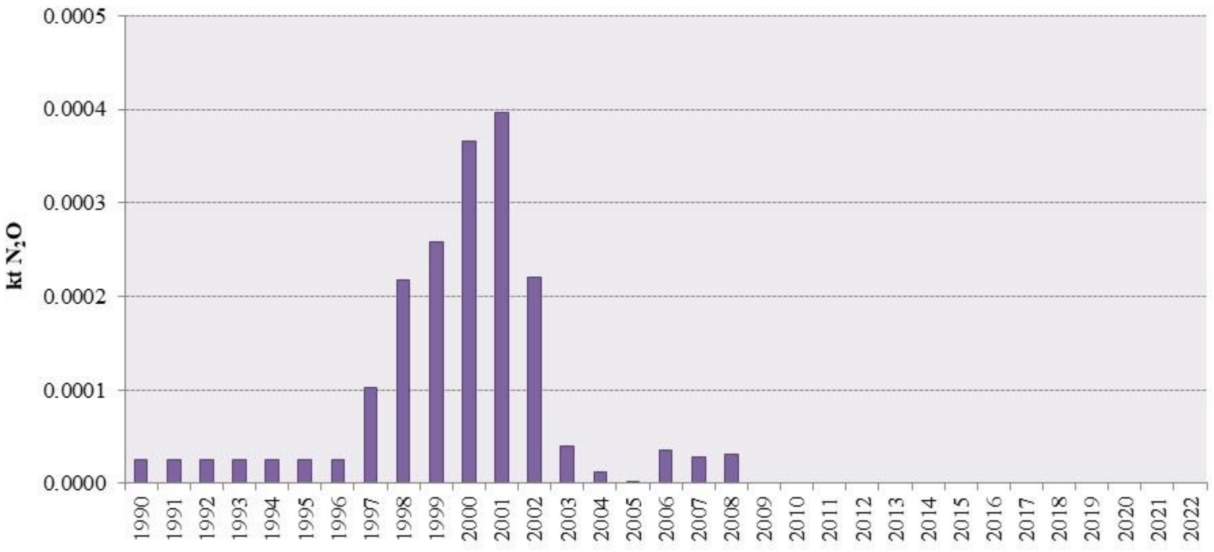



Figure 7.4-2: Emissions of $N_2O$ from 5.C.1 Waste incineration (1990 - 2008)




Notation key IE is used in the CRF 5.C.1.1.b for entire period 1990 - 2016. Allocation in the CRF 5.C.1.2.b and NK explanation are included in the cell comments, and this information should be visible in the Reporting Table 5.C Sectoral Background Data for Waste.

### 7.4.2.2. Open burning of waste

Category 5.C.2 Open burning of waste is not a key source. Default emission factors are used for emissions calculation from category 5.C.2 Open burning of waste because of insufficient data to use higher tier. Pruning residues from orchards, olive groves and vineyards are open-burned. There is no practice of open burning pruning residues from forests in the Republic of Croatia.

The $CO_2$ emissions from open burning of agricultural residues (pruning residues orchards, olive groves and vineyards) are biogenic emissions and are not included in national total emission estimates.

$CH_4$ emissions from open burning of agricultural residues have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total open-burned waste (tonnes, wet weight) with default values for $CH_4$ emission factor for MSW (6.5 kg $CH_4$/t waste treated, on a wet weight basis). This value of $CH_4$ emission factor is proposed by 2006 IPCC Guidelines, Volume 5, Chapter 5.4, pg. 5.20.

$N_2O$ emissions from open burning of agricultural residues have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines, by multiplying the total open-burned waste (tonnes, dry weight) with default values for $N_2O$ emission factor (0.15 kg $N_2O$/t waste treated, on a dry weight basis). This value of $N_2O$ emission factor is proposed by 2006 IPCC Guidelines, Volume 5, Chapter 5.4.3, pg. 5.22.

Assuming a dry matter content of the pruning residues of more than 90%, the emission factors on a wet weight basis are assumed to be the same as the emission factors on a dry weight basis.

Relevant activity data is the annual mass of open-burned waste - agricultural residue. Data on mass of open-burned agricultural residue (pruning residues from forests, orchards, olive groves and vineyards) and the area of the Republic of Croatia under forests, orchards, olive groves and vineyards have been collected. The project for improving the pollutant inventory for the sector open burning of waste[99] has been prepared in 2022. In the framework of this project, data on mass of open burned agricultural waste have been collected for the period 1990 - 2020 (Elaborate 1, Chapter 2.2.1.1., Table 2.2-22 and Table 2.2-23). For the years 2021 and 2022, data on mass of open burned agricultural waste have been collected by Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste[100].

The sources of activity data are presented in the Table 7.4-2.

Table 7.4-2: Sources of collected data for the calculation of $CH_4$ and $N_2O$ emissions from the source category 5.C.2 Open burning of waste

| Data | Period | Source |
|---|---|---|
| Burnt pruning residues from orchards, olive groves and vineyards (t) | 1990 - 2022 | Ministry of Agriculture, Directorate for professional support to agricultural development |
| Data information on the non-existence of the practice of open burning pruning residues from forests in the Republic of Croatia | 1990 - 2022 | Ministry of Agriculture, Directorate of forestry, hunting and wood industry |
| The area of the Republic of Croatia under forests (ha) | 1990 - 2022 | Ministry of Agriculture, Directorate of forestry, hunting and wood industry<br>Source: General Forest management plan for the Republic of Croatia (2016 - 2025), data on |

[99] Izvješće o unapređenju proračuna za sektor spaljivanje otpada na otvorenom (NFR 5.C.2), in Croatian (Report on inventory improvement for sector open burning of waste (NFR 5.C.2)), Client: Ministry of Economy and Sustainable Development, Executor: EKONERG d.o.o., 2022

[100] Annual Data Collection Plan (ADCP) for NIR 2024 - Sector Waste; Ministry of Economy and Sustainable Development (the web format of the document is not available at the time the NIR report is being created)

| Data | Period | Source |
| --- | --- | --- |
| | | overgrown forest areas prepared for the GHG inventory preparation in the LULUCF sector |
| The area of the Republic of Croatia under orchards, olive groves and vineyards | 1990 - 2022 | CBS |

Data on the area of the Republic of Croatia under forests, orchards, olive groves and vineyards are shown in Table 7.4-3. Pruning residues from orchards, olive groves and vineyards are shown in Table 7.4-4.

Table 7.4-3: The area of the Republic of Croatia under forests, orchards, olive groves and vineyards (ha)

| Year | Area under forests (ha) | Area under orchards (ha) | Area under olive groves (ha) | Area under vineyards (ha) |
| --- | --- | --- | --- | --- |
| 1990 | 2,356,831.70 | 19,474.35 | IE | 54,315.75 |
| 1991 | 2,357,045.00 | 19,544.88 | IE | 53,667.00 |
| 1992 | 2,357,207.60 | 19,615.40 | IE | 42,295.50 |
| 1993 | 2,357,505.60 | 19,685.93 | IE | 42,493.50 |
| 1994 | 2,357,705.00 | 19,756.45 | IE | 41,661.00 |
| 1995 | 2,357,933.50 | 19,826.98 | IE | 41,514.00 |
| 1996 | 2,358,221.00 | 19,897.50 | IE | 43,289.25 |
| 1997 | 2,358,338.70 | 19,968.03 | IE | 43,527.75 |
| 1998 | 2,358,494.20 | 20,038.55 | IE | 45,109.50 |
| 1999 | 2,358,793.50 | 15,880.13 | 5,464.32 | 44,328.00 |
| 2000 | 2,358,869.10 | 20,179.60 | 5,699.00 | 21,295.50 |
| 2001 | 2,358,768.50 | 20,596.80 | 5,706.00 | 20,792.25 |
| 2002 | 2,358,840.50 | 21,119.00 | 5,740.00 | 20,795.25 |
| 2003 | 2,359,029.20 | 21,632.10 | 5,637.50 | 20,766.00 |
| 2004 | 2,359,333.00 | 20,594.70 | 6,195.50 | 21,000.00 |
| 2005 | 2,362,013.80 | 21,196.00 | 6,178.50 | 22,252.50 |
| 2006 | 2,364,534.00 | 22,264.90 | 6,681.50 | 23,074.50 |
| 2007 | 2,368,271.40 | 22,904.00 | 7,173.00 | 24,340.50 |
| 2008 | 2,369,695.90 | 25,153.10 | 7,485.50 | 25,305.75 |
| 2009 | 2,373,540.20 | 25,661.30 | 7,652.00 | 25,785.00 |
| 2010 | 2,377,998.50 | 23,022.30 | 8,548.00 | 24,531.75 |
| 2011 | 2,383,851.80 | 22,792.00 | 8,600.00 | 24,363.75 |
| 2012 | 2,388,633.70 | 21,592.20 | 9,050.00 | 21,927.75 |
| 2013 | 2,395,608.60 | 19,874.40 | 9,295.00 | 19,575.00 |
| 2014 | 2,403,911.80 | 22,206.80 | 9,541.00 | 19,623.00 |
| 2015 | 2,410,050.40 | 21,078.40 | 9,550.00 | 19,190.25 |
| 2016 | 2,411,443.70 | 20,633.20 | 9,092.00 | 17,550.00 |
| 2017 | 2,415,366.50 | 21,443.80 | 8,341.50 | 16,425.00 |
| 2018 | 2,417,091.40 | 22,705.20 | 9,348.50 | 15,384.00 |
| 2019 | 2,417,594.70 | 24,173.80 | 9,303.00 | 14,868.00 |
| 2020 | 2,417,915.80 | 23,220.40 | 10,141.00 | 16,090.50 |
| 2021 | 2,418,302.40 | 23,534.00 | 9,970.00 | 15,909.75 |
| 2022 | 2,418,408.20 | 24,460.08 | 9,950.00 | 15,717.75 |

IE (included elsewhere) - olive grove areas for the period 1990 - 1998 are included under orchard areas

Table 7.4-4. Activity data - pruning residues from orchards, olive groves and vineyards (kt)

| Year | Pruning residues from forests (kt) | Pruning residues from orchards (kt) | Pruning residues from olive groves (kt) | Pruning residues from vineyards (kt) | **TOTAL pruning residues (kt)** |
|---|---|---|---|---|---|
| 1990 | NO | 6.426 | IE | 99.067 | **105.493** |
| 1991 | NO | 6.449 | IE | 93.222 | **99.671** |
| 1992 | NO | 6.473 | IE | 69.971 | **76.444** |
| 1993 | NO | 6.496 | IE | 66.951 | **73.447** |
| 1994 | NO | 6.519 | IE | 62.514 | **69.033** |
| 1995 | NO | 6.542 | IE | 59.327 | **65.869** |
| 1996 | NO | 6.566 | IE | 58.918 | **65.484** |
| 1997 | NO | 6.589 | IE | 56.421 | **63.010** |
| 1998 | NO | 6.612 | IE | 55.687 | **62.299** |
| 1999 | NO | 5.241 | 0.000* | 52.117 | **57.358** |
| 2000 | NO | 6.659 | 21.371 | 23.845 | **51.875** |
| 2001 | NO | 7.031 | 21.398 | 22.173 | **50.601** |
| 2002 | NO | 6.940 | 21.525 | 21.120 | **49.585** |
| 2003 | NO | 7.019 | 21.141 | 20.086 | **48.246** |
| 2004 | NO | 6.123 | 22.923 | 19.345 | **48.391** |
| 2005 | NO | 6.042 | 22.552 | 19.523 | **48.116** |
| 2006 | NO | 6.049 | 24.053 | 19.280 | **49.382** |
| 2007 | NO | 5.891 | 25.464 | 19.842 | **51.197** |
| 2008 | NO | 6.084 | 26.199 | 20.125 | **52.409** |
| 2009 | NO | 5.847 | 26.399 | 20.006 | **52.253** |
| 2010 | NO | 5.376 | 29.063 | 18.570 | **53.009** |
| 2011 | NO | 3.708 | 28.810 | 17.993 | **50.511** |
| 2012 | NO | 3.174 | 29.865 | 15.799 | **48.838** |
| 2013 | NO | 2.567 | 30.209 | 13.760 | **46.535** |
| 2014 | NO | 2.696 | 30.531 | 13.457 | **46.684** |
| 2015 | NO | 2.409 | 30.083 | 12.839 | **45.331** |
| 2016 | NO | 2.259 | 28.185 | 11.455 | **41.900** |
| 2017 | NO | 1.851 | 25.442 | 10.460 | **37.752** |
| 2018 | NO | 1.664 | 28.046 | 9.558 | **39.267** |
| 2019 | NO | 1.516 | 25.583 | 9.012 | **36.111** |
| 2020 | NO | 1.268 | 25.353 | 9.515 | **36.136** |
| 2021 | NO | 1.353 | 23.840 | 8.108 | **33.301** |
| 2022 | NO | 1.166 | 23.754 | 7.702 | **32.622** |

NO (not occurring) - there is no practice of open burning pruning residues from forests in the Republic of Croatia

IE (included elsewhere) - pruning residues from olive groves for the period 1990 - 1998 are included under pruning residues from orchards

* estimate by the Ministry of Agriculture, Directorate for professional support to agricultural development - pruning residues from olive groves for 1999 did not include due to a significant deviation from the trend

The resulting emissions of $CH_4$ and $N_2O$ from 5.C.2 Open burning of waste in the period 1990 - 2022 are presented in the Table 7.4-5.

Table 7.4-5: Emissions of $CH_4$ and $N_2O$ from 5.C.2 Open burning of waste (1990 - 2022)

| Year | $CH_4$ emission (kt) | $N_2O$ emission (kt) |
|---|---|---|
| 1990 | 0.686 | 0.016 |
| 1991 | 0.648 | 0.015 |
| 1992 | 0.497 | 0.011 |
| 1993 | 0.477 | 0.011 |
| 1994 | 0.449 | 0.010 |
| 1995 | 0.428 | 0.010 |
| 1996 | 0.426 | 0.010 |
| 1997 | 0.410 | 0.009 |
| 1998 | 0.405 | 0.009 |
| 1999 | 0.373 | 0.009 |
| 2000 | 0.337 | 0.008 |
| 2001 | 0.329 | 0.008 |
| 2002 | 0.322 | 0.007 |
| 2003 | 0.314 | 0.007 |
| 2004 | 0.315 | 0.007 |
| 2005 | 0.313 | 0.007 |
| 2006 | 0.321 | 0.007 |
| 2007 | 0.333 | 0.008 |
| 2008 | 0.341 | 0.008 |
| 2009 | 0.340 | 0.008 |
| 2010 | 0.345 | 0.008 |
| 2011 | 0.328 | 0.008 |
| 2012 | 0.317 | 0.007 |
| 2013 | 0.302 | 0.007 |
| 2014 | 0.303 | 0.007 |
| 2015 | 0.295 | 0.007 |
| 2016 | 0.272 | 0.006 |
| 2017 | 0.245 | 0.006 |
| 2018 | 0.255 | 0.006 |
| 2019 | 0.235 | 0.005 |
| 2020 | 0.235 | 0.005 |
| 2021 | 0.216 | 0.005 |
| 2022 | 0.212 | 0.005 |

### 7.4.3. Uncertainties and time-series consistency

The uncertainties contained in $CO_2$, $CH_4$ and $N_2O$ emissions estimates from incineration and open burning of waste are related primarily to agregated activity data and applied default emission factors.

A detailed explanation of the uncertainty assessment is presented in Elaborate 7, Chapter 2.2. (uncertainty estimate associated with activity data) and Chapter 2.3. (uncertainty estimate associated with emission factor).

Accordingly collected detailed information on activity data (based on professional literature and research), the team of experts involved in the Project estimated uncertainty of activity data using values recommended in the 2006 IPCC Guidelines, which are included in the tables in the uncertainty assessment chapters for individual categories. Uncertainty estimation based on expert judgment follows the 2006 IPCC Guidelines, Volume 1, Chapter 3. Uncertainties of activity data are given in the Table 7.4-6.

Uncertainties of emission factor were estimated using values recommended in the 2006 IPCC Guidelines. Uncertainties of emission factor are given in the Table 7.4-7.

Table 7.4-6: Uncertainty range of activity data for category 5.C

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.C Incineration and open burning of waste** | **$CO_2$** | | |
| 5.C.1 Waste incineration / Industrial waste | $CO_2$ | -50 | 50 |
| 5.C.1 Waste incineration / Clinical waste | $CO_2$ | -50 | 50 |
| **5.C Incineration and open burning of waste** | **$N_2O$** | | |
| 5.C.1 Waste incineration / Industrial waste | $N_2O$ | -50 | 50 |
| 5.C.2 Open burning of waste | $N_2O$ | -30 | 30 |
| **5.C Incineration and open burning of waste** | **$CH_4$** | | |
| 5.C.2 Open burning of waste | $CH_4$ | -30 | 30 |

Table 7.4-7: Uncertainty range of emission factor for category 5.C

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.C Incineration and open burning of waste** | **$CO_2$** | | |
| 5.C.1 Waste incineration / Industrial waste | $CO_2$ | -30 | 30 |
| 5.C.1 Waste incineration / Clinical waste | $CO_2$ | -30 | 30 |
| **5.C Incineration and open burning of waste** | **$N_2O$** | | |
| 5.C.1 Waste incineration / Industrial waste | $N_2O$ | -200 | 200 |
| 5.C.2 Open burning of waste | $N_2O$ | -100 | 100 |
| **5.C Incineration and open burning of waste** | **$CH_4$** | | |
| 5.C.2 Open burning of waste | $CH_4$ | -100 | 100 |

More detailed information on uncertainty assessment is presented in Annex 2.

Emissions from 5.C Incineration and open burning of waste have been calculated using the same method for every year in the time series. Different sources of information were used for data sets.

### 7.4.4. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness and consistency of emission estimates and correct transformation/transcription into CRF tables as well proper use of notation keys, according to QA/QC plan.

During the data collection and administration, data were checked in terms of completeness and plausibility. To clarify any discrepancies, the institution responsible for providing the data was contacted. All steps of data verification and validation are documented.

