REPUBLIC OF CROATIA

MINISTRY OF ECONOMY AND SUSTAINABLE DEVELOPMENT

Croatian greenhouse gas inventory for the period 1990 - 2020 (National Inventory Report 2022)

CROATIAN GREENHOUSE GAS INVENTORY REPORT FOR THE PERIOD 1990-2020 (NATIONAL INVENTORY REPORT 2022)

SUBMISSION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE AND
KYOTO PROTOCOL

Project coordinator
Tatjana Obučina, Ministry of Economy and Sustainable Development

List of authors

Generalist:	Iva Švedek, Ekonerg ltd
Energy:	Iva Švedek, Valentina Delija-Ružić, Vladimir Jelavić, Ph. D., Ekonerg ltd
IPPU:	Renata Kos, Ekonerg ltd
Agriculture:	Berislav Marković, Borna Glückselig, Ekonerg ltd
LULUCF:	Delfa Radoš, Stjepan Hima, Ekonerg ltd
Waste:	Andrea Hublin Ph. D., Morana Česnik Katulić Ph. D., Ekonerg ltd
KP LULUCF:	Delfa Radoš, Stjepan Hima Ekonerg ltd
Uncertainty, Key Srcs.:	Igor Stankić Ph. D., Goran Vuleta Ekonerg ltd
Pollutants:	Mirela Poljanac, M. Sc., Ekonerg ltd
QA/QC:	Tatjana Obučina, Iva Prgomet Ernst, Ministry of Economy and Sustainable Development
National Registry:	Tomislav Glušac, Ministry of Economy and Sustainable Development
ETS expert:	Goran Janeković Ekonerg ltd
Agriculture:	Krešimir Salajpal Ph.D., Faculty of Agriculture

Contributors

Energy:	Branko Vuk Ph.D., Energy Institute Hrvoje Požar – preparation of National Energy balance
	Arijan Abrashi Ph.D., Ekonerg ltd – preparation of road vehicle database
Agriculture:	Krešimir Salajpal Ph.D., Faculty of Agriculture
	Goran Kiš Ph.D., Faculty of Agriculture – preparation of input data
LULUCF/KP:	Peter Weiss Ph.D., UBA Austria – LULUCF/KP advisor
Forestry:	Goran Kovač, Croatian forests Ltd – Preparation of input data

Zagreb, May 2022.

NATIONAL INVENTORY REPORT 2022

SUBMISSION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON

CLIMATE CHANGE AND

KYOTO PROTOCOL

May, 2022

EKONERG – Energy Research and Environmental Protection Institute

Koranska 5, Zagreb, Croatia

Ordered by: Ministry of Economy and Sustainable Development

Contract No: 99/18 (I-08-0257_1)

Title:

NATIONAL INVENTORY REPORT 2022
Croatian greenhouse gas inventory
for the period 1990-2020

Inventory team coordinator: Iva Švedek

Authors:

Energy: Iva Švedek, Valentina Delija-Ružić, Vladimir Jelavić
Industrial Processes: Renata Kos
Agriculture: Berislav Marković, Borna Glückselig
LULUCF: Delfa Radoš, Stjepan Hima
Waste: Andrea Hublin, Morana Česnik Katulić
KP LULUCF: Delfa Radoš, Stjepan Hima
Uncertainty, Key sources: Igor Stankić, Goran Vuleta
Pollutants: Mirela Poljanac
ETS: Goran Janeković
QA/QC: Vladimir Jelavić

Atmospheric Protection And Climate Change Department Manager:

General Manager:

Vladimir Jelavić, Ph. D.

Zdravko Mužek, M. Sc.

Zagreb, May 2022

Contents

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 2020. 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 fourteen reviews so far, in-country review in 2004, 2007, 2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016 and 2020. 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 on a mechanism for monitoring and reporting greenhouse gas emissions in the European Union and its Member States (Regulation (EU) No 525/2013.)

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 2022 inventory submission.

ES.1.2.2. Background information on supplementary information required under article 7, paragraph 1, of the Kyoto Protocol

LULUCF

MESD, as the UNFCCC focal point, initiated intensive and continuous consultation and knowledge sharing with relevant national institutions responsible for the forestry sector in Croatia. The overall goal of this effort was to establish procedural arrangements necessary for streamlined data flow needed for reporting of information related to accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol.

In Croatia, there is a long tradition of forest management and a comprehensive national system for monitoring, data collection and reporting on the condition and activities in the forestry sector. In that respect, the main effort was directed in the harmonization of current system with the KP-LULUCF requirements. In the beginning of 2010, MESD commissioned a preparation of Action plan for implementation of Article 3, paragraphs 3 and 4 of the Kyoto Protocol which should facilitate the process of data collection and preparation of information related to accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol. Terms of reference for this Action plan included harmonization of definitions and their appliance to national circumstances, identification of lands subject to activities under Article 3.3 and elected activity under Article 3.4, data collection for estimation of carbon stock change and non-CO_2 greenhouse gas emissions and uncertainty assessment and verification.