During the inventory preparation, the correctness of all data and parameters in the estimate files were checked. Plausibility of the results of estimations and their trends were checked and documented. All assumptions, expert judgements and recalculations were explained. Transformation/transcription of activity data and calculated emissions into CRF were checked to compare with information in background calculation tables.

The $CO_2$, $CH_4$ and $N_2O$ emissions from 5.C.1 Waste Incineration and 5.C.2 Open burning of waste were estimated using the Tier 1 methodology.

All input data and information relevant for the emissions calculation have been documented and archived.

### 7.4.5. Category-specific recalculations

**Waste incineration**

There are no source-specific recalculations in this report.

**Open burning of waste**

In the previous report, activity data for $CH_4$ and $N_2O$ emissions calculation for 2021 were not available, so they were estimated as the mean value of data for the period 2018 - 2020. In this report, updated data on mass of open burned agricultural waste for 2021 were collected by ADCP for NIR 2024 - Sector Waste. Therefore, recalculations of $CH_4$ and $N_2O$ emissions were made for 2021.

The difference in $CO_2$-eq emission from category 5.C.2 Open burning of waste calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for 2021 amounts -0.858 kt $CO_2$-eq, respectively -10.41%.

### 7.4.6. Category-specific planned improvements

The aim of the project is improving the transparency, accuracy, completeness, comparability and consistency of GHG inventory from the category 5.C Incineration and open burning of waste, in accordance with the recommendations/requirements of ERT. An effort was made to evaluate and compile data coming from different sources and adjust them to the recommended IPCC methodology which used for $CO_2$, $CH_4$ and $N_2O$ emission estimation.

Data sources defined by the project for improving the pollutant inventory for the sector open burning of waste will be used to collect of national data and information in future inventories, as well as methodologies to adjust country-specific circumstances to the IPCC methodological guidelines.

## 7.5. Wastewater treatment and discharge (CRF 5.D)

### 7.5.1. Category description

Aerobic biological process is used mostly in wastewater treatment. Aerobic and anaerobic treatment of wastewater occurs in the country for individual wastewater treatment systems. Disposal of domestic wastewater, particularly in rural areas where systems such as septic tanks are used, are partly anaerobic without flaring, which results with $CH_4$ emissions. Direct discharge of untreated wastewater results in indirect $CH_4$ emissions.

Anaerobic process is applied in some industrial wastewater treatment. Data for 3 industries with the largest potential for wastewater methane emissions (Manufacture of food products and beverages, Manufacture of pulp, paper and paper products and Manufacture of chemicals and chemical products) were considered.

According to the Ordinance on the Environmental Pollution Register the completed forms should be submitted for the previous calendar year not later than 1 March of the current year. According to the article 21 of the Ordinance, the competent authority (administrative department of the county and the City of Zagreb) in collaboration with the environmental inspection ensures the checking of data submitted in terms of their completeness, consistency and credibility. The MESD coordinates activities relating to data quality assurance and control.

State company Croatian Waters receive and interpret data on the systems for collection and treatment of domestic wastewater in accordance with the obligations from the Water Act (OG 66/2019, 84/2021) and relevant by-laws. The data sources are always providers of water services, and the quality of the original data depends on their internal data tracking systems and information provided, but systematic flow of information needs to be improved.

Croatian Waters are working to improve the Water Information System that will include all relevant information collected directly from the water service supplier. Until the full functionality of the system and standardization of the output data and information on wastewater treatment is established, the calculations are based on potentially available data and on estimates.

In Croatia, as well as in the other EU member states, agglomerations have been identified, 747 of them (reference year is 2018), in whose territory construction of the public sewerage system for domestic wastewater and/or individual systems is planned. From the total number of identified agglomerations, 260 have total generated load exceeding 2000 population equivalent (PE) and whose status is required to be reported to the European Commission.

According to the estimates of Croatian Waters, out of the total population of Croatia, 80% resides in the settlements of mentioned 260 agglomerations for whom the construction of the public sewerage system is planned in a period of several years. It is estimated that 67.5% of these residents are already connected to public drainage systems. Also, in the agglomerations with total generated load below 2000 PE, there is inhabitants connected to the existing public drainage system. Concluding, at the Croatian national level it is estimated that about 55% of the total population is connected to public drainage systems. It is considered that others have an individual solution for collecting wastewater from households.

## 7.5.2. Methodological issues

### 7.5.2.1. Domestic wastewater

Category 5.D.1 Domestic wastewater is a key source. The $CH_4$ and $N_2O$ emissions from the treatment of domestic wastewater are included in emission estimates for the period 1990 - 2022.

**Methane ($CH_4$) emissions from domestic wastewater**

Methane emissions from domestic wastewater (disposal particularly in rural areas where systems such as septic tanks and similar are used) have been calculated using the IPCC Tier 1 methodology proposed by 2006 IPCC Guidelines.

Data for population with an individual system of drainage and data for calculation of degradable organic component in kg BOD/1000 person/yr have been obtained by Croatian Water (Hrvatske vode) for 1990, 1995, 2000 and for the period 2003 - 2022. Insufficient data for years between those years have been assessed by the interpolation method.

Generally, number of inhabitants with individual systems for wastewater collection and treatment has been slightly declining during the observed period of time. Reason for this is mainly in the construction of the public collecting system followed by the connection of the inhabitants and consequent closure of the individual systems.

Data for $CH_4$ emission calculation from individual systems for collecting and treatment of the wastewaters for the period 1990 - 2022 are presented in the Table 7.5-1.

Table 7.5-1: Data for $CH_4$ emission calculation from individual systems for collecting and treatment of the wastewaters (1990 - 2022)

| Year | DOC (kg BOD/1000persons/yr) | Population (with individual system)* | Total organic product (kt DC/yr) |
|---|---|---|---|
| 1990 | 21,899.86 | 2,866,000 | 62.765 |
| 1991 | 21,899.55 | 2,842,800 | 62.256 |
| 1992 | 21,899.58 | 2,819,600 | 61.748 |
| 1993 | 21,899.60 | 2,796,400 | 61.240 |
| 1994 | 21,899.63 | 2,773,200 | 60.732 |

| Year | DOC (kg BOD/1000persons/yr) | Population (with individual system)* | Total organic product (kt DC/yr) |
|---|---|---|---|
| 1995 | 21,900.00 | 2,750,000 | 60.225 |
| 1996 | 21,900.00 | 2,732,000 | 59.831 |
| 1997 | 21,900.00 | 2,714,000 | 59.437 |
| 1998 | 21,900.00 | 2,696,000 | 59.042 |
| 1999 | 21,900.00 | 2,678,000 | 58.648 |
| 2000 | 21,900.00 | 2,660,000 | 58.254 |
| 2001 | 21,899.65 | 2,630,333 | 57.603 |
| 2002 | 21,899.70 | 2,601,666 | 56.976 |
| 2003 | 21,900.16 | 2,574,000 | 56.371 |
| 2004 | 21,900.00 | 2,560,000 | 56.064 |
| 2005 | 21,900.01 | 2,541,460 | 55.658 |
| 2006 | 21,900.17 | 2,525,460 | 55.308 |
| 2007 | 21,899.89 | 2,514,488 | 55.067 |
| 2008 | 21,900.13 | 2,478,889 | 54.288 |
| 2009 | 21,900.13 | 2,459,300 | 53.859 |
| 2010 | 21,902.04 | 2,450,000 | 53.660 |
| 2011 | 21,865.31 | 2,450,000 | 53.570 |
| 2012 | 21,878.26 | 2,300,000 | 50.320 |
| 2013 | 21,900.95 | 2,275,700 | 49.840 |
| 2014 | 21,894.41 | 2,254,000 | 49.350 |
| 2015 | 21,897.40 | 2,232,000 | 48.875 |
| 2016 | 21,898.90 | 2,209,700 | 48.390 |
| 2017 | 21,945.14 | 2,005,000 | 44.000 |
| 2018 | 21,899.78 | 1,939,700 | 42.479 |
| 2019 | 21,899.78 | 1,919,700 | 42.041 |
| 2020 | 21,900,35 | 1,655,225 | 36.250 |
| 2021 | 21,901.17 | 1,638,725 | 35.890 |
| 2022 | 21,899.93 | 1,622,425 | 35.531 |

* data for population with individual drainage system

Default value for methane correction factor (MCF) for septic system (MCF = 0.5), proposed by 2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.3, has been used for emission calculation for the entire period 1990 - 2022. For septic tanks, MCF already accommodates for 50% removal of BOD as sludge (Comment in the Table 6.3: "Half of BOD settles in anaerobic tank”).

Default value for maximum methane producing capacity (Bo) of 0.6 kg $CH_4$/kg BOD, proposed by 2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.2, has been used for emission calculation for the entire period 1990 - 2022.

No data are available for the amount of methane recovered or flared. Default value of zero, proposed by 2006 IPCC Guidelines, has been used for emission calculation for the entire period 1990 - 2022.

Fraction of treated wastewater in septic tank amounts to 100%. Wastewater emission from septic tank depend on organic pollution ($BOD_5$) only, and not on the amount or use of water. This approach is complying with 2006 IPCC Guidelines for estimating emissions from wastewater. Proposed values of 100% have been used for methane emission calculation for the entire period 1990 - 2022.

Septic tank combines two processes. Sedimentation takes place in the upper portion of the tank, and the accumulated solids are digested by anaerobic decomposition in the lower portion. As sewage from a building enters a septic tank, its rate of flow is reduced so that the heavier solids sink to the bottom and the lighter solids including fats and grease rise to the surface. These solids are retained in the septic tank, and the clear effluent is discharged.

The following are some information on the fraction of wastewater type treated by a particular type of system, according to the estimates of Croatian Waters. All systems and parts of the public wastewater system built so far, still do not end with a functional device for treatment of domestic wastewater. According to the data collected from the public water service companies for the reference year 2018, it is estimated that wastewaters of 76% of the population connected to public wastewater systems are purified through public wastewater treatment plants. At the national level – looking at the overall population of the Republic of Croatia, the share of residents whose wastewaters are treated with some of the purification processes is 43%, and the share of residents whose wastewaters are collected but not treated is about 11%.

In Croatia, the largest number of population is connected to the most common devices for the treatment of domestic wastewater - secondary wastewater treatment. The following are preliminary purification devices that are built mainly in the coastal area. Preliminary purification procedures include treatment processes of lower levels than the primary treatment (i.e. removal of solids dispersed and floating matter and the release through the long sea outfalls), which allows the receiving water to meet water quality objectives. The smallest number of devices built are for the third level of wastewater treatment, and the lowest number of inhabitants are connected to such devices.

For the reference year 2018, it is estimated that, at the national level, 14.8% of the total population is connected to devices with preliminary purification and the primary level of treated wastewater, and approximately 28% of the total population is connected to devices with secondary and tertiary wastewater treatment.

More detailed information on the procedures and technologies that are applied to devices for domestic wastewater treatment are still not collected in Croatian Waters in the full extent. Monitoring of such information is planned with the development of the Water Information System.

Receivers of treated wastewater, as well as collected and untreated wastewater, are mainly the waterways and the sea, but release to the underground (through the soil) is rare.

Domestic water in areas where the public sewerage system is not yet built, whose functioning is under competent utility company, are treated by individual treatment and discharge of wastewater. The source of information on individual solutions could be the suppliers of water services in the area of its jurisdiction. Croatian Waters have no sufficient information on such individual systems and estimates on the number of residents who have individual drainage are only indicative. Croatian Waters have no accurate information on individual solutions for purification and drainage (septic tanks, small individual devices etc.) and that is why the estimates were included in the calculation. A precondition for better information and data on individual ways of wastewater treatment is to establish a system for monitoring at the data source, i.e. on the level of water suppliers.

As above mentioned, for around 11% of the population wastewater is collected and not treated. It is assumed that it is directly discharged. According to the technical correction provided by the TERT during the 2020 ESD review, direct discharge of untreated wastewater is added as another relevant wastewater treatment pathway.

Data for population with direct discharge of untreated wastewater have been estimated by calculating 11% of the total population (population estimates of the Republic of Croatia for the period 1990 - 2022 were taken from Statistical Yearbooks and Statistical First Releases[101]). Data for calculation of degradable organic component in kg BOD/1000 person/yr (the same data as for septic tank) have been

[101] Croatian Bureau of Statistics, First Releases STAN-2023-3-1 Population Estimate of Republic of Croatia, 2022 (8 September 2023) https://podaci.dzs.hr/en/statistics/population/

obtained by Croatian Waters (Hrvatske vode) for 1990, 1995, 2000 and for the period 2003 - 2022. Insufficient data for years between those years have been assessed by the interpolation method.

Direct discharge of untreated wastewater results in indirect $CH_4$ emissions. However since this is a collected wastewater stream, the correction factor for additional industrial BOD discharged into sewers (I) of 1.25 (2006 IPCC Guidelines, Volume 5, Chapter 6, page 6.14) has been applied.

Data for indirect $CH_4$ emission calculation from discharge of collected untreated wastewater for the period 1990 - 2022 are presented in the Table 7.5-2.

Table 7.5-2: Data for indirect $CH_4$ emission calculation from discharge of collected untreated wastewater (1990 - 2022)

| Year | DOC (kg BOD/1000persons/yr) | Population* | Total organic product (kt DC/yr) |
|---|---|---|---|
| 1990 | 21,899.86 | 526,000 | 14.399 |
| 1991 | 21,899.55 | 496,000 | 13.578 |
| 1992 | 21,899.58 | 492,000 | 13.468 |
| 1993 | 21,899.60 | 511,000 | 13.988 |
| 1994 | 21,899.63 | 511,000 | 13.988 |
| 1995 | 21,900.00 | 514,000 | 14.071 |
| 1996 | 21,900.00 | 494,000 | 13.523 |
| 1997 | 21,900.00 | 503,000 | 13.770 |
| 1998 | 21,900.00 | 495,000 | 13.551 |
| 1999 | 21,900.00 | 501,000 | 13.715 |
| 2000 | 21,900.00 | 487,000 | 13.195 |
| 2001 | 21,899.65 | 473,000 | 12.976 |
| 2002 | 21,899.70 | 473,000 | 12.976 |
| 2003 | 21,900.16 | 473,000 | 12.976 |
| 2004 | 21,900.00 | 474,000 | 12.976 |
| 2005 | 21,900.01 | 474,000 | 12.976 |
| 2006 | 21,900.17 | 474,000 | 12.976 |
| 2007 | 21,899.89 | 474,000 | 12.976 |
| 2008 | 21,900.13 | 474,000 | 12.976 |
| 2009 | 21,900.13 | 474,000 | 12.948 |
| 2010 | 21,902.04 | 472,000 | 12.922 |
| 2011 | 21,865.31 | 471,000 | 12.873 |
| 2012 | 21,878.26 | 469,000 | 12.826 |
| 2013 | 21,900.95 | 468,000 | 12.812 |
| 2014 | 21,894.41 | 466,000 | 12.753 |
| 2015 | 21,897.40 | 462,000 | 12.646 |
| 2016 | 21,898.90 | 459,000 | 12.564 |
| 2017 | 21,945.14 | 454,000 | 12.454 |
| 2018 | 21,899.78 | 450,000 | 12.319 |
| 2019 | 21,899.78 | 447,000 | 12.236 |
| 2020 | 21,900.35 | 445,000 | 12.182 |
| 2021 | 21,901.17 | 427,000 | 11.689 |
| 2022 | 21,899.93 | 424,000 | 11.607 |

* 11% of total population

Default value for methane correction factor MCF for direct discharge (MCF = 0.1), proposed by 2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.3, has been used for emission calculation for the entire period 1990 - 2022.

Default value for maximum methane producing capacity (Bo) of 0.6 kg $CH_4$/kg BOD, proposed by 2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.2, has been used for emission calculation for the entire period 1990 - 2022.

The total organic product (kt DC/yr) that is entered in the CRF 5.D.1 is obtained by summation the total organic product (kt DC/yr) for septic tank and the total organic product (kt DC/yr) for discharge of untreated wastewater (Table 7.5-3).

Table 7.5-3: The total organic product (kt DC/yr) that is entered in the CRF 5.D.1 (1990 - 2022)

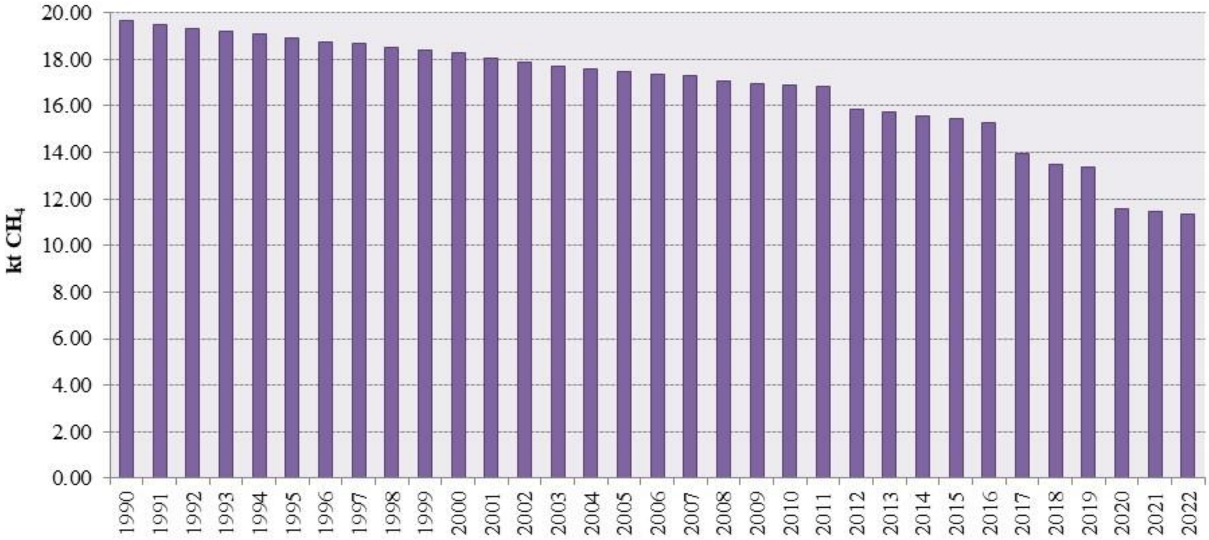
| Year | Total organic product (kt DC/yr) – septic tank | Total organic product (kt DC/yr) – discharge of untreated WW | **Total organic product (kt DC/yr) – CRF 5.D.1** |
|---|---|---|---|
| 1990 | 62.765 | 14.399 | **77.164** |
| 1991 | 62.256 | 13.578 | **75.834** |
| 1992 | 61.748 | 13.468 | **75.216** |
| 1993 | 61.240 | 13.988 | **75.228** |
| 1994 | 60.732 | 13.988 | **74.720** |
| 1995 | 60.225 | 14.071 | **74.296** |
| 1996 | 59.831 | 13.523 | **73.354** |
| 1997 | 59.437 | 13.770 | **73.206** |
| 1998 | 59.042 | 13.551 | **72.593** |
| 1999 | 58.648 | 13.715 | **72.363** |
| 2000 | 58.254 | 13.195 | **71.449** |
| 2001 | 57.603 | 12.976 | **70.579** |
| 2002 | 56.976 | 12.976 | **69.951** |
| 2003 | 56.371 | 12.976 | **69.347** |
| 2004 | 56.064 | 12.976 | **69.040** |
| 2005 | 55.658 | 12.976 | **68.634** |
| 2006 | 55.308 | 12.976 | **68.284** |
| 2007 | 55.067 | 12.976 | **68.043** |
| 2008 | 54.288 | 12.976 | **67.264** |
| 2009 | 53.859 | 12.948 | **66.807** |
| 2010 | 53.660 | 12.922 | **66.582** |
| 2011 | 53.570 | 12.873 | **66.443** |
| 2012 | 50.320 | 12.826 | **63.146** |
| 2013 | 49.840 | 12.812 | **62.652** |
| 2014 | 49.350 | 12.753 | **62.103** |
| 2015 | 48.875 | 12.646 | **61.521** |
| 2016 | 48.390 | 12.564 | **60.954** |
| 2017 | 44.000 | 12.454 | **56.454** |
| 2018 | 42.479 | 12.319 | **54.798** |
| 2019 | 42.041 | 12.236 | **54.277** |
| 2020 | 36.250 | 12.182 | **48.432** |
| 2021 | 35.890 | 11.690 | **47.580** |
| 2022 | 35.531 | 11.607 | **47.138** |

In addition, as mentioned before, 14.8% of the population has wastewater treated only by primary treatment. For primary treatment no MCF is included in the 2006 IPCC Guidelines.

It is assumed that all centralized secondary and higher WWTP are well managed and their emissions can be neglected (since MCF=0).

The resulting annual emissions of $CH_4$ from 5.D.1 Domestic Wastewater (from individual systems for collecting and treatment of the wastewaters and discharge of collected untreated wastewaters) in the period 1990 - 2022 are presented in the Figure 7.5-1.

Figure 7.5-1: Emissions of $CH_4$ from 5.D.1 Domestic Wastewater (1990 - 2022)




There is a continuous decline in $CH_4$ emissions during the reporting period due to decrease in the number of population with individual drainage system as well discharge of untreated wastewater.

According to the ERT recommendation during the 2022 centralized review, it is necessary to collect more detailed and complete information on domestic wastewater treated in various systems occurring in the country, in particular individual wastewater treatment systems. This information should be used for estimating and improving the accuracy of the $CH_4$ emissions from domestic wastewater. This is included in the Annual data collection plan.

Emissions of $NH_3$ for the period 1990 - 2022 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution'.

**Nitrous oxide ($N_2O$) emissions from wastewater**

The $N_2O$ emissions from wastewater treatment effluent have been calculated using the IPCC Tier 1 methodology proposed by the 2006 IPCC Guidelines.

The population estimate of the Republic of Croatia for the period 1990 - 2022 were taken from Statistical Yearbooks and Statistical First Releases[102]). Croatian data on the annual per capita protein intake value (PIV), for the period 1992 -2021, were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. Considering the PIV trend, the pattern from 1992 to 1994 has been used for calculation of data in 1990 and 1991. Considering the PIV trend, the pattern from 2019 to 2021 has been used for calculation of insufficient data for 2022. Data on population and PIV for the period 1990 - 2022 are presented in the Table 7.5-4.

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[102] Croatian Bureau of Statistics, First Releases STAN-2023-3-1 Population Estimate of Republic of Croatia, 2022 (8 September 2023) https://podaci.dzs.hr/en/statistics/population/

Table 7.5-4: Data on population and PIV (1990 - 2022)

| Year | Population | Protein intake (kg/person/yr) |
|---|---|---|
| 1990 | 4,778,000 | 21.35 |
| 1991 | 4,513,000 | 21.38 |
| 1992 | 4,470,000 | 21.72 |
| 1993 | 4,641,000 | 20.99 |
| 1994 | 4,649,000 | 21.78 |
| 1995 | 4,669,000 | 23.54 |
| 1996 | 4,494,000 | 23.33 |
| 1997 | 4,572,000 | 23.12 |
| 1998 | 4,501,000 | 22.83 |
| 1999 | 4,554,000 | 24.30 |
| 2000 | 4,426,000 | 24.34 |
| 2001 | 4,299,642 | 26.40 |
| 2002 | 4,302,174 | 27.81 |
| 2003 | 4,303,399 | 27.61 |
| 2004 | 4,304,600 | 27.46 |
| 2005 | 4,310,145 | 28.52 |
| 2006 | 4,311,159 | 29.38 |
| 2007 | 4,310,217 | 29.76 |
| 2008 | 4,309,705 | 30.16 |
| 2009 | 4,305,181 | 30.72 |
| 2010 | 4,295,427 | 31.12 |
| 2011 | 4,280,622 | 31.51 |
| 2012 | 4,267,558 | 32.29 |
| 2013 | 4,255,689 | 32.69 |
| 2014 | 4,238,389 | 32.82 |
| 2015 | 4,203,604 | 34.14 |
| 2016 | 4,174,349 | 35.12 |
| 2017 | 4,124,531 | 35.61 |
| 2018 | 4,087,843 | 36.57 |
| 2019 | 4,065,253 | 37.58 |
| 2020 | 4,047,680 | 37.46 |
| 2021 | 3,878,981 | 39.00 |
| 2022 | 3,855,641 | 39.50 |

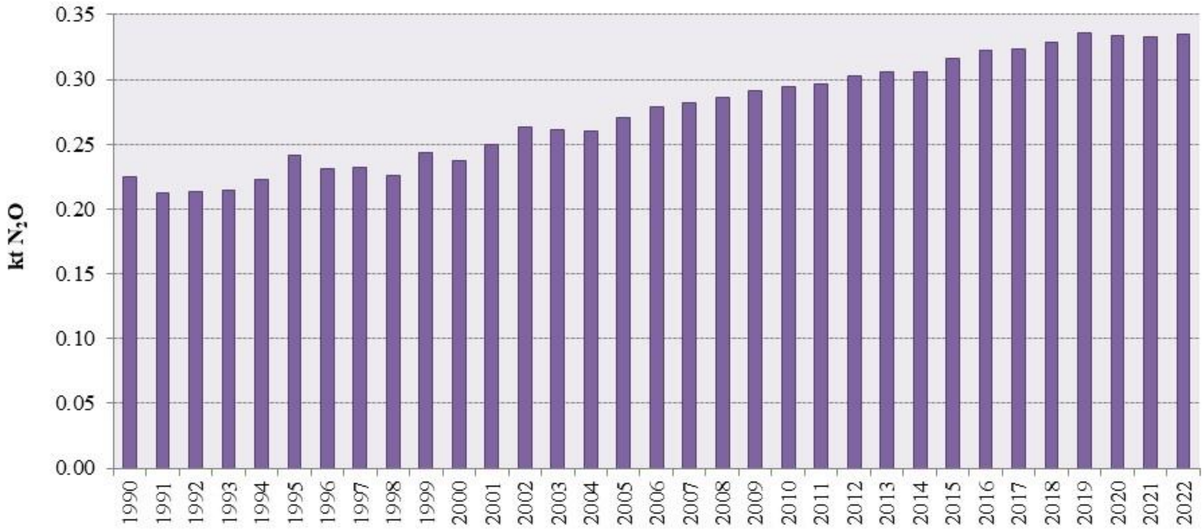
Default values of factors and parameters proposed by the 2006 IPCC Guidelines (Volume 5, Table 6.11) have been used for emission calculation for entire period 1990 - 2022:

- emission factor ($EF_{EFFLUENT}$) = 0.005 kg $N_2O$-N/kg - N;
- fraction of nitrogen in protein ($F_{NPR}$) = 0.16 kg N/kg protein;
- factor for non-consumed protein added to the wastewater ($F_{NON-CON}$) = 1.4[103];
- factor for industrial and commercial co-discharged protein into the sewer system ($F_{IND-COM}$) = 1.25;
- nitrogen removed with sludge ($N_{SLUDGE}$) = 0 kg N/yr.

[103] There is no data on the use of garbage disposal units in households in Croatia. Croatia uses the factor for non-consumed protein F (non-con) = 1.4 for developed countries. Data on the percentage of households that use garbage disposal units are not available. The competent institution should confirm the assumption that less than 1% of household uses garbage disposal units and, in which case Croatia will use the factor for non-consumed protein F (non-con) = 1.1 for developing countries. This is included in the Annual data collection plan.

The resulting annual $N_2O$ emissions from wastewater in the period 1990 - 2022 are presented in the Figure 7.5-2.

Figure 7.5-2: $N_2O$ Emissions from Wastewater (1990 - 2022)




The trend of $N_2O$ emissions during the reporting period depends on the PIV trend.

#### 7.5.2.2. Industrial wastewater

The $CH_4$ emissions from industrial wastewater have been calculated using the IPCC Tier 1 methodology proposed by the 2006 IPCC Guidelines.

Croatian Bureau of Statistics is responsible for the data on industrial output (tonne/yr). Data on industrial output (tonne/yr) for 3 industries with the largest potential for wastewater methane emissions (Manufacture of food products and beverages, Manufacture of pulp, paper and paper products and Manufacture of chemicals and chemical products) were provided by the MESD. Insufficient data were estimated mainly by interpolation/extrapolation method.

For calculation of total organically degradable material in wastewater from industry (in kg COD/yr) it is necessary to multiply total industrial output (in tonne) with wastewater produced (in $m^3$/tonne product) and degradable organic component, DOC (in kg COD/$m^3$ wastewater).

$$t\ x\ \frac{m^3}{\mathrm{t}} x \frac{kg\ COD}{\mathrm{m}^3} = kg\ COD$$

Data on industrial output for the period 1990 - 2022 are presented in the Table 7.5-5.

Table 7.5-5: Data on industrial output (1990 - 2022)

| Year | Total industrial output (tonne) | | |
|---|---|---|---|
| | Manufacture of food products and beverages | Manufacture of pulp, paper and paper products | Manufacture of chemicals and chemical products |
| 1990 | 5,315,793* | 339,150* | 3,318,280* |
| 1991 | 5,351,454* | 353,635* | 3,255,152* |
| 1992 | 5,387,114* | 368,120* | 3,192,024* |
| 1993 | 5,422,775* | 382,605* | 3,128,896* |

| Year | Total industrial output (tonne) | | |
|---|---|---|---|
| | Manufacture of food products and beverages | Manufacture of pulp, paper and paper products | Manufacture of chemicals and chemical products |
| 1994 | 5,458,436* | 453,729 | 3,065,768* |
| 1995 | 5,494,097* | 412,203 | 3,147,255 |
| 1996 | 5,529,757* | 371,798 | 2,915,042 |
| 1997 | 5,446,749 | 425,155 | 2,957,173 |
| 1998 | 5,824,329 | 416,693 | 2,370,884 |
| 1999 | 5,544,368 | 461,676 | 2,773,894 |
| 2000 | 5,658,938 | 540,973 | 2,907,306 |
| 2001 | 3,131,009 | 542,469 | 2,414,577 |
| 2002 | 3,335,776* | 568,227 | 2,325,925 |
| 2003 | 3,544,664* | 544,932 | 2,342,540 |
| 2004 | 3,757,680 | 566,745 | 2,784,861 |
| 2005 | 4,969,306 | 468,791 | 3,066,741 |
| 2006 | 5,455,702 | 538,793 | 2,939,226 |
| 2007 | 5,179,332 | 583,172 | 3,282,811 |
| 2008 | 5,173,879 | 595,836 | 3,127,388 |
| 2009 | 4,332,625 | 406,574 | 2,369,124 |
| 2010 | 4,138,898 | 656,501 | 2,717,498 |
| 2011 | 4,264,109 | 639,814 | 2,652,785 |
| 2012 | 4,201,798 | 559,322 | 2,428,151 |
| 2013 | 4,031,991 | 505,283 | 2,349,055 |
| 2014 | 4,270,581 | 506,894 | 2,473,474 |
| 2015 | 4,170,060 | 522,121 | 2,677,131 |
| 2016 | 4,278,281 | 597,989 | 2,636,934 |
| 2017 | 4,317,779 | 623,360 | 3,040,299 |
| 2018 | 4,114,213 | 618,384 | 2,736,170 |
| 2019 | 4,525,702 | 643,389 | 2,955,198 |
| 2020 | 4,144,084 | 646,114 | 2,891,373 |
| 2021 | 4,019,984 | 717,029 | 2,030,907 |
| 2022 | 4,126,166 | 682,917 | 806,861 |

* insufficient data on industrial output (tonne/yr) were estimated as follows:

- manufacture of food products and beverages: data for the period 1990 - 1996 were assessed by extrapolation method taking into account the pattern from 1997 to 2000; data for 2002 and 2003 were assessed by interpolation method taking into account the pattern from 2001 to 2004;
- manufacture of pulp, paper and paper products: data for the period 1990 - 1993 were assessed by extrapolation method taking into account the pattern from 1994 to 2000;
- manufacture of chemicals and chemical products: data for the period 1990 - 1994 were assessed by extrapolation method taking into account the pattern from 1995 to 2000.

No country-specific data are available for the degradable organic component, DOC (kg COD/$m^3$ wastewater) and wastewater produced ($m^3$/tonnes of product). Average values calculated using default values for different industry type, proposed by 2006 IPCC Guidelines, Volume 5, Table 6.9, has been used for emission calculation for entire period 1990 - 2022 (Table 7.5-6).

Table 7.5-6: Data on degradable organic component and wastewater produced (1990 - 2022)

| Parameter | Manufacture of food products and beverages | Manufacture of pulp, paper and paper products | Manufacture of chemicals and chemical products |
|---|---|---|---|
| DOC (kg COD/$m^3$ wastewater)* | 4.66 | 9.00 | 3.00 |
| Wastewater produced ($m^3$/tonne product)** | 15.55 | 162.00 | 67.00 |

* following default values for DOC (kg COD/$m^3$ wastewater) have been used:

- manufacture of food products and beverages: Alcohol Refining: 11; Beer&Malt: 2.9; Coffee: 9; Dairy products: 2.7; Fish processing: 2.5; Meat&Poultry: 4.1; Sugar refining: 3.2; Vegetables, fruits&juices: 5.0; Wine&vinegar: 1.5 (average = 4.66 kg COD/$m^3$ wastewater);
- manufacture of pulp, paper and paper products: Pulp&Paper (combined): 9.00 kg COD/$m^3$ wastewater;
- manufacture of chemicals and chemical products: Organic chemicals: 3.00 kg COD/$m^3$ wastewater.

** following default values for wastewater produced ($m^3$/tonne product) have been used:

- manufacture of food products and beverages: Alcohol Refining: 24; Beer&Malt: 6.3; Coffee: NA; Dairy products: 7; Fish processing: NA; Meat&Poultry: 13; Sugar refining: NA; Vegetables, fruits&juices: 20; Wine&vinegar: 23 (average = 15.55 $m^3$/tonne product);
- manufacture of pulp, paper and paper products: Pulp&Paper (combined): 162.00 $m^3$/tonne product;
- manufacture of chemicals and chemical products: Organic chemicals: 67.00 $m^3$/tonne product.

Organic component removed as sludge that is deposited at landfills and used for other purposes (composting, agriculture application) was excluded from the total organic product for entire period 1990 - 2022 and reported in the CRF table 5.D.2. (Table 7.5-7)

Table 7.5-7: Data on sludge removed (kt DC/yr) for the period 1990 – 2022

| Year | Landfilling (kt)* | Agriculture application (kt)** | Composting (kt)*** |
|---|---|---|---|
| 1990 | 20.23 | ** | NO |
| 1991 | 20.51 | ** | NO |
| 1992 | 20.80 | ** | NO |
| 1993 | 21.11 | ** | NO |
| 1994 | 21.42 | ** | NO |
| 1995 | 21.75 | ** | NO |
| 1996 | 23.31 | ** | NO |
| 1997 | 23.66 | ** | NO |
| 1998 | 24.05 | ** | NO |
| 1999 | 25.32 | ** | NO |
| 2000 | 26.07 | ** | NO |
| 2001 | 26.83 | ** | NO |
| 2002 | 28.42 | ** | NO |
| 2003 | 29.05 | ** | NO |
| 2004 | 29.02 | ** | NO |
| 2005 | 29.89 | 0.02 | NO |
| 2006 | 30.35 | 0.03 | NO |

| Year | Landfilling (kt)* | Agriculture application (kt)** | Composting (kt)*** |
|---|---|---|---|
| 2007 | 31.06 | 0.04 | NO |
| 2008 | 36.81 | 0.08 | NO |
| 2009 | 24.38 | 2.30 | NO |
| 2010 | 18.48 | 2.17 | NO |
| 2011 | 21.29 | 3.42 | NO |
| 2012 | 26.00 | 4.78 | NO |
| 2013 | 29.19 | 7.84 | 4.54 |
| 2014 | 28.06 | 4.60 | 1.62 |
| 2015 | 29.46 | 6.61 | 1.21 |
| 2016 | 14.91 | 7.78 | 1.29 |
| 2017 | 21.51 | 6.45 | 0.66 |
| 2018 | 23.39 | 8.56 | 1.25 |
| 2019 | 18.20 | 3.12 | 1.00 |
| 2020 | 31.66 | 3.15 | 4.14 |
| 2021 | 23.67 | 3.49 | 9.77 |
| 2022 | 48.71 | 4.36 | 27.83 |

NO – not occuring

* outputs of the Project (Elaborate 3, Chapter 2.2.2., Table 2.2-9, updated with new data for 2022 from ADCP for NIR 2024 - Sector Waste)[104]

** the mass of dry matter is used for agriculture application - conversion factor 0.2 is used for calculation the mass of sludge on a wet weight basis

Activity data are available from 2005 - see explanation in this Report, Chapter 5.5. Agricultural soils (CRF 3.D) / 5.5.1. Direct $N_2O$ emissions from managed soils (CRF 3.D.1) / *Sewage Sludge applied to Soils (3.D.1.2.b.)*

***outputs of the Project (Elaborate 3, Chapter 2.2.2., Table 2.2-10, updated with new data for 2022 from ADCP for NIR 2024 - Sector Waste)

Organic wastewater from industrial sources (kt COD/yr) and the total sludge removed (kt DC/yr) for the period 1990 - 2022 are presented in the Table 7.5-8.