The Ministry of Agriculture and MESD agreed that preparation of the annual GHG Inventory in respect of the LULUCF sector should be based on forest management plans. As for the first Croatian National Forest Inventory (CRONFI), it is still not official. Once CRONFI becomes official and published, it could be used to fill the gaps in reporting.

ES.1.2.3. Information on Kyoto Protocol units

Assigned Amount Units (AAUs)

Pursuant to Article 3(7bis), (8) and (8bis) of the Kyoto Protocol and Paragraph 2 of Annex I to document FCCC/SBSTA//2015/L.13, the assigned amount for the second commitment period is equal to the percentage inscribed in the third column of Annex B of the Annex to the Doha Amendment of the aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases in the base year multiplied by eight, taking into account Article 3(7bis) of the Kyoto Protocol and paragraph 2 of the Annex to document FCCC/SBSTA/2015/L.13.

The amount of the Assigned amount units (AAUs) for Croatia for the period from 2013 till 2020 is 162,271,086 t CO_2-eq.

Commitment period reserve

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and Paragraph 18 of Decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8. Table ES1.2-1 provides a calculation using both methods to calculate the commitment period reserve. The last column presents the commitment period reserve applicable for the second commitment period for Croatia.

Table ES1.2-1: Commitment period reserve

	t CO$_2$-eq
Assigned amount for second commitment period	162,271,086
90 % of assigned amount	146,043,977
Emission from last submitted inventory	23,758,399
100% of most recently reviewed* inventory multiplied by 8	190,050,817
Commitment period reserve	146,043,977

*emission from last submitted inventory used for calculation

Information from national registry

Changes to the national registry of HR in 2021 are presented in Table ES1.2-2.

Table ES1.2-2: Information on Kyoto Protocol units

Reporting Item	Description
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2021 has been submitted to the UNFCCC Secretariat electronically.
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2021.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2021.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2021.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2021.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.
15/CMP.1 annex I.E Publicly accessible information	The public website of Croatian National registry can be found at https://unionregistry.ec.europa.eu/euregistry/HR/index.xhtml in English and Croatian language and at http://www.haop.hr/hr/tematska-podrucja/zrak-klima-tlo/klimatske-promjene in Croatian language.
15/CMP.1 annex I.E paragraph 18 CPR Calculation	The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8 (ES1.2-1).

There has not been any issuance, acquisition, holding, transfer, cancellation, retirement and/or carry-over of CP2 AAUs, RMUs, ERUs, CERs, tCERs and lCERs in 2021.

Croatia has performed issuance and cancellation of CP1 ERUs in 2015 to account for the LULUCF activities in the first commitment period of the Kyoto protocol. Pursuant to Commission Delegated Regulation (EU) 2015/1844, CP1 AAUs have been exchanged in return for the CER and ERU units exchanged by the operators pursuant to Article 60 of the Regulation (EU) No 389/2013. Retirement transactions have been performed in 2015 to account for the CP1 emissions.

SEF report which is submitted together with this report contains the information on the transactions in the reporting period, the year 2021. Croatia did not have any holdings or performed any transactions involving CP2 Kyoto units in the reporting period.

Croatia did not conclude any transfers of its annual emission allocation to other Member States pursuant to Decision 406/2009/EC.

ES.1.2.4. 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 2022 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.

ES.1.2.5. Changes in national registry

Croatian part of Union Registry is operational and it is a part of the Consolidated System of European Registries (CSEUR) operated by the European Commission since 01.01.2013.

It is accessible through the Internet page https://unionregistry.ec.europa.eu/euregistry/HR/index.xhtml.

The following changes to the national registry of Croatia have occurred in 2021.

Table ES1.2-3: Changes in national registry

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change of name or contact occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	There was a change in the cooperation arrangement during the reported period as the United Kingdom of Great Britain and Northern Ireland no longer operate their registry in a consolidated manner within the Consolidated System of EU registries, CS EUR.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security were introduced.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.
1/CMP.8 paragraph 23 PPSR account	Previous period surplus reserve (PPSR) account will be established in the Consolidated System of European Registries (CSEUR).

The Annexes A and B are submitted together with this report. They are considered as confidential and are available upon request.

ES.1.2.6. 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.

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 2020. 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 Annex III of Decision 24/CP.19 Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. Global warming potential values for certain gases (100- year time horizon) are presented below.

Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
HFC-23	14800
HFC-32	675
HFC-125	3500
HFC-134a	1430
HFC-143a	4470
HFC-152a	124
HFC-227ea	3220
HFC-236fa	9810
CF4	7390
C2F6	12200
C3F8	8830
SF6	22800

Source: 24/CP.19

The results of the greenhouse gas (GHG) emission calculation are presented for the period from 1990 to 2020. 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 2012 (kt CO_2-eq)

Greenhouse gas source and sink categories	1990	1995	2000	2005	2010	2011	2012
1. Energy	21,439.5	15,972.4	18,217.1	21,564.5	19,708.3	19,453.0	18,035.2
2. Industrial processes and product use	4,617.6	2,403.7	3,038.0	3,474.9	3,519.3	3,402.5	3,187.1
3. Agriculture	4,353.0	3,042.4	3,018.3	3,277.0	3,028.8	3,082.2	2,959.1
4. Land use, land-use change and forestry	-5,971.9	-8,178.0	-6,383.3	-7,700.7	-6,871.9	-5,608.6	-5,172.7
5. Waste	1,006.1	1,081.2	1,216.1	1,346.9	1,674.9	1,707.7	1,703.4
6. Other	NO	NO	NO	NO	NO	NO	NO
Total (with LULUCF)	25,444.4	14,321.7	19,106.2	21,962.6	21,059.3	22,036.8	20,712.1
Total (without LULUCF)	31,416.3	22,499.7	25,489.5	29,663.4	27,931.3	27,645.4	25,884.8

Table ES.2-2: Emissions/removals of GHG by sectors for the period from 2013 to 2020 (kt CO_2-eq)

Greenhouse gas source and sink categories	2013	2014	2015	2016	2017	2018	2019	2020
1. Energy	17,286.7	16,344.0	16,591.2	16,998.6	17,380.3	16,437.3	16,496.1	15,516.6
2. Industrial processes and product use	2,942.9	3,183.2	3,290.3	3,098.8	3,483.8	3,463.8	3,644.7	3,760.7
3. Agriculture	2,693.4	2,617.9	2,689.9	2,702.4	2,789.2	2,696.6	2,696.8	2,692.3
4. Land use, land-use change and	-5,868.1	-5,740.3	-5,429.0	-5,410.8	-4,877.3	-5,223.1	-5,353.5	-5,305.7
5. Waste	1,688.9	1,730.9	1,777.7	1,809.4	1,825.8	1,802.5	1,784.7	1,786.7
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (with LULUCF)	18,743.8	18,135.6	18,920.1	19,198.4	20,601.7	19,177.1	19,268.8	18,450.6
Total (without LULUCF)	24,611.9	23,876.0	24,349.1	24,609.2	25,479.0	24,400.2	24,622.3	23,756.4

Figure ES2-1: Trend of GHG emissions, by sectors
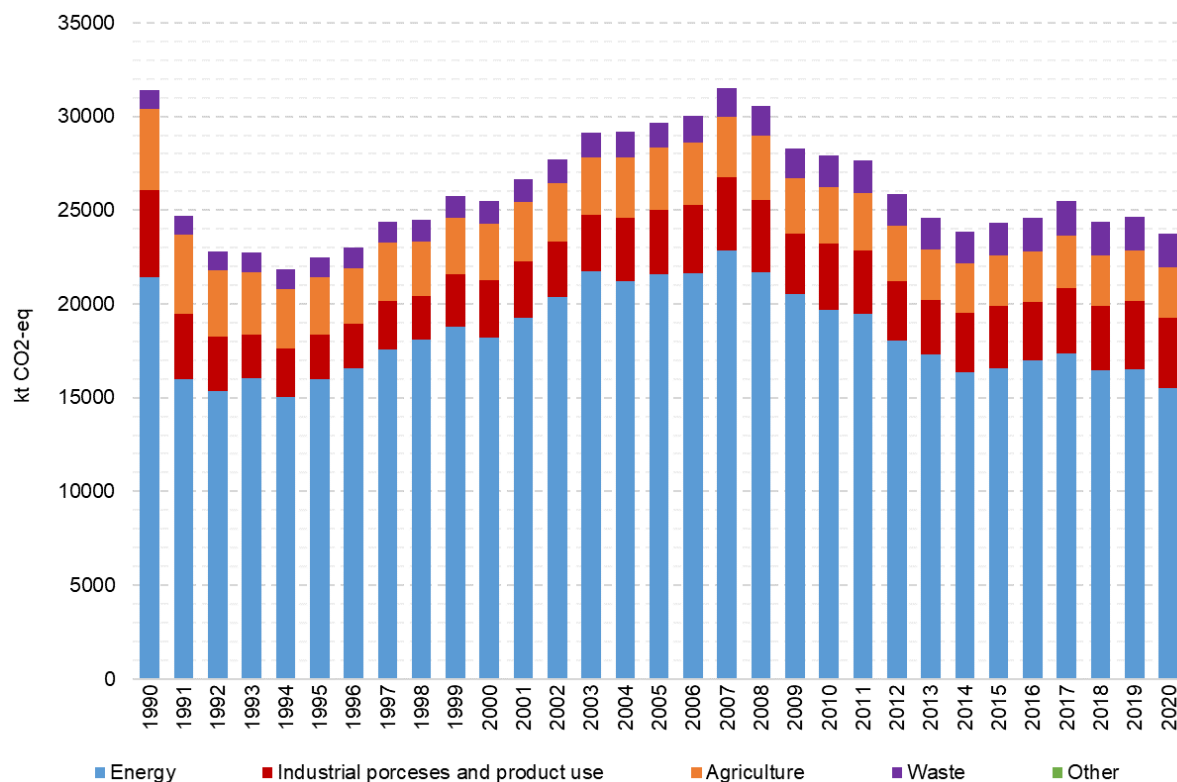
Tables ES.2-1, ES.2-2 and Figure ES.2-1 represents the contribution of the individual sectors to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2020 excluding LULUCF has the Energy sector with 65.3 %, followed by Industrial Processes and product use with 15.9 %, Agriculture with 11.3 % and Waste with 7.5 %. This structure is with minor changes consistent through all the observed period from 1990 to 2020. In the year 2020, the total GHG emissions in Croatia was 23,756.4 kt CO_2-eq excluding LULUCF sector while the total emission was 18,450.6 kt CO_2-eq including the LULUCF sector which represents removals by sink from 22.3 % in that year.