Table 7.5-8: Organic wastewater from industrial sources and the total sludge removed (1990 - 2022)

| Year | Organic wastewater from industrial sources (kt COD/yr) | | | **Total organic wastewater (kt COD/yr)** | **Sludge removed (kt DC/yr)** |
|---|---|---|---|---|---|
| | Manufacture of food products and beverages | Manufacture of pulp, paper and paper products | Manufacture of chemicals and chemical products | | |
| 1990 | 384.831 | 494.481 | 666.974 | **1,546.286** | **20.228** |
| 1991 | 387.413 | 515.600 | 654.286 | **1,557.298** | **20.511** |
| 1992 | 389.994 | 536.719 | 641.597 | **1,568.310** | **20.804** |
| 1993 | 392.576 | 557.838 | 628.908 | **1,579.322** | **21.108** |
| 1994 | 395.157 | 661.537 | 616.219 | **1,672.914** | **21.422** |

[104] With the aim of collecting all the necessary data for the emission calculation and improving reporting on greenhouse gas emissions from the Waste sector (CRF 5), categories Solid waste disposal (CRF 5.A), Biological waste treatment (CRF 5.B) and Waste incineration and open burning of waste (CRF 5 .C), the Ministry of Economy and Sustainable Development launched the project System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950.

| Year | Organic wastewater from industrial sources (kt COD/yr) | | | **Total organic wastewater (kt COD/yr)** | **Sludge removed (kt DC/yr)** |
|---|---|---|---|---|---|
| | Manufacture of food products and beverages | Manufacture of pulp, paper and paper products | Manufacture of chemicals and chemical products | | |
| 1995 | 397.739 | 600.992 | 632.598 | **1,631.329** | **21.747** |
| 1996 | 400.321 | 542.081 | 585.923 | **1,528.326** | **23.311** |
| 1997 | 394.311 | 619.876 | 594.392 | **1,608.579** | **23.664** |
| 1998 | 421.646 | 607.538 | 476.548 | **1,505.732** | **24.051** |
| 1999 | 401.378 | 673.124 | 557.553 | **1,632.055** | **25.320** |
| 2000 | 409.673 | 788.739 | 584.369 | **1,782.780** | **26.067** |
| 2001 | 226.666 | 790.920 | 485.330 | **1,502.916** | **26.834** |
| 2002 | 241.490 | 828.475 | 467.511 | **1,537.476** | **28.423** |
| 2003 | 256.612 | 794.511 | 470.851 | **1,521.973** | **29.049** |
| 2004 | 272.033 | 826.314 | 559.757 | **1,658.104** | **29.018** |
| 2005 | 359.747 | 683.497 | 616.415 | **1,659.660** | **29.901** |
| 2006 | 394.959 | 785.560 | 590.784 | **1,771.304** | **30.377** |
| 2007 | 374.952 | 850.265 | 659.845 | **1,885.062** | **31.092** |
| 2008 | 374.557 | 868.729 | 628.605 | **1,871.891** | **36.885** |
| 2009 | 313.656 | 592.785 | 476.194 | **1,382.634** | **26.680** |
| 2010 | 299.631 | 957.178 | 546.217 | **1,803.03** | **20.655** |
| 2011 | 308.695 | 932.849 | 533.210 | **1,774.75** | **24.708** |
| 2012 | 304.184 | 815.491 | 488.058 | **1,607.73** | **30.776** |
| 2013 | 291.892 | 736.703 | 472.160 | **1,500.75** | **41.562** |
| 2014 | 309.164 | 739.051 | 497.168 | **1,545.38** | **34.273** |
| 2015 | 301.887 | 761.252 | 538.103 | **1,601.24** | **37.270** |
| 2016 | 309.721 | 871.868 | 530.024 | **1,711.613** | **23.977** |
| 2017 | 312.581 | 908.859 | 611.100 | **1,832.540** | **28.620** |
| 2018 | 297.844 | 901.603 | 549.970 | **1,749.418** | **33.199** |
| 2019 | 327.633 | 938.062 | 593.995 | **1,859.689** | **22.322** |
| 2020 | 300.006 | 942.034 | 581.166 | **1,823.206** | **38.955** |
| 2021 | 291.022 | 1,045.428 | 408.212 | **1,744.663** | **36.926** |
| 2022 | 298.709 | 995.693 | 162.179 | **1,456.581** | **80.897** |

There is no sufficient information on the fraction of wastewater type treated by a particular type of system. According to the ERT recommendation during the 2022 centralized review, it is necessary to include a description of the industrial wastewater treatment system used, and the amount of industrial wastewater treated aerobically and anaerobically and discharged into waterways and the seas. This is included in the Annual data collection plan.

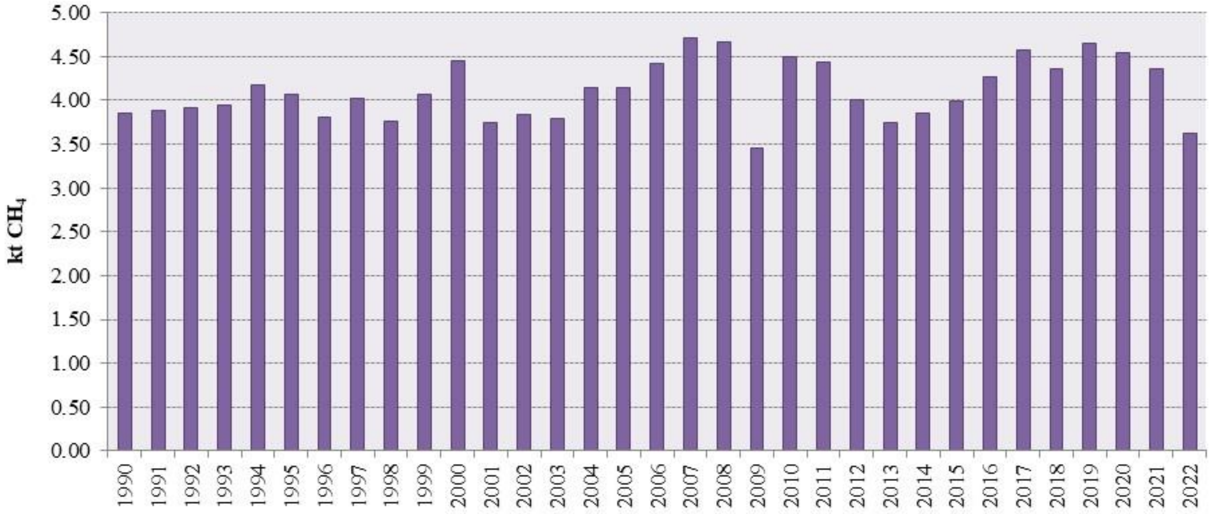
No country-specific data are available for methane correction factor (MCF). Due to the fact that wastewaters are mostly handled aerobically, MCF is assessed to be 0.01 according to expert judgement (the range of values provided by 2006 IPCC Guidelines, Volume 5, Chapter 6.2.3.2, Table 6.8). This value has been used for emission calculation for the entire period 1990 - 2022.

Default value for maximum methane producing capacity (Bo) of 0.25 kg $CH_4$/kg COD, proposed by the 2006 IPCC Guidelines, Volume 5, Chapter 6.2.3.2, page 6.21, has been used for emission calculation for the entire period 1990 - 2022.

No data are available for the amount of methane recovered or flared. Default value of zero, proposed by 2006 IPCC Guidelines, has been used for emission calculation for the entire period 1990 - 2022.

The resulting annual emissions of $CH_4$ from 5.D.2 Industrial Wastewater in the period 1990 - 2022 are presented in the Figure 7.5-3.

Figure 7.5-3: Emissions of $CH_4$ from 5.D.2 Industrial Wastewater (1990 - 2022)




The fluctuating trend of $CH_4$ emissions during the reporting period depends on the data on industrial outputs.

Emissions of NMVOC and $NH_3$ for the period 1990 - 2022 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2022* Submission to the Convention on Long-range Transboundary Air Pollution'.

### 7.5.3. Uncertainties and time-series consistency

The uncertainties contained in $CH_4$ emissions from domestic and industrial wastewater are related primarily to applied default emission factor and assessed values for degradable organic component. Data have been assessed based on information from different sources and consequently have high uncertainty. Also, insufficient data have been assessed by extrapolation/interpolation method and other splicing techniques, which represents additional uncertainty in the estimations.

The uncertainties contained in $N_2O$ emissions from wastewater are related primarily to applied default emission factor and extrapolated values for protein intake.

Based on the obtained information on activity data according to the ADCP, expert responsible for emission calculation for the Waste sector estimated uncertainty of activity data using values recommended in the 2006 IPCC Guidelines, which are included in the tables in the uncertainty assessment chapters for individual categories. Uncertainty estimation based on expert judgment follows the 2006 IPCC Guidelines, Volume 1, Chapter 3. Uncertainties of activity data are given in the Table 7.5-9.

Table 7.5-9: Uncertainty range of activity data for category 5.D

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.D Wastewater treatment and discharge** | **$CH_4$** | | |
| 5.D.1 Domestic wastewater | $CH_4$ | -30 | 30 |
| 5.D.2 Industrial wastewater | $CH_4$ | -30 | 30 |
| **5.D Wastewater treatment and discharge** | **$N_2O$** | | |
| 5.D.1 Domestic wastewater | $N_2O$ | -50 | 50 |

Uncertainties of emission factor were estimated using values recommended in the 2006 IPCC Guidelines. Uncertainties of emission factor are given in the Table 7.5-10.

Table 7.5-10: Uncertainty range of emission factor for category 5.D

| IPCC category | Gas | Uncertainty of activity data | |
|---|---|---|---|
| | | ( - ) % | ( + ) % |
| **5.D Wastewater treatment and discharge** | **$CH_4$** | | |
| 5.D.1 Domestic wastewater | $CH_4$ | -30 | 30 |
| 5.D.2 Industrial wastewater | $CH_4$ | -30 | 30 |
| **5.D Wastewater treatment and discharge** | **$N_2O$** | | |
| 5.D.1 Domestic wastewater | $N_2O$ | -50 | 50 |

More detailed information on uncertainty assessment is presented in Annex 2.

Emissions from 5.D Wastewater Treatment and discharge have been calculated using the same method for every year in the time series. Different sources of information were used for data sets.

### 7.5.4. Category-specific QA/QC and verification

During the preparation of the inventory submission activities related to quality control were mainly focused on completeness and consistency of emission estimates and correct transformation/transcription into CRF tables as well proper use of notation keys, according to QA/QC plan.

During the data collection and administration, data were checked in terms of completeness and plausibility. To clarify any discrepancies, the institution responsible for providing the data was contacted. All steps of data verification and validation are documented.

During the inventory preparation, the correctness of all data and parameters in the estimate files were checked. Plausibility of the results of estimations and their trends were checked and documented. All assumptions, expert judgements and recalculations were explained. Transformation/transcription of activity data and calculated emissions into CRF were checked to compare with information in background calculation tables.

The $CH_4$ and $N_2O$ emissions from 5.D Wastewater treatment and discharge are estimated using Tier 1 method. The uncertainty is high due to the assessment of insufficient data and applied default emission factors. It is necessary to collect more accurate activity data and data for calculation the country-specific emission factors for domestic and industrial wastewater in order to use a higher tier method for $CH_4$ emissions calculation.

All input data and information relevant for the emissions calculation have been documented and archived.

### 7.5.5. Category-specific recalculations

**Domestic wastewater**

***Methane ($CH_4$) emissions from domestic wastewater***

In the previous report, data on population with an individual system of drainage and data for calculation of degradable organic component in kg BOD/1000 person/yr for the years 2020 and 2021 were not available, so they were estimated according to data from 2019. In this report, updated data on population with an individual system of drainage and data for calculation of degradable organic component for the years 2020 and 2021 were collected using ADCP for NIR 2024 - Sector Waste. Therefore, recalculations of $CH_4$ emission were made for the years 2020 and 2021.

***Nitrous oxide ($N_2O$) emissions from wastewater***

In this report, updated data on the annual per capita protein intake value (PIV), for the period 2010 - 2021, were obtained by the FAOSTAT Statistical Database (Update: October 27, 2023). Therefore, recalculations of $N_2O$ emission were made for the period 2010 - 2021.

**Industrial wastewater**

In this report, updated data on total industrial output (t) for the period 2019 - 2021 were collected using ADCP for NIR 2024 - Sector Waste. Additionally, new data on sludge removed were included in the $CH_4$ emission calculation for the period 1990 - 2021. Therefore, recalculations of $CH_4$ emission were made for the period 1990 - 2021.

The difference in $CO_2$-eq emission from category 5.D Wastewater treatment and discharge calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 - 2021 are presented in the Table 7.5-11.

Table 7.5-11: The difference in $CO_2$-eq emission from category 5.D Wastewater treatment and discharge calculated in the previous and current inventory (the difference between NIR 2024 and NIR 2023) for the period 1990 – 2021

| Year | The mass difference in emissions $CO_2$-eq (kt) | The percentage difference in emissions $CO_2$-eq (%) |
|---|---|---|
| 1990 | -0.027 | 0.00 |
| 1991 | -0.029 | 0.00 |
| 1992 | -0.031 | 0.00 |
| 1993 | -0.034 | 0.00 |
| 1994 | -0.036 | -0.01 |
| 1995 | -0.038 | -0.01 |
| 1996 | -0.049 | -0.01 |
| 1997 | -0.051 | -0.01 |
| 1998 | -0.054 | -0.01 |
| 1999 | -0.063 | -0.01 |
| 2000 | -0.068 | -0.01 |
| 2001 | -0.074 | -0.01 |
| 2002 | -0.085 | -0.01 |
| 2003 | -0.089 | -0.01 |
| 2004 | -0.089 | -0.01 |
| 2005 | -0.095 | -0.01 |
| 2006 | -0.098 | -0.01 |
| 2007 | -0.103 | -0.01 |
| 2008 | -0.137 | -0.02 |
| 2009 | -0.029 | 0.00 |
| 2010 | 4.185 | 0.62 |
| 2011 | 4.200 | 0.63 |
| 2012 | 4.447 | 0.70 |
| 2013 | 4.701 | 0.76 |
| 2014 | 4.618 | 0.74 |
| 2015 | 5.126 | 0.82 |
| 2016 | 5.715 | 0.91 |
| 2017 | 6.026 | 1.01 |
| 2018 | 8.342 | 1.44 |
| 2019 | 9.667 | 1.66 |
| 2020 | -40.135 | -6.91 |
| 2021 | -45.516 | -7.89 |

### 7.5.6. Category-specific planned improvements

Improvements in the 5.D Wastewater treatment and discharge related primarily to the establishment of effectively Water Information System with base for systematic gathering/provision of insufficient data and information needed for emissions calculation.

According to the ERT recommendation during the 2022 centralized review, it is necessary to collect more detailed and complete information on domestic wastewater treated in various systems occurring in the country, in particular individual wastewater treatment systems, as well more detailed information and further clarifications on discharge pathways for domestic wastewater treated in the individual system. Furthermore, it is necessary to provide a description of the industrial wastewater treatment system used, and the amount of industrial wastewater treated aerobically and anaerobically and discharged into waterways and the seas (more information on fraction of wastewater type treated by a particular type of system; more information on wastewater flows and treatment system…). This information should be used for estimating and improving the accuracy of the $CH_4$ emissions estimations. Transparent descriptions and accurate data for the whole time series should be provided. It refers to occurrence in the country of (a) anaerobic domestic wastewater installations; (b) anaerobic industrial wastewater installations; (c) aerobic domestic wastewater installations; and (d) aerobic industrial wastewater installations. Accordingly, it is necessary to carry out comprehensive research regarding these issues.

A comprehensive research needs to be performed to collect data for calculation the country-specific emission factors for domestic and industrial wastewater in order to use a higher tier method for $CH_4$ emissions calculation.

All necessary improvements regarding emissions calculations for the entire reporting period are included in the Annual data collection plan as well in the Section 10.4 of this report, defined as long-term goals (over 1 year).

# Chapter 8: Other (CRF sector 6)

UNFCCC Reporting Guidelines (Decision 24/CP.19) paragraph 29 indicates that Annex I Parties should report and explicitly describe the details of emissions from each country-specific source of gases which are not part of the IPCC Guidelines.

Among $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, $NF_3$, no emissions and removals are reported in Other sector.

# Chapter 9: Indirect $CO_2$ and nitrous oxide emissions

## 9.1. Description of sources of indirect emissions in GHG inventory

Although Parties may now choose to report indirect $CO_2$, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, Croatia does not choose to report indirect $CO_2$ emissions from the atmospheric oxidation of $CH_4$, CO and NMVOCs, or indirect $N_2O$ emissions arising from sources other than those in the agriculture and LULUCF sectors.

Information on the following precursor gases: carbon monoxide (CO), nitrogen oxides ($NO_X$) and non-methane volatile organic compounds (NMVOCs), as well as sulphur oxides ($SO_2$) are given in the Chapter 9.2.

## 9.2. Methodological issues

The photochemically active gases, carbon monoxide (CO), oxides of nitrogen (NOX) and non-methane volatile organic compounds (NMVOCs) indirectly contribute to the greenhouse gas effect. These are generally called indirect greenhouse gases or ozone precursors because they are involved in the creation and degradation of ozone which is also one of the greenhouse gases. Sulphur dioxide ($SO_2$), as a precursor of sulphate and aerosols, is believed to contribute negatively to the greenhouse effect. Emissions of indirect GHGs have been taken from the draft of emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution'.

The calculations of aggregated results for the emissions of indirect gases in the period 1990-2022 are given in table 9.2-1.

Table 9.2-1: Emissions of ozone precursors and $SO_2$ by sectors (kt)

| Pollutants | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| NOx Emission | 100.03 | 75.76 | 86.84 | 81.58 | 65.82 | 53.61 | 44.30 | 44.49 | 44.95 |
| Energy | 94.19 | 70.37 | 78.14 | 75.84 | 61.18 | 49.74 | 39.65 | 40.82 | 41.54 |
| Industrial Processes | 2.66 | 2.53 | 2.53 | 2.29 | 1.52 | 1.03 | 0.94 | 0.65 | 0.14 |
| Agriculture | 2.79 | 2.43 | 3.07 | 3.15 | 2.84 | 2.27 | 2.57 | 2.66 | 2.66 |
| LULUCF | 0.04 | 0.21 | 2.89 | 0.09 | 0.05 | 0.36 | 0.98 | 0.22 | 0.46 |
| Waste | 0.35 | 0.22 | 0.22 | 0.21 | 0.23 | 0.20 | 0.16 | 0.15 | 0.15 |
| CO Emission | 558.62 | 447.03 | 550.33 | 415.14 | 328.88 | 279.92 | 244.23 | 232.85 | 216.50 |
| Energy | 512.05 | 409.06 | 426.71 | 392.27 | 323.87 | 266.24 | 211.56 | 224.84 | 203.64 |
| Industrial Processes | 39.91 | 27.26 | 30.12 | 17.37 | 0.18 | 0.21 | 0.08 | 0.31 | 0.29 |
| Agriculture | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| LULUCF | 0.74 | 6.98 | 90.40 | 2.62 | 1.63 | 10.71 | 30.38 | 5.65 | 10.57 |
| Waste | 5.93 | 3.72 | 3.09 | 2.89 | 3.20 | 2.76 | 2.21 | 2.04 | 2.00 |
| NMVOC Emission | 164.28 | 114.70 | 106.37 | 109.40 | 88.00 | 69.35 | 70.08 | 66.08 | 60.29 |
| Energy | 66.52 | 54.75 | 57.69 | 52.42 | 42.93 | 33.76 | 26.41 | 27.87 | 25.76 |
| Industrial Processes | 86.10 | 49.87 | 31.11 | 46.28 | 33.85 | 23.55 | 30.36 | 27.42 | 23.45 |
| Agriculture | 10.83 | 8.67 | 8.71 | 9.42 | 9.56 | 9.34 | 9.02 | 8.85 | 8.85 |
| LULUCF | 0.10 | 0.63 | 7.94 | 0.21 | 0.15 | 0.92 | 2.66 | 0.45 | 0.75 |
| Waste | 0.72 | 0.79 | 0.92 | 1.07 | 1.50 | 1.78 | 1.63 | 1.49 | 1.47 |
| SO2 Emission | 169.68 | 76.83 | 60.00 | 58.36 | 34.98 | 15.52 | 5.88 | 5.10 | 5.47 |

| Pollutants | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|
| Energy | 168.95 | 76.55 | 59.55 | 57.94 | 34.97 | 15.51 | 5.87 | 5.08 | 5.46 |
| Industrial Processes | 0.72 | 0.27 | 0.44 | 0.41 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 |
| Agriculture | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| LULUCF | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Waste | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

## 9.3. Uncertainties and time-series consistency

For detailed information refer to ‘Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution’.

## 9.4. Category-specific QA/QC and verification

For detailed information refer to ‘Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution’.

## 9.5. Category-specific recalculations

For detailed information refer to ‘Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution’.

## 9.6. Category-specific planned improvements

For detailed information refer to ‘Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2022 Submission to the Convention on Long-range Transboundary Air Pollution’.

# Chapter 10: Recalculations and improvements

## 10.1. Explanations and justifications for recalculations, including in response to the review process

The key differences between the previous and latest submission of CRF tables for the time series 1990-2021 are described in each chapter of Inventory.

Table 10.1-1: Difference between emissions estimated in NIR 2024 and NIR 2023 for 1990

| Difference between NIR 2024 and NIR 2023 submission for 1990 | $CO_2$ (1) | $CH_4$ | $N_2O$ | HFCs, PFCs, $SF_6$, $NF_3$ | Total |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt ) | | | | |
| Total (net emissions)(1) | -137.4 | 187.2 | 6.5 | NO | 56.3 |
| **1. Energy** | -105.5 | -0.5 | 5.1 | NO | -100.9 |
| A. Fuel combustion (sectoral approach) | -105.5 | -0.5 | 5.1 | NO | -100.9 |
| B. Fugitive emissions from fuels | 0.0 | 0.0 | 0.0 | NO | 0.0 |
| **2. Industrial processes and product use** | 5.3 | 0.0 | 0.0 | NO | 5.3 |
| A. Mineral industry | 0.0 | NO | NO | NO | 0.0 |
| B. Chemical industry | 0.0 | 0.0 | 0.0 | NO | 0.0 |
| C. Metal industry | 0.0 | 0.0 | NO | NO | 0.0 |
| D. Non-energy products from fuels and solvent use | 5.3 | NO | NO | NO | 5.3 |
| E. Electronic industry | NO | NO | NO | NO | NO |
| F. Product uses as ODS substitutes | NO | NO | NO | NO | NO |
| G. Other product manufacture and use | NO | NO | 0.0 | NO | 0.0 |
| **3. Agriculture** | 0.0 | 0.0 | 0.0 | NO | 0.0 |
| A. Enteric fermentation | NO | 0.0 | NO | NO | 0.0 |
| B. Manure management | NO | 0.0 | 0.0 | NO | 0.0 |
| C. Rice cultivation | NO | NO | NO | NO | NO |
| D. Agricultural soils | NO | NO | 0.0 | NO | 0.0 |
| E. Prescribed burning of savannas | NO | NO | NO | NO | NO |
| F. Field burning of agricultural residues | NO | NO | NO | NO | NO |
| G. Liming | NO | NO | NO | NO | NO |
| H. Urea application | 0.0 | NO | NO | NO | 0.0 |
| **4. Land use, land-use change and forestry** | -37.2 | 0.0 | 1.4 | NO | -35.8 |
| A. Forest land | -37.2 | 0.0 | 0.0 | NO | -37.2 |
| B. Cropland | 0.0 | NO | 0.0 | NO | 0.0 |
| C. Grassland | 0.0 | 0.0 | 1.4 | NO | 1.4 |
| D. Wetlands | 0.0 | NO | 0.0 | NO | 0.0 |
| E. Settlements | 0.0 | NO | 0.0 | NO | 0.0 |
| F. Other land | NO | NO | NO | NO | NO |
| G. Harvested wood products | 0.0 | NO | NO | NO | 0.0 |
| **5. Waste** | 0.0 | 187.7 | 0.0 | 0.0 | 187.7 |
| A. Solid waste disposal | 0.0 | 187.7 | 0.0 | 0.0 | 187.7 |
| B. Biological treatment of solid waste | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| C. Incineration and open burning of waste | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D. Waste water treatment and discharge | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total $CO_2$ equivalent emissions without land use, land-use change and forestry | | | | | 92.14 |
| Total $CO_2$ equivalent emissions with land use, land-use change and forestry | | | | | 56.30 |

Table 10.1-2: Difference between emissions estimated in NIR 2024 and NIR 2023 for 2021

| Difference between NIR 2024 and NIR 2023 submission for 2021 | $CO_2$(1) | $CH_4$ | $N_2O$ | HFCs, PFCs, $SF_6$, $NF_3$ | Total |
|---|---|---|---|---|---|
| | $CO_2$ equivalent (kt ) | | | | |
| Total (net emissions)(1) | -6.6 | -11.3 | 49.6 | NO | 29.4 |
| **1. Energy** | 12.5 | 1.1 | -3.3 | NO | 10.2 |
| A. Fuel combustion (sectoral approach) | 12.5 | 0.7 | -3.3 | NO | 9.8 |
| B. Fugitive emissions from fuels | 0.0 | 0.4 | 0.0 | NO | 0.4 |
| **2. Industrial processes and product use** | -1.9 | NO | 0.0 | NO | -4.1 |
| A. Mineral industry | 0.0 | NO | NO | NO | 0.0 |
| B. Chemical industry | 0.0 | NO | 0.0 | NO | 0.0 |
| C. Metal industry | 0.0 | NO | NO | NO | 0.0 |
| D. Non-energy products from fuels and | -1.9 | NO | NO | NO | -1.9 |
| E. Electronic industry | NO | NO | NO | NO | NO |
| F. Product uses as ODS substitutes | NO | NO | NO | NO | -2.3 |
| G. Other product manufacture and use | NO | NO | 0.0 | 0.00 | 0.0 |
| **3. Agriculture** | -10.6 | 0.0 | -2.9 | NO | -13.5 |
| A. Enteric fermentation | NO | 0.0 | NO | NO | 0.0 |
| B. Manure management | NO | 0.0 | -1.9 | NO | -1.9 |
| C. Rice cultivation | NO | NO | NO | NO | NO |
| D. Agricultural soils | NO | NO | -1.1 | NO | -1.1 |
| E. Prescribed burning of savannas | NO | NO | NO | NO | NO |
| F. Field burning of agricultural residues | NO | NO | NO | NO | NO |
| G. Liming | 0.0 | NO | NO | NO | 0.0 |
| H. Urea application | -10.6 | NO | NO | NO | -10.6 |
| **4. Land use, land-use change and forestry(1)** | -6.7 | 0.0 | 45.3 | NO | 38.6 |
| A. Forest land | -34.9 | 0.0 | 0.0 | NO | -34.9 |
| B. Cropland | 0.0 | 0.0 | 0.0 | NO | 0.0 |
| C. Grassland | 0.0 | 0.0 | 45.3 | NO | 45.3 |
| D. Wetlands | 0.0 | NO | 0.0 | NO | 0.0 |
| E. Settlements | -0.8 | NO | 0.0 | NO | -0.8 |
| F. Other land | NO | NO | NO | NO | NO |
| G. Harvested wood products | 29.0 | NO | NO | NO | 29.0 |
| **5. Waste** | NO | -12.4 | 10.5 | NO | -1.9 |
| A. Solid waste disposal | NO | 48.2 | NO | NO | 48.2 |
| B. Biological treatment of solid waste | NO | -3.9 | 0.2 | NO | -3.7 |
| C. Incineration and open burning of waste | NO | -0.7 | -0.2 | NO | -0.9 |
| D. Waste water treatment and discharge | NO | -56.0 | 10.5 | NO | -45.5 |
| Total $CO_2$ equivalent emissions without land use, land-use change and forestry | | | | | -9.24 |
| Total $CO_2$ equivalent emissions with land use, land-use change and forestry | | | | | 29.39 |

## 10.2. Implications for emission levels

The recalculations are performed in accordance with:

1) Decisions of sectoral experts

2) Suggestions of the expert review team (suggestions reported in Report of the individual review of the annual submission of Croatia submitted in 2022)

## 10.3. Implications for emission trends, including time-series consistency

In 2024 Inventory recalculations are mainly made according to ESD and UNFCCC experts review teams and because of correction of errors and usage of higher tier method for emission calculation.

## 10.4. Planned improvements, including in response to the review process

Croatian National system, as required by Decision 19/CMP.1, was established in 2007 on the basis of Climate change and Ozone Layer Protection Act (NN 127/2019) and Regulation on the Greenhouse Gas Emissions Monitoring in the Republic of Croatia. In 2012 new Regulation on the Monitoring of Greenhouse Gas Emissions, Policies and Mitigation Measures in the Republic of Croatia was enacted with the purpose to harmonize national system with requirements of EU mechanisms for monitoring and reporting greenhouse gas emissions stipulated by Decisions 280/2004/EC, 2005/166/EC, 406/2009/EC and draft of new MMR Regulation. This national regulation has been replaced by Regulation (EU) No 525/2013 of the European Parliament and of the council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC. According to the latest annual review report (ARR) Croatian National System continues to perform its general and specific functions.

Inventory development process, in general, encompasses inventory planning, preparation and management and each of these components have to be periodically assessed and improved. Basis for planning of improvements to the inventory are QA/QC plan, Improvements plan, recommendations identified by Committee for inter-sectoral coordination for national system and recommendations identified by the expert review teams in the course of the inventory review process.

Cross-cutting and general planned improvements

In regard to inventory planning phase, more attention will be given to the effectiveness of activity data flow between collaborating institutions particularly in cases when deadlines for submission of activity data by different data providers are not fully met and/or activity data are missing in case higher IPCC methodology tiers are planned to be implemented for emission estimations.

Since inventory preparation is according to national regulation out-sourced to external authorized institution it is critical to follow the timetable established by the regulatory framework and QA/QC plan and Annual data collection plan. In that respect, written protocols for activity data submission and adjustments per sectors will be prepared to envisage potential bottlenecks and actions to resolve them. Focus of the protocols will be on providing eligible and robust adjustment techniques, technical corrections and recalculations performed by Ministry and/or authorized institution if activity data are missing for entire time series and/or data providers are not in a position to make such adjustments.

Secondly, Committee for inter-sectoral coordination for national system was established by Government's decision in 2014 and it will perform a more active role in streamlining activity data collection according to the agreed timetable, provide recommendations for inventory improvement and in official consideration and approval of the inventory.

Still, annual review process carried out by the UNFCCC Expert Review Teams will continue to be the key driver for changes, prioritization and improvements of the inventory. In that regard recommendations from the latest ARR are presented in Table 10.4-3 with indication on the timeline of their implementation.

In inventory preparation phase it is decided to strengthen implementation of source-category specific QC procedures (tier 2) for key source categories and to explore possibilities to utilize bottom-up annual GHG emission reports prepared by operators or owners of installations and verified by accredited verification bodies which fall under the EU ETS Directive in order to harmonize GHG emissions reported under different monitoring and reporting regimes. If emission calculations prepared by bottom-up installation-specific approach (tier 3) could be reconciled with existing tier 1 or tier 2 approach then the inventory team will apply higher tier approach.

For inventory management, it is decided to improve the existing archiving system, particularly Inventory Data Record Sheets (IDRS), by means of developing database solution for archiving information contained in IDRS in order to allow better and more user-friendly search and analysis since the amount of data have grown substantially. Better coordination among stakeholders will be applied in responding to requests for clarifying inventory information resulting from the different stages of the review process of the inventory information, and information on the national system in a timely manner.

In the Table 10.4-1 recommendations from the latest ARR are addressed with indication of feasible timeline for their accomplishment (long-term indicates period which lasts more than 2 years in order to apply specific recommendation). This plan will be embedded in the Annual Improvement Plan and approved by competent authorities.

Table 10.4-1: Recommendations from the last draft of ARR with the status of implementation

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| Energy sector | | | | |
| 1.A Fuel combustion – sectoral approach – gaseous, liquid and solid fuels – $CO_2$ | The ERT recommends that Croatia implement as a priority the improvement projects for the energy sector addressing the methodological approach used for emission estimates for key categories in accordance with the 2006 IPCC Guidelines. | E.1. | Long term goal | 3.2.4 |
| 1.A.2 Manufacturing industries and construction – gaseous, liquid and solid fuels – $CO_2$, $CH_4$ and $N_2O$ | Distribute fuel consumption and emissions from the generation of electricity and heat in manufacturing industries and construction for 1990–2000 in accordance with the detailed industrial split for stationary combustion provided in the 2006 IPCC Guidelines. | E.5. | Long term goal | 3.2.5. |
| 1.A.2.a Iron and steel – gaseous fuels – $CO_2$ | Remove the amount of natural gas used as a feedstock for steel production from the subcategory 1.A.2.a (iron and steel) and correspondingly revise its $CO_2$ emission estimates for iron and steel production by ensuring that no double counting of emissions from natural gas consumption occurs for the entire time series, in accordance with the 2006 IPCC Guidelines. | E.6. | It is currently only possible to calculate these emissions in aggregate from the national energy balance. | 3.2.5. |
| 1.A.2.g Other | Report emissions from cement production under subcategory 1.A.2.f (non-metallic minerals), not under 1.A.2.g.v (construction). | E.7 | Implemented | 3.2.5. |
| 1.B.2.b Natural gas – gaseous fuels – $CO_2$ | Strive to develop a country-specific $CO_2$ EF for 1.B.2.b.3 (natural gas – processing) (considering that $CO_2$ emissions from 1.B.2.b (natural gas) is a key category), taking into account data on $CO_2$ scrubbing provided by gas field and plant operators and, if this is not possible, use the IPCC $CO_2$ EF default values, avoiding the double counting of emissions from scrubbing under natural gas processing for the | E.11 | Long term goal | 3.3.2. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| | entire time series, and report the revised estimates of $CO_2$ emissions from 1.B.2.b.3 (natural gas – processing) | | | |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| Industrial processes and product use | | | | |
| 2.A.1 Cement production – $CO_2$, Accuracy | Confirm that all sources of CaO are correctly included in the estimation of emissions in accordance with the 2006 IPCC Guidelines. | I.4 | Implemented. | 4.2.1. |
| 2.B.8 Petrochemical and carbon black production – $CO_2$, Accuracy | Move from a tier 1 method to a higher-tier method for estimating $CO_2$ emissions from petrochemical and carbon black production, in accordance with the corresponding decision trees in the 2006 IPCC Guidelines. | I.6 | Not implemented. Input data for a higher tier method for this category are not available. | |
| 2.C.1 Iron and steel production – $CO_2$, Accuracy | Specify all sources of ferrous materials for steel production used in the country and provide this information in the NIR, and also revise the Party's $CO_2$ emission estimates from steel production if the ferrous charge materials were not accurately taken into account in the calculations. | I.10 | No further recalculations were needed for the category in this submission.<br>No additional information could be provided in NIR due to the confidentiality constraints. Based on its preliminary assessment, the ERT concluded that there is no underestimation of emissions. The ERT acknowledged that reporting of information by a Party as confidential is consistent with the UNFCCC Annex I inventory reporting guidelines and noted that Croatia offered to provide, on a confidential basis in response to a request made by the ERT, the confidential data or information needed to consider the emission estimates reported by the Party. | |
| 2.C.1 Iron and steel production – | Allocate the estimates of emissions from natural gas consumption from Energy sector to the IPPU sector. | I.11 | Not implemented. Since all quantities of natural gas are included in the energy balance, ie they are already included in the Energy sector, they have been subtracted from this category within IPPU sector to avoid double counting. | 3.1.1. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| $CO_2$, Comparability | | | | |
| 2.C.1 Iron and steel production – $CO_2$, Transparency | Croatia did not report in its NIR the NCV of natural gas used in the emission calculations for steel production. | I.12 | $CO_2$ emissions corresponding to natural gas input to steel production were reported under the energy sector (see ID# I.11 above). | 3.1.1. |
| 2.D.1 Lubricant use – $CO_2$ | Explain transparently in the NIR the reasons for the significant change in AD of lubricant use in 2003–2004 and, if appropriate, in other years. | I.15 | Not implemented. Consumption of lubricants was taken from the national energy balance. There are no detailed data available on the quantities consumed by type of lubricant use. | 4.5.1. |
| 2.D.1 Lubricant use – $CO_2$, Accuracy | Confirm the balance of lubricants used in Croatia, as shown to the ERT during the review (50 per cent of lubricant is lost during the primary use), and report corresponding emissions from all lubricants oxidized during the primary use under the IPPU sector, from lubricants combusted for energy purposes under the energy sector and from the incineration of lubricants under the waste sector. | I.18 | Not implemented. The fraction of lubricants oxidized during primary use and disposal, including incineration, is not taken into consideration, as the data required for the emission estimate are not available. | |
| 2.D.3 Other (non-energy products from fuels and solvent use) – $CO_2$, Convention reporting adherence | Croatia reported $CO_2$ emissions from solvent use, road paving with asphalt and asphalt roofing in CRF table 2(I).A-H, while reporting indirect $CO_2$ emissions from the IPPU sector as “NA” in CRF table 6. | I.20 | Not implemented. | |
| 2.F.1 Refrigeration and air conditioning - HFCs and PFCs, Transparency | Continue to conduct surveys on the status of disposal of refrigeration and air-conditioning equipment and include the results in the NIR. | I.21 | Implemented. All information on AD, EFs, methods and assumptions used for estimating HFC emissions from the disposal of equipment containing HFCs are included in the NIR. | 4.7.1. |
| 2.F.1 Refrigeration and air conditioning – | Document in detail the sources of actual AD used in the calculations of HFC emissions, the splicing techniques used for estimating missing AD and how the consistency of the time series was ensured, as well as document up-to-date information | I.24 | Implemented. | 4.7.1. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| HFCs and PFCs, Transparency | indicating that PFC emissions are not occurring in Croatia under category 2.F.1. If the latter is not possible, continue reporting PFC emissions under category 2.F.1 in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. | | | |
| 2.F.3 Fire protection – HFCs, Accuracy | Estimate emissions in accordance with the chosen tier 2a method of the 2006 IPCC Guidelines for all HFCs used in category 2.F.3 (fire protection) (HFC-125, HFC-227ea and HFC-236fa) and apply the correct EF for stationary fire protection systems for all years of the time series. | I.28 | Implemented in CRF. | |
| 2.G.3 $N_2O$ from product uses – $N_2O$, Accuracy | Implement the planned improvement regarding gathering accurate and consistent data on $N_2O$ product uses to ensure the accuracy of AD and $N_2O$ emission estimates for $N_2O$ used in anaesthesia and aerosol cans under category 2.G.3 ($N_2O$ from product uses), report a consistent time series of emissions in the CRF tables. | I.35 | Implemented in previous submission. All AD had been reassessed, however, those that were found to be correct were not changed. | |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| Agriculture | | | | |
| 3. General (agriculture) – $CH_4$,<br>Convention reporting adherence | Justify in the NIR the use of the notation key “NO” or otherwise use the notation key “NE” for reporting $CH_4$ emissions from enteric fermentation of poultry under category 3.A.4 (other livestock), and justify in the NIR the use of the notation key “NA” or otherwise use the notation key “NE” for reporting $CH_4$ emissions for category 3.D (agricultural soils). | A.2 | See explanation for issue A.22 in this table | |
| 3. General (agriculture) – $CH_4$ and $N_2O$,<br>Transparency | Cite references in the agriculture chapter of the NIR to the sources of data used to estimate emissions in the agriculture sector, including, when possible, the web address of the source, and make specific references to years or other relevant information to make the source easy to identify. | A.3 | Implemented in NIR 2023. The reference list was updated. | References |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 3. General (agriculture) – $CH_4$,<br>Transparency | Croatia reported as “NE” CH4 emissions from enteric fermentation of poultry (CRF table 3.As1) and $CH_4$ emissions from agricultural soils (CRF table 3s2) without providing an explanation in its NIR as to why it did not estimate the emissions for these categories. During the review, the Party explained that $CH_4$ emissions from enteric fermentation of poultry and from agricultural soils were not estimated because an estimation method for these categories has not been developed and no default EFs for the tier 1 methodology are provided in the 2006 IPCC Guidelines.<br>The ERT recommends that Croatia improve the transparency of its reporting by explicitly including in the NIR the rationale for not estimating $CH_4$ emissions from enteric fermentation of poultry and $CH_4$ emissions from agricultural soils as well as for any other categories of the agriculture sector for which emissions were not estimated. | A.22 | Implemented in NIR 2021.<br>The rationale was added in the relevant chapters. | NIR 2021:<br>5.2.2, 5.5 |
| 3.A.1 Cattle –<br>$CH_4$,<br>Transparency | Report in the NIR the correct maintenance coefficients from the 2006 IPCC Guidelines (vol. 4, table 10.4) that were used to estimate $CH_4$ emissions from enteric fermentation of cattle. | A.5 | Implemented in NIR 2023. | Table 5.2-4 |
| 3.A.1 Cattle –<br>$CH_4$,<br>Accuracy | Estimate $CH_4$ emissions from enteric fermentation and manure management consistently using, if appropriate, representative livestock subcategories from table 10.1 of the 2006 IPCC Guidelines (vol. 4, p.10.11) and report the results in the annual submission. Assumptions and documented expert judgment can be used where data gaps are observed (e.g. the population of other cows for 1990–1999 can be derived from the structure of the herd in 2000–2017 and it can be assumed that other cows mostly comprise beef cows). | A.6 | Implemented in NIR 2020 - 2022.<br>Table 5.2-3 contains information on how CBS categories for cattle were reclassified into the appropriate IPCC categories. | Table 5.2-3 |
| 3.A Enteric fermentation – $CH_4$,<br>Accuracy | Croatia estimated $CH_4$ emissions from enteric fermentation for all livestock categories by applying a tier 1 method and default EFs from the 2006 IPCC Guidelines (vol. 4, table 10.11) (NIR p.178). National data on animal populations were provided by CBS and the Croatian Agricultural Agency and, where national data were not available, FAO data were used. The ERT noted that Croatia reported in its 2018 submission that a tier 2 method was applied for estimating $CH_4$ emissions from enteric fermentation of cattle, sheep and swine through the use of country-specific values for average gross energy intake and average $CH_4$ conversion rate to estimate country- specific EFs.<br>The ERT recommends that Croatia prioritize efforts and resources to apply a higher-tier methodology for estimating emissions from enteric fermentation, and report the estimates obtained from using that methodology as well as a description of country-specific parameters (i.e. gross energy and $CH_4$ conversion rate), at least for cattle, which represent 81 per cent of $CH_4$ emissions from enteric fermentation, in line with the decision tree for $CH_4$ emissions from enteric fermentation in the 2006 IPCC Guidelines | A.23 | Implemented in NIR 2023.<br>New national CS have been used in emission estimate. | Chapter 5.3.1.5 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 3.A.1 Cattle – $CH_4$, Transparency | Report the feeding situation for cattle in CRF table 3.A (e.g. stall, pasture) instead of reporting activity coefficients, and include on the NIR a description of the approach used to derive activity coefficients for estimating net energy for each activity, based on equation 10.4 of the 2006 IPCC Guidelines (vol.4) for mature dairy and non dairy cattle. | A.7 | Planned. | |
| 3.B Manure management - $N_2O$, Transparency | Include in the NIR a description of the method, data and assumptions used to estimate country- specific Nex values for cattle as well as weight data and the assumptions used to derive default Nex values for other livestock categories, with supporting references, and also report Nex rates in CRF table 3.B(b) disaggregated by other mature cattle and growing cattle subcategories, as required when reporting under Option B, instead of using a single aggregated Nex rate for both above- mentioned animal subcategories | A.9 | | |
| 3.B Manure management – $CH_4$, Convention reporting adherence | Croatia reported in CRF table 3.B(a)s2 the following notation keys for MCF: "NE" for mature dairy cattle – anaerobic lagoon, cool climate region; "NO" for other mature cattle – anaerobic lagoon, cool climate region; "NE" for market swine – solid storage and dry lot, cool climate region; and "NE" for horses – solid storage, dry lot, and pasture, range and paddock, cool climate region. However, Croatia reported the Nex rate for each MMS in CRF table 3.B(b) for all animal categories for which the MMS applied. During the review, the Party explained that notation keys in CRF table 3.B(a)s2 had been entered incorrectly.<br><br>The ERT recommends that Croatia report in CRF table 3.B(a)s2 appropriate MCF data for animal categories allocated to MMS in the cool climate region: mature dairy cattle – anaerobic lagoon; other mature cattle – anaerobic lagoon; market swine – solid storage and dry lot; and horses – solid storage, dry lot, and pasture, range and paddock | A.24 | Implemented in NIR 2023.<br><br>Correct notation keys were entered. | CRF tables |
| 3.B Manure management – $CH_4$, Transparency | Croatia used an MCF for its liquid systems (22 per cent) that is within the range of the IPCC default for liquid/ slurry without crust cover in cool climate (17–25 per cent). The Party also used the same MCF value (22 per cent) for anaerobic lagoons. The MCF value for anaerobic lagoons is lower than the IPCC default range for cool climate (66–73 per cent) (see NIR table 5.3-1 and table 10.17 of the 2006 IPCC Guidelines (vol. 4)). During the review, the Party explained that the MCFs of 22 per cent for liquid systems and anaerobic lagoons were proposed by the EU during its review of member States' GHG inventories for the NIR 2016, where anaerobic lagoons were characterized with similar conditions to those of liquid systems owing to a combination of a cool temperature and the environmental legislation of Croatia. Noting the cool temperature conditions of Croatia and the available scientific information on anaerobic lagoons for manure management (e.g. the Wastewater Technology Fact Sheet prepared by the United States Environmental Protection Agency (https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=OW&dirEntryID=23812), the ERT considers the use of an MCF of 22 per cent for anaerobic lagoon MMS to be reasonable. However, the ERT also considers that this must be scientifically justified by the Party. | A.25 | Planned. | |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| | The ERT recommends that Croatia include in its NIR a detailed rationale for using MCFs of 22 per cent for both liquid systems and anaerobic lagoons or revise the estimates of $CH_4$ emissions from these MMS using the default MCF values from the 2006 IPCC Guidelines (i.e. 17–25 per cent for liquid systems without crust cover and 66–73 per cent for anaerobic lagoons). | | | |
| 3.B.1 Cattle – $CH_4$, Accuracy | Follow the guidance in the decision tree in the 2006 IPCC Guidelines (vol. 4, chap. 10, p.10.36, figure 10.3) for estimating $CH_4$ emissions from manure management of cattle, including the use of currently available data on gross energy and feed digestibility for estimating country-specific VS values, and report the results in the next annual submission. | A.10 | Implemented in NIR 2023.<br>New national CS have been used in emission estimate. | Chapter 5.3.1.5 |
| 3.B.1.Cattle – $CH_4$, Convention reporting adherence | The ERT noted that the total percentage of growing cattle allocated to MMS is 98.8 per cent (CRF table 3.B(a)s2), thus 1.2 per cent of the animal population was not assigned to a specific MMS. During the review, Croatia explained that the remaining 1.2 per cent of growing cattle was allocated to anaerobic lagoons. The ERT notes that this is an error only in the CRF metadata; emissions were calculated correctly and attributed to this MMS.<br>The ERT recommends that Croatia revise and report in the CRF tables the correct percentages of growing cattle allocated to each MMS for the cool climate region, ensuring that the allocation totals 100 per cent. | A.27 | Implemented in NIR 2023. | CRF |
| 3.B.2 Sheep – $N_2O$, Completeness | Croatia reported the total amount of direct $N_2O$ emissions from manure management as 0.138 kt $N_2O$ (40.99 kt $CO_2$-eq) in CRF table 3.B(b). The ERT noted that the total amount is different when $N_2O$ emissions by livestock category are aggregated during the review, the Party provided the ERT with the spreadsheet used in estimating direct $N_2O$ emissions from manure management. However, the ERT noted that the annual direct $N_2O$ emissions from manure management do not include direct $N_2O$ emissions from solid storage MMS of sheep, which amounted to 13,540.9 kg $N_2O$/year. In response to a question raised by the ERT about the rationale for not including these emissions, Croatia explained that the omission is attributable to an error in the spreadsheet; that is, direct $N_2O$ emissions from solid storage MMS of sheep should have been included in the total. Using the spreadsheet provided by Croatia, the ERT estimated an amount of 0.151 kt $N_2O$ (44.9 kt $CO_2$-eq) for total annual direct $N_2O$ emissions from manure management including direct $N_2O$ emissions from solid storage MMS of sheep. The ERT notes that the difference of 4.0 kt $CO_2$-eq is below the significance threshold (0.05 per cent of national total emissions without LULUCF).<br>The ERT recommends that Croatia report revised direct $N_2O$ emissions from manure management that include the direct $N_2O$ emissions from solid storage MMS of sheep, and ensure that all direct $N_2O$ emissions from manure management of all livestock categories are included in the total amount in order to avoid a potential underestimation of emissions | A.28 | Implemented in NIR 2021.<br>Solid storage MMS for sheep was correctly included in the reported estimate. | NIR 2021: 5.3.2.5 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 3.B.4 Other livestock – $CH_4$ and $N_2O$, Completeness | Estimate $CH_4$ and $N_2O$ emissions from manure management of rabbits under category 3.B.4 (other livestock) using default EFs and parameters from tables 10.16 and 10.A.9 (vol. 4, chap. 10, pp.10.41 and 10.83, respectively) and Nex value from table<br>10.19 (vol. 4, chap. 10, p.10.59) of the 2006 IPCC Guidelines, or ensure that the related cells in CRF tables 3, 3.A, 3.B(a) and 3.B(b) are filled in with the corresponding notation keys. | A.13 | Implemented in NIR 2021.<br>Rabbits animal category was added to the emission estimate. | NIR 2021: 5.2.2, 5.2.5<br>NIR 2022: 5.2.2 |
| 3.B Manure management – $N_2O$, Accuracy | Croatia estimated direct $N_2O$ emissions from manure management for all livestock categories by applying a tier 1 method from the 2006 IPCC Guidelines (vol. 4) and using national animal population data from CBS, the Croatian Agricultural Agency and FAOSTAT; default values for Nex rate for all livestock categories (table 10.19 in the 2006 IPCC Guidelines); default values for typical animal mass for all livestock categories (tables 10A-4 to 10A-9 in the 2006 IPCC Guidelines) except for cattle, for which country-specific typical animal mass values were used (562.8 kg for mature dairy cattle, 529.1 kg for other mature cattle and 301.6 kg for growing cattle); and a country- specific MMS distribution and default EFs for manure management systems (table 10.21 in the 2006 IPCC Guidelines) (NIR p.185).<br>The ERT recommends that Croatia apply a tier 2 method with collected data to develop and revise the Nex rates and country-specific EFs for typical animal mass and a country-specific MMS distribution and report in the NIR a description of the country-specific parameters used, especially for cattle and poultry, which represent 52.8 and 28.7 per cent of direct $N_2O$ emissions from manure management, respectively, in line with the decision tree for $N_2O$ emissions from manure management in the 2006 IPCC Guidelines. | A.26 | Implemented in NIR 2023.<br>New national CS have been used in emission estimate. | Chapter 5.5.1.5 |
| 3.B.5. Indirect $N_2O$ emissions – $N_2O$, Accuracy | Croatia reported the total N volatilized as $NH_3$ and $NO_X$ as 12,209,771.4 kg N/year in CRF table 3.B(b). The ERT noted that, in the spreadsheet used in estimating the emissions, which was provided by the Party during the review, the estimated amount was 18,215,665.6 kg N/year, which is higher than the amount reported in CRF table 3.B(b). During the review, in response to a question raised by the ERT about the rationale for different N amounts being estimated and reported, the Party explained that the spreadsheet contains values revised following the ESD technical correction by the EU related to the incorrect use of FracGasMS and FracLossMS. On the other hand, the ERT noted that Croatia did not include the amount of N volatilized as $NH_3$ and $NO_X$ from the solid storage MMS of sheep (206,806.9 kg N/year) in the total amount of N volatilized as $NH_3$ and $NO_X$ from all MMS for all livestock categories (18,215,665.6 kg N/year) in its estimates reported in CRF table 3.B(b) (see ID# A.28 above). Further, in response to a question on the reason why the IEF for N volatilization and re-deposition reported in CRF table 3.B(b) (0.0251 kg $N_2O$-N/kg N) is higher than the default EF4 (0.01 kg $N_2O$-N) from table 11.3 of the 2006 IPCC Guidelines (vol. 4), the Party explained that a conversion of $N_2O$-N emissions to $N_2O$ emissions (conversion factor: 44/28) was performed twice in estimating emissions for the 2020 submission, resulting in an overestimation of emissions and a high IEF. Using the spreadsheet provided by Croatia, the ERT estimated an amount of 18,422,472.5 kt N/year as total N volatilized as $NH_3$ and $NO_X$ – including the amount of N volatilized from the solid storage MMS of sheep. When the appropriate default EF4 (0.01 kg | A.29 | Implemented in NIR 2021.<br>Solid storage MMS for sheep was correctly included in the reported estimate and the incorrect double conversion on $N_2O$-N to $N_2O$ emission was removed, correcting the reported overestimated emissions from the source. | NIR 2021: 5.3.2.5 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| | $N_2O$-N) is applied, the result is an amount of 0.289 kt $N_2O$ (86.3 kt $CO_2$-eq), which is lower than the 0.307 kt $N_2O$ (91.4 kt $CO_2$-eq) reported by Croatia in its CRF table 3.B(b). The ERT concludes that even though Croatia underestimated the amount of N volatilized, the indirect $N_2O$ emissions from atmospheric deposition were overestimated owing to the error in the conversion factor of $N_2O$-N emissions to $N_2O$ emissions, which was applied twice.<br>The ERT recommends that Croatia correct its estimation of total N volatilized as $NH_3$ and $NO_X$ by including the amount of N volatilized as $NH_3$ and $NO_X$ from the solid storage MMS of sheep, and by revising the conversion of $N_2O$-N emissions to $N_2O$ emissions. | | | |
| 3.D Direct and indirect $N_2O$ emissions from agricultural soils – $N_2O$,<br>Accuracy | Correct the error concerning the N content of dry matter used to estimate emissions and improve QA/QC for the data received from the Croatian Environment Agency.<br>Croatia continued to report an unrealistically high value of 11.0 per cent for the N content of dry matter of sewage sludge for 2005–2008. During the review, the Party clarified that the recommendation had not been implemented as the updated AD were not yet available, but that correcting this error is a planned improvement. | A.15 | Implemented in NIR 2021.<br>N% for AD in for 2005-2008 was changed from 11% to 3.89%. | NIR 2021:<br>5.5.1.1,<br>Table 5.5-3,<br>5.5.1.3 |
| 3.D Direct and indirect $N_2O$ emissions from agricultural soils – $N_2O$,<br>Accuracy | Croatia reported N input from animal manure applied to soils as 30,214,097.1 kg N/year in CRF table 3.D. However, the ERT noted that in the spreadsheet used in estimating emissions from animal manure applied to soils provided by the Party during the review, N input from manure applied to soils was indicated as 24,693,615.3 kg N/year, which is lower than the amount reported in CRF table 3.D. In response to a question raised by the ERT about the rationale for different N amounts being estimated and reported, Croatia explained that the spreadsheet contains values revised following the ESD review findings related to the incorrect use of FracGasMS and FracLossMS. The revisions implemented resulted in a change in the total N input from manure applied to soils. The ERT noted that applying the N input from animal manure applied to soils corrected by the ESD review would result in lower $N_2O$ emissions – that is, 0.388 kt $N_2O$ (115.6 kt $CO_2$-eq) – than those reported in CRF table 3.D (0.475 kt $N_2O$, or 141.5 kt $CO_2$-eq).<br>The ERT recommends that Croatia increase the accuracy of the estimated direct $N_2O$ emissions from animal manure applied to soils by applying FracGasMS and FracLossMS in accordance with the 2006 IPCC Guidelines (vol. 4, tables 10.22 and 10.23) for each animal category in each manure management system used in the country. The ERT also recommends that the Party revise indirect $N_2O$ emissions from animal manure applied to soils due to changes in N input from manure applied to soils that directly affect indirect $N_2O$ emissions from atmospheric deposition and N leaching and run-off. | A.30 | Implemented in NIR 2021. | NIR 2021:<br>5.3.2.5,<br>5.5.1.5,<br>5.5.2.5 |
| 3.D.a Direct $N_2O$ emissions from managed soils – | Justify on the NIR the assumptions used to derive the uncertainty value of ±30 per cent for the EF1 for mineral fertilizers, N-fixing crops and crop residues and ±50 per cent for animal manure, or use the | A.16 | Implemented in NIR 2023 – the uncertainty | NIR 2021:<br>5.5.1.3 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| $N_2O$,<br>Convention reporting adherence | appropriate uncertainty range for the default EF1 from table 11.1 of the 2006 IPCC Guidelines (0.003–0.03 kg $N_2O$-N/kg N) in the Monte Carlo uncertainty analysis. | | values were changed (see A.31) | |
| 3.D.a Direct $N_2O$ emissions from managed soils –<br>$N_2O$,<br>Convention reporting adherence | Croatia performed an uncertainty analysis using approach 2, and reported the use of uncertainty values for the default EF1 that is within the uncertainty range of –70 to +200 per cent for mineral fertilizers and N-fixing crops and crop residues and within the combined uncertainty range of –50 to +150 per cent for urine and dung deposited by grazing animals (NIR p.198). However, the ERT noted that in NIR annex table A2:3-1, an uncertainty value of ±30 per cent was used for organic N fertilizers and mineralization/immobilization associated with loss/gain of soil organic matter. This range is not in line with the uncertainty ranges for the default values of EF1 (0.003–0.03 kg $N_2O$-N/kg N) in table 11.1 of the 2006 IPCC Guidelines (vol. 4). During the review, the Party acknowledged the issue, stated that the range of –70 to +200 per cent should be applied to organic N fertilizers and mineralization/immobilization associated with loss/gain of soil organic matter, and indicated that this issue would be corrected in the uncertainty estimates reported in the next NIR.<br>The ERT recommends that Croatia apply the appropriate uncertainty range for the default EF1 from the 2006 IPCC Guidelines (0.003–0.03 kg $N_2O$-N/kg N) and report the results. | A.31 | Implemented in NIR 2023.<br>The uncertainty values were changed according to the recommendation. | NIR 2021:<br>5.5.1.3 |
| 3.D.a Direct $N_2O$<br>emissions from managed<br>soils –<br>$N_2O$,<br>Accuracy | Investigate the reasons for the substantial discrepancies observed between data from producing companies and statistical data on the consumption of inorganic N fertilizers in the country for 2006–2016 (e.g. by analysing production, export and import data), including relevant data from the Food and Agriculture Organization of the United Nations in the comparison analysis, revise the estimates for the consumption of inorganic N fertilizers for 2006– 2016 on the basis of the investigation and using the most reliable source of data, if appropriate, while ensuring time-series consistency, and report the results in the next annual submission. | A.17 | Inquiry performed. CBS data is considered to be official national value on N fertilizer consumption for 2000-2021. | 5.5.1.2 |
| 3.D.a.2.b Sewage sludge applied to soils – $N_2O$,<br>Completeness | Considering the increasing trend in the amount of sludge applied during 2005–2016, make all the necessary efforts to obtain reliable data on sludge applied during 1990–2008. If this is not possible, extrapolate the values for 2009–2016 or use another, more appropriate splicing technique recommended by the 2006 IPCC Guidelines to derive the amount of sludge applied to soils for 2005–2008 and report the resulting $N_2O$ emissions for subcategory 3.D.a.2.b (sewage sludge applied to soils). Also investigate and confirm whether sludge application occurred in earlier years of the time series (1990–2004) and, if so, use the same splicing technique to expand the period and report $N_2O$ emissions for subcategory 3.D.a.2.b for the complete time series. | A.19 | Planned. | 5.5.1.6 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| **LULUCF** | | | | |
| 4. General (LULUCF) – $CO_2$, $CH_4$ and $N_2O$ (L.1, 2020) (L.3, 2018) (L.12, 2016) (L.12, 2015) Convention reporting adherence | Determine which carbon pools and subcategories are significant in each key category based on the guidance provided in the 2006 IPCC Guidelines, and provide detailed information on the results of such determination in the NIR. | L.1 | Addressing. Croatia will provide details on the carbon pools that have a significant impact on total national emissions and removals, and their trend or uncertainty for land-use categories other than forest land remaining forest land, for which above-ground biomass and soil were considered significant pools. Analysis will be carried out in NIR 2025 submission. | LULUCF - general |
| 4. General (LULUCF) – $CO_2$, $CH_4$ and $N_2O$ (L.3, 2020) (L.21, 2018) Comparability | Use "NA" for reporting a specific carbon pool for which an IPCC default method is applied that assumes that no net CSCs occur, accompanied by an explanation in the information box of the corresponding CRF table stating that "NA" indicates a tier 1 estimate. | L.3 | Addressing. The Party changed the notation key "NO" to "NA" for the category of forest land remaining forest land. However, for all other land-use categories for which it assumes that no net CSCs occur, it continued to report "NO" without including any information in documentation boxes. During the review, Croatia resubmitted its CRF tables but in the resubmitted file net CSCs in dead organic matter were still reported as "NO". During the review, the Party noted the urgent need to improve the QA/QC plan for the LULUCF sector. The comprehensive QA/QC has been predicted for NIR 2025 | LULUCF - general |
| 4. General (LULUCF) | Correct all the inconsistencies identified in the NIR and between the NIR and the CRF tables, and further improve the QA/QC system's effectiveness by enhancing related QA/QC procedures such as internal audits, and corrective and preventive activities following the national QA/QC plan, in order to be able to identify and correct such inconsistencies during the inventory preparation process in the future. | L.5 | Addressing. Croatia corrected the inconsistencies identified in the NIR 2023 and between the NIR and the CRF tables for the NIR 2024 submission. Party clarified that it recognizes the urgent need to improve its QA/QC plan for the LULUCF sector. These improvements will be initiated for the next annual | LULUCF - general |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| | | | submission and subsequent improvements will be made over the following three years.<br>Short- and midterm improvements will be described in the next annual submission. | |
| LULUCF – land representation | Review the uncertainty estimations in forest land remaining forest land, land converted to forest land, grassland and land-use changes to and from cropland and, if the uncertainty ranges are confirmed, undertake improvements to the approaches used to reduce the uncertainty of the estimates, taking into account and focusing on the identified significant sources of uncertainties associated with the use of approaches 1, 2 and 3 for land representation as well as those related to the use of the tier 1 parameters from the 2006 IPCC Guidelines. | L.7 | Addressing. Planned for NIR 2025 submission . | LULUCF - general |
| Land representation – $CO_2$, $CH_4$ and $N_2O$ | Report in the NIR a detailed description of the method implemented to estimate uncertainties in AD, in particular regarding the assumptions. | L.8 | Addressing. Planned for NIR 2025 submission. | LULUCF - general |
| Land representation – $CO_2$, $CH_4$ and $N_2O$ (L.23, 2020) Transparency) | Transparently report in the NIR the data used and assumptions made in estimating the gross fluxes of land-use change between cropland and grassland. | L.10 | Croatia began a project in 2020 (*Croatian Land Information System*, *CROLIS*) to improve its reporting on this land use change to complement the data held in its Land Parcel Identification System by providing the necessary data on agricultural land use in order to improve the report. | |
| 4.A Forest land – $CO_2$ (L.10, 2020) (L.25, 2018) Accuracy | Develop country-specific BEFs and ratios of below-ground biomass to above-ground biomass to fully implement the tier 2 method for this key category, in line with the 2006 IPCC Guidelines. | L.11 | Adressing. The Party explained in its NIR (section 6.4.2.1, under table 6.4.3) and during the review that a separate project is required to estimate national values of BEF, which will be considered when planning future activities in the LULUCF sector. | Table A3.2-1: Implemented and planned projects in LUULCF sector |
| 4.A Forest land – $CO_2$ (L.10, 2020) (L.25, 2018) Transparency | Develop country-specific BEFs and ratios of below-ground biomass to above-ground biomass to fully implement the tier 2 method for this key category, in line with the 2006 IPCC Guidelines, and report on this in the next annual submission. | L.12 | Adressing. A specific project needs to be initiated. | Table A3.2-1: Implemented and planned projects in LUULCF sector |
| 4.A.2 Land converted to forest land – $CO_2$ | Provide detailed information on the analysis of the data from CRONFI to check their usefulness for the GHG inventory, and clarify whether the CRONFI data cover both the deadwood and the litter pools. | L.15 | Resolved. Crootia provided detailed description for deadwood and litter pools under section 6.B.2.1., table 6.5.3. | 6.1 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| (L.13, 2020) (L.10, 2018) (L.16, 2016) (L.16, 2015) Transparency | | | | |
| 4(IV) Indirect $N_2O$ emissions from managed soils – $N_2$ | Estimate indirect $N_2O$ emissions associated with the loss of soil organic matter resulting from a change in land use or management of mineral soils | L.19 | Resolved | |
| 4.G HWP – $CO_2$ (L.25, 2020) Convention reporting adherence | Verify and report the correct amount of gains and losses of HWP in t C as required in CRF table 4.Gs1. | L.20 | Resolved. Croatia reported HWP values in t C in CRF table 4.Gs1 for NIR 2024 submission. | |
| 4.G HWP – $CO_2$ (L.26, 2020) Transparency | If the import and export of roundwood continues to be reported as input to HWP on the basis of equations 2.8.1 and 2.8.4 of the Kyoto Protocol Supplement, apply equation 2.8.4 correctly by taking into account the import–export balance of wood pulp for the paper and paperboard pool. | L.22 | Resolved. | 6.10 |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 5.A Solid waste disposal on land – $CH_4$ | Provide information on the type of waste disposed of in SWDS and ensure that all types of solid waste, including industrial waste, sludge, and construction and demolition waste, disposed of in SWDS are included in the emission estimates. | W.1 | Resolved | 7.2.2.1. |
| 5.A Solid waste disposal on land – $CH_4$ | Provide comprehensive information on solid waste management practices in the NIR, if possible in tabular format, covering the number of active and closed SWDS (including unofficial ones), the type of SWDS and management practices used at all landfills in the country (including unofficial ones), including the type of waste and amounts disposed of. | W.2 | Resolved | 7.2.1. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 5.A Solid waste disposal on land – $CH_4$ | Continue the efforts to obtain accurate country-specific historical AD and parameters, in particular on population, waste generation per capita and the percentage of waste disposed of at SWDS for different periods of time from 1955 to 1990, with the aim of estimating $CH_4$ emissions for the entire time series for category 5.A (solid waste disposal). | W.3 | Resolved | 7.2.2. |
| 5.A Solid waste disposal on land – $CH_4$ | Document the efforts to obtain accurate country-specific historical AD and parameters on waste disposed of at SWDS comprehensively in the NIR, including a description of improvements made to the assumptions, in particular by referring to the annual increases in population, waste generation per capita and the percentage of waste disposed of at SWDS for different periods of time from 1955 to 1990. | W.4 | Resolved | 7.2.2.1. |
| 5.A Solid waste disposal on land – $CH_4$ | Provide in the NIR the DOC values not only for MSW but also for industrial waste and sludge. | W.5 | Resolved | 7.2.2.2. |
| 5.A Solid waste disposal on land – $CH_4$ | Revise estimates of $CH_4$ emissions from industrial waste by using the amount of each waste type (e.g. paper/cardboard, textiles, food waste, wood) rather than the total amount of industrial waste disposed of. | W.6 | Resolved<br>The total average DOC was calculated using detailed data on mass of disposed IW from different sub-groups of groups 01, 17 and 19, which account for an average of about 90% of disposed IW during the observed period. Default values for DOC content are taken from the 2006 IPCC Guidelines. In this way, all degradable components in IW are covered for the DOC calculation. | 7.2.2.2. |
| 5.A Solid waste disposal on land – $CH_4$ | Clearly report in the NIR that construction and demolition waste is included in industrial waste as AD for this category. | W.7 | Resolved | 7.2.2.2. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 5.A Solid waste disposal on land – $CH_4$ | Investigate the amount of waste disposed of at unofficial sites and include the emissions from those sites in the estimates for the category. | W.8 | Resolved<br>Electronic application Discarded Waste Location Records System (in Croatian: Sustav Evidencija lokacija odbačenog otpada, ELOO) for registering the locations in the territory of the Republic of Croatia where waste is improperly discarded into the environment. | 7.2.1 |
| 5.B.1 Composting - $CH_4$ and $N_2O$ | Provide in the NIR information on the official source of AD for composting and anaerobic digestion and the period for which AD are available, including information on when these activities started in the country. | W.9 | Resolved | 7.3.2.1., 7.3.2.2. |
| 5.B Biological treatment of solid waste - $CH_4$ and $N_2O$ | Correctly report AD for composting on a dry weight basis. | W.10 | Resolved | 7.3.2.1. |
| 5.C.1 Waste incineration - $CO_2$ | Extrapolate back in order to estimate $CO_2$ emissions from the incineration of plastic waste between 1990 and 2006 to improve the consistency of the time series and transparency. | W11 | Resolved | 7.4.2.1 |
| 5.C.1 Waste incineration - $CO_2$, $CH_4$ and $N_2O$ | Provide information in the NIR on the systems and amounts of plastic waste deposited of and/or incinerated for the entire time series, including information on plastic waste that is not collected and recycled and total AD for plastic waste that is generated in the country. | W.12 | Resolved | 7.4.6 |
| 5.C.1 Waste incineration - $N_2O$ | Report in the NIR the value of the default $N_2O$ EF for industrial waste used for estimating $N_2O$ emissions from waste incineration, that is, 100 g $N_2O$/t waste. | W.13 | Resolved | 7.4.2.1. |

| CRF category / issue | Review recommendation | | MS response / status of implementation | Chap. NIR |
|---|---|---|---|---|
| 5.D.1 Domestic wastewater - $CH_4$ | Collect more detailed and complete information on domestic wastewater treated in various systems in the country, in particular individual wastewater treatment systems, and use this information to estimate and improve the accuracy of the $CH_4$ emissions from domestic wastewater. | W.14 | Planned as long-term goal | 7.5.6 |
| 5.D.1 Domestic wastewater - $CH_4$ | Provide in the NIR transparent descriptions and accurate data for the whole time series (1990–2016) related to the occurrence in the country of (1) anaerobic domestic wastewater installations, (2) anaerobic industrial wastewater installations, (3) aerobic domestic wastewater installations and (4) aerobic industrial wastewater installations. | W.15 | Planned as long-term goal | 7.5.6 |
| 5.D.2 Industrial wastewater - $CH_4$ and $N_2O$ | Provide in the NIR a transparent description of the industrial wastewater treatment systems used in the country and the amounts of industrial wastewater treated aerobically and anaerobically | W.16 | Planned as long-term goal | 7.5.6 |

European Commission and Convention performed reviews on Croatian inventory and give recommendations for recalculations. Implemented recommendations from the European Commission and Convention are given in Table 10.4-2.

Table 10.4-2: Recalculations performed in NIR 2024

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| Energy sector | | | | |
| 1A2 Manufacturing industry | | | In 2024 cycle there were recalculations in 1A2gvii Off road vehicless category. It was noticed that fuel consumptions are wrong calculated in Industry analysis balance. Differences in emissions due to recalculations are shown in Table 3.2-8. | 3.2.5.5. |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| Industrial processes and product use | - | | | |
| 2.D.3 Other | - | - | $CO_2$ emissions from Solvent use were recalculated for the entire time series due to data harmonization with the IIR. | 4.5.3 |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| 2.F.1 Refrigeration and Air Conditioning | - | - | In Domestic Refrigeration (2.F.1.b), for HFC-134a, errors were found and corrected in the calculation of emissions from stocks for the period 1995-2021.<br>In Mobile Air-Conditioning (2.F.1.e), for HFC-134a, errors were corrected in the calculation of emissions from disposal for the period 2007-2021 and emissions from stocks for the period 2020-2021. | 4.7.1 |
| | | | | |
| | | | | |

| CRF category / issue | Review recommendation | | | Chapter/section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| Agriculture | | | | |
| 3.A $CH_4$ emissions from enteric fermentation in domestic livestock | | | Emissions were recalculated for the period 2016 – 2019 due to the correction of AD for swine. | 5.2.5 |
| 3.B Manure Management – $N_2O$ and $CH_4$ | | | Emissions were recalculated:<br>- for the period 2016 – 2019 due to the correction of AD for swine.<br>- for the year 2021 due to the correction of AD for geese and correction of calculation errors | 5.3.1.5, 5.3.2.5 |
| 3.D.1.2.a Animal Manure applied to Soils –<br>$N_2O$ | | | Emissions were recalculated for the entire 2016-2019 period and year 2021 due to corrections of estimate in for 3B source. | 5.3.2.5, 5.5.1.5 |
| 3.D.2. Indirect $N_2O$ Emissions from Managed Soils -<br>$N_2O$ | | | Emissions were recalculated for the 2016-2019 period and year 2021 due to AD changes and improvements made in source: Manure Management – $N_2O$ Emissions (CRF 3.B.2). | 5.3.2.5, 5.5.1.5,<br>5.5.2.5 |
| 3.H. Urea application – $CO_2$ | | | Emissions were recalculated for the year 2021 due to correction of invalidly entered AD value. | 5.9.5 |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| **LULUCF** | | | | |
| 4A, 4B, 4C, 4.D, 4.E | | | Nationally determined value for CS in pCL in biomass pool has been used in the estimation for CL-CL and land converted to and from Cropland category | 6.4-6.8 |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| Waste | | | | |
| 5.A Solid waste disposal on land | With the aim of collecting all the necessary data for the emission calculation and improving reporting on GHG emissions from category 5.A, the Ministry of Economy and Sustainable Development launched the project **System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950**. Comprehensive research in the Project regarding system improvements and the development of historical databases resulted in data and parameters that are included in the IPCC FOD model. The results of the emission calculations show a significant deviation from the results of the previous emission calculations, since the data collected by the Project are more detailed and accurate, based on scientific and professional literature and research. Until now, Croatia | | | 7.2.5. |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| | used single-phase model based on bulk waste. The Project defined amounts of components (food, garden, paper, wood, textile, nappies, plastics and other inert waste) of deposited MSW, required for multi-phase model based on waste composition data, which is currently in use. Therefore, recalculations of $CH_4$ emissions were made for the period 1990 - 2021. | | | |
| 5.B Biological treatment of solid waste | With the aim of collecting all the necessary data for the emission calculation and improving reporting on GHG emissions from category 5.B Biological treatment of solid waste, the Ministry of Economy and Sustainable Development launched the project **System improvement and creation of databases with historical data for calculation and reporting of greenhouse gas emissions from the Waste sector including data for the historical series from 1950**. Comprehensive research in the Project regarding system improvements and the development of historical databases resulted in data that are included in the IPCC models. The results of the emission calculations show a deviation from the results of the previous emission calculations, since the data collected by the Project are more detailed and accurate, based on professional literature and research. Therefore, recalculations of $CH_4$ emissions were made for the period 1990 - 2021, and recalculations of $N_2O$ emissions were made for the period 2013 - 2021. | | | 7.3.5. |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| 5.C Incineration and open burning of waste | | | Open burning of waste<br>In the previous report, activity data for $CH_4$ and $N_2O$ emissions calculation for 2021 were not available, so they were estimated as the mean value of data for the period 2018 - 2020. In this report, updated data on mass of open burned agricultural waste for 2021 were collected by ADCP for NIR 2024 - Sector Waste. Therefore, recalculations of $CH_4$ and $N_2O$ emissions were made for 2021. | 7.4.5 |
| 5.D Wastewater treatment and discharge | | | Methane ($CH_4$) emissions from domestic wastewater<br>In the previous report, data on population with an individual system of drainage and data for calculation of degradable organic component in kg BOD/1000 person/yr for the years 2020 and 2021 were not available, so they were estimated according to data from 2019. In this report, updated data on population with an individual system of drainage and data for calculation of degradable organic component for the years 2020 and 2021 were collected using ADCP for NIR 2024 - Sector Waste. Therefore, recalculations of $CH_4$ emission were made for the years 2020 and 2021. | 7.5.5. |
| 5.D Wastewater treatment and discharge | | | Nitrous oxide ($N_2O$) emissions from wastewater<br>In this report, updated data on the annual per capita protein intake value (PIV), for the period 2010 - 2021, were obtained by the FAOSTAT Statistical Database (Update: October 27, 2023). Therefore, recalculations of $N_2O$ emission were made for the period 2010 - 2021. | 7.5.5. |

| CRF category / issue | Review recommendation | | | Chapter /section in the NIR |
|---|---|---|---|---|
| | UNFCCC | ESD | Error detected by Expert | |
| 5.D Wastewater treatment and discharge | | | Industrial wastewater<br>In this report, updated data on total industrial output (t) for the period 2019 - 2021 were collected using ADCP for NIR 2024 - Sector Waste. Additionally, new data on sludge removed were included in the $CH_4$ emission calculation for the period 1990 - 2021. Therefore, recalculations of $CH_4$ emission were made for the period 1990 - 2021. | 7.5.5. |

Table 10.4-3: Indication on timeline of implementation

Sector-specific planned improvements

Energy

| Category | Recommendation | NIR 2024 | NIR 2025 | Long-term |
|---|---|---|---|---|
| 1.A Fuel combustion – sectoral approach – | The ERT recommends that Croatia implement as a priority the improvement projects for the energy sector addressing the methodological approach used for emission estimates for key categories in accordance with the 2006 IPCC Guidelines. | | | • |
| 1.A.2 Manufacturing industries and construction | Distribute fuel consumption and emissions from the generation of electricity and heat in manufacturing industries and construction for 1990–2000 in accordance with the detailed industrial split for stationary combustion provided in the 2006 IPCC Guidelines. | | | • |
| 1.A.2.a Iron and steel | Remove the amount of natural gas used as a feedstock for steel production from the subcategory 1.A.2.a (iron and steel) and correspondingly revise its $CO_2$ emission estimates for iron and steel | | | • |

| | | | | |
|---|---|---|---|---|
| | production by ensuring that no double counting of emissions from natural gas consumption occurs for the entire time series, in accordance with the 2006 IPCC Guidelines. | | | |
| 1.A.2.g Other | Report emissions from cement production under subcategory 1.A.2.f (non-metallic minerals), not under 1.A.2.g.v (construction). | | | • |
| 1.B.2.b Natural gas – gaseous fuels – $CO_2$ | Strive to develop a country-specific $CO_2$ EF for 1.B.2.b.3 (natural gas – processing) (considering that $CO_2$ emissions from 1.B.2.b (natural gas) is a key category), taking into account data on $CO_2$ scrubbing provided by gas field and plant operators and, if this is not possible, use the IPCC | | | • |

Industrial Processes and Product Use

| Category | Recommendation | NIR 2024 | NIR 2025 | Long-term |
|---|---|---|---|---|
| 2.B.1 Ammonia production | In addition to $CO_2$ recovered being used as a feedstock in the production of urea and NPK fertilizers, there is some information on its use in dry ice production as well. However, there is no available information on the dry ice production process, and, for now, Croatia has no accurate information on where dry ice is applied (in the country or abroad). Since according to the 2006 IPCC Guidelines, the amount of $CO_2$ recovered from ammonia production used in freezing applications is not accounted for separately and because it should be assumed that all the $CO_2$ will be released in the producing country, currently $CO_2$ recovered for this use is not included in calculations. If additional resources will be available, this matter will be further investigated and it is currently specified as a long term plan for improvement. | | | • |
| 2.B.8 Petrochemical and carbon black production | This sub-sector has been identified as a key category and not all of the estimates within this sub-sector use a tier 2 or higher approach. Data for using higher tier for petrochemicals are currently not available. Majority of production was halted several years ago, which has consequently decreased the possibility to collect data required for higher tier methodology. Croatia has recently reviewed this sub-sector and incorporated additional sources using what is believed to be the best currently available data. This matter is included in the Data collection plan, and, depending on the available resources, further investigation will be made. At the moment, this issue is categorised as a long-term plan for improvement. | | | • |
| 2.C.2 Ferroalloys production | All input data in this category were investigated to the extent it was currently possible. Ferroalloys production in Croatia was halted over 15 years ago, which makes it highly unlikely to collect more detailed activity data required for higher tier approach. Thus, it has been concluded that there is no realistic possibility for improvements in this category under the current circumstances.<br><br>However, the Annual data collection plan will continue to include this information, as it has hitherto been the case, and should additional data become available in the future, a further investigation of this category would be made. | | | • |

| Category | Recommendation | NIR 2024 | NIR 2025 | Long-term |
| --- | --- | --- | --- | --- |
| 2.C.3 Aluminium production | Primary aluminium production (electrolysis) was shut down almost 3 decades ago, mainly due to war activities, which makes it highly unlikely to collect more detailed activity data required for higher tier methodology. Thus, it has been concluded that there is no realistic possibility for improvements in this category under the given circumstances.<br>However, the Annual data collection plan will continue to include this information, as it has hitherto been the case, and should additional data become available in the future, a further investigation of this category would be made. | | | • |

Agriculture

| Category | Recommendation | NIR 2024 | NIR 2025 | Long-term |
| --- | --- | --- | --- | --- |
| Sectoral | Continued investigation of activity data (livestock population) with the purpose of gathering more detailed activity data. | | | • |
| 3.A. Enteric Fermentation | Report the feeding situation for cattle in CRF table 3.A instead of reporting activity coefficients | | • | |
| 3.B Manure management | Analysys and confirmation of MCFs values used for $CH_4$ emissions from MMS systems. | • | | |
| 3.D.1 Direct $N_2O$ emissions from managed soils | Verification of the amount of sludge applied to soils for 2005–2008, investigation and confirmation whether sludge application occurred in earlier years of the time series (1990–2004). | | | • |
| 3.D.1 Direct $N_2O$ emissions from managed soils | Improving emission calculation from agricultural soils due to mineral fertilizers. | | | • |
| 3.H Urea application | Development of proportion estimates of urea in applied urea solutions AD. | | | • |

## LULUCF

| Forest land remaining forest land – $CO_2$ | Make significant efforts to use the results of CRONFI to improve the LULUCF sector inventory | NIR 2024 | NIR 2025 | Long-term |
|---|---|---|---|---|
| Land converted to forest land – $CO_2$ | Make significant efforts to use the results of CRONFI to improve the LULUCF sector inventory | Resolved in NIR 2022 | | |
| Land converted to forest land – $CO_2$ | Make significant efforts to use the results of CRONFI to improve the LULUCF sector inventory | Resolved in NIR 2022 | | |
| Cropland remaining cropland – $CO_2$ | Implement the tier 2 approach to perennial cropland remaining perennial cropland | Resolved in NIR 2022 | | |
| Land converted to cropland – $CO_2$ | Improve cropland CSC biomass estimation in order to implement Tier 2 in biomass pool for this category | Resolved in NIR 2022 | | |
| Land converted to grassland – $CO_2$ | Improve cropland CSC biomass estimation in order to implement Tier 2 in biomass pool for this category | Resolved in NIR 2022 | | |
| Settlements – $CO_2$ | Improve cropland CSC biomass estimation in order to implement Tier 2 in biomass pool for this category | Resolved in NIR 2022 | | |

## Waste

| Category | Recommendation | NIR 2024 | NIR 2025 | Long-term |
|---|---|---|---|---|
| 5.D.1 Domestic wastewater - $CH_4$ | Collect more detailed and complete information on domestic wastewater treated in various systems in the country, in particular individual wastewater treatment systems, and use this information to estimate and improve the accuracy of the $CH_4$ emissions from domestic wastewater | | | ● |
| 5.D.1 Domestic wastewater - $CH_4$ | Provide in the NIR transparent descriptions and accurate data for the whole time series (1990– 2016) related to the occurrence in the country of, (1) anaerobic domestic wastewater installations, (2) anaerobic industrial wastewater installations, (3) aerobic domestic wastewater installations and (4) aerobic industrial wastewater installations | | | ● |
| 5.D.2 Industrial wastewater – $CH_4$ and $N_2O$ | Provide in the NIR a transparent description of the industrial wastewater treatment systems used in the country and the amounts of industrial wastewater treated aerobically and anaerobically | | | ● |

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108. Waste Management Act (OG 84/2021)

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# List of abbreviations

| | |
|---|---|
| AD | - Activity Data |
| ARKOD | - Land parcel identification system |
| CAA | - Croatian Agricultural Agency |
| CBS | - Central Bureau of Statistics |
| CEM | - Continuous Emission Monitoring |
| CFC | - Chlorofluorocarbons |
| CHC | - Croatian Centre for Horse Breeding |
| CLC | - CORINE Land Cover |
| CLRTAP | - Convention on Long-range Transboundary Air Pollution |
| CNG | - Compressed Natural Gas |
| COP | - Conference of Parties |
| COPERT | - Computer Programme to Calculate Emissions from Road Transport |
| CORINAIR | - Core Inventory of Air Emissions in Europe |
| CORINE | - Coordination Of Information On The Environment |
| CPS Molve | - Central Gas Station Molve |
| CRF | - Common Reporting Format |
| CRONFI | - Croatian National Forest Inventory |
| D | - Domestic |
| EAF | - Electric Arc Furnace |
| EEA | - European Environment Agency |
| EF | - Emission Factor |
| EIHP | - Energy Institute “Hrvoje Požar” |
| EKONERG | -Energy Research and Environmental Protection Institute |
| EMEP | - Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe |
| EOR Project | - Enhanced Oil Recovery Project |
| EPEEF | - Environmental Protection and Energy Efficiency Fund |
| EU ETS | - European Union Emissions Trading Scheme |
| ERT | - Expert Review Team |
| FAO | - Food and Agriculture Organization of the United Nations |
| FAOSTAT | - FAO statistical database |
| FAS | - Forest Advisory Service |
| FMAP | - Forest Management Area Plan |
| FSC | - Forest Stewardship Council |
| GHG | - Greenhouse gas |
| GIS | - Gas Insulated Switchgear |
| GWP | - Global Warming Potential |
| HEP | - Croatian Electricity Utility Company |
| HEP ODS | - HEP Distribution System Operator; subsidiary company of HEP |

| | |
|---|---|
| HEP OPS | - HEP Transmission System Operator; subsidiary company of HEP |
| HFC | - Hydrofluorocarbons |
| HPP | - Hydro Power Plant |
| HRK | - Croatian currency; kuna |
| IACS | - Integrated Administration and Control System |
| IEA | - International Energy Agency |
| INA | - Croatian Oil and Gas Company |
| IPCC | - Intergovernmental Panel on Climate Change |
| ISWA | - International Solid Waste Association |
| KP-LULUCF | - Kyoto Protocol Land Use, Land Use Change and Forestry |
| LPG | - Liquefied Petroleum Gas |
| LRTAP | - Long-range Transboundary Air Pollution |
| LULUCF | - Land-use, Land Use Change and Forestry |
| MA | - Ministry of Agriculture |
| MESD | - Ministry of Economy and Sustainable Development |
| MSW | - Municipal Solid Waste |
| NCV | - Net Calorific Values |
| NGGIP | - National Greenhouse Gas Inventories Programme |
| NIR | - National Inventory Report |
| NMVOC | - Non-methane Volatile organic Compounds |
| NPP | - Nuclear Power Plant |
| ODS | - Ozone Depleting Substances |
| OG | - Official Gazette |
| PCP | - Public Cogeneration Plant |
| PFC | - Perfluorocarbons |
| PHP | - Public Heating Plant |
| PRODCOM | - PRODuction in the COMmunity |
| PS | - Plant specific |
| QA/QC | - Quality Assurance/Quality Control |
| SF6 | - Sulphur hexafluoride |
| TPP | - Thermal Power Plant |
| T | - Tier |
| UNDP | - United Nations Development Program |
| UNDP/GEF | - United Nations Development Programme/Global Environment Facility |
| UNECE | - United Nations Economic Commission for Europe |
| UNFCCC | - United Nations Framework Convention on Climate Change |
| WW | - Wastewaters |