Table ES.2-3: Emissions/removals of GHG by gases for the every five years from 1990 to 2012 (kt CO_2-eq)

Greenhouse gas emissions	1990	1995	2000	2005	2010	2011	2012
CO_2 emissions without net CO_2 from	22,979.8	16,817.7	19,662.5	23,343.9	21,016.3	20,649.6	19,087.4
CO_2 emissions with net CO_2 from	16,958.6	8,585.2	13,077.8	15,573.1	14,038.5	14,896.7	13,728.1
CH_4 emissions without CH_4 from	4,324.9	3,373.1	3,294.2	3,658.1	3,879.4	3,832.0	3,785.4
CH_4 emissions with CH_4 from	4,326.2	3,380.6	3,391.2	3,660.8	3,881.1	3,850.6	3,824.3
N_2O emissions without N_2O from	2,860.6	2,275.0	2,467.5	2,460.4	2,432.5	2,492.7	2,263.2
N_2O emissions with N_2O from	2,908.7	2,322.0	2,572.0	2,527.8	2,536.6	2,618.3	2,410.9
HFCs	NO	21.8	52.9	186.7	593.3	660.8	737.9
PFCs	1,240.2	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO
SF_6	10.7	12.1	12.3	14.3	9.8	10.3	11.0
NF_3	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	31,416.3	22,499.7	25,489.5	29,663.4	27,931.3	27,645.4	25,884.8
Total (with LULUCF)	25,444.4	14,321.7	19,106.2	21,962.6	21,059.3	22,036.8	20,712.1
Total (without LULUCF, with	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA

Table ES.2-4: Emissions/removals of GHG by sectors for the every five years from 2013 to 2020 (kt CO_2-eq)

Greenhouse gas emissions	2013	2014	2015	2016	2017	2018	2019	2020
CO_2 emissions without net CO_2 from	18,432.2	17,681.6	17,824.7	18,109.0	18,744.0	17,724.2	17,857.4	16,870.5
CO_2 emissions with net CO_2 from LULUCF	12,439.8	11,819.8	12,250.9	12,561.8	13,627.5	12,377.7	12,378.1	11,388.3
CH_4 emissions without CH_4 from LULUCF	3,686.2	3,649.9	3,744.4	3,808.7	3,769.1	3,625.7	3,586.4	3,538.7
CH_4 emissions with CH_4 from LULUCF	3,688.1	3,650.2	3,758.4	3,817.6	3,838.3	3,627.0	3,589.2	3,571.2
N_2O emissions without N_2O from LULUCF	1,678.6	1,638.8	1,777.7	1,545.7	1,665.6	1,615.6	1,619.6	1,658.2
N_2O emissions with N_2O from LULUCF	1,801.0	1,760.0	1,908.5	1,673.1	1,835.5	1,737.6	1,742.6	1,802.2
HFCs	807.8	898.1	996.6	1,139.3	1,293.3	1,428.5	1,551.0	1,680.2
PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	7.2	7.7	5.6	6.6	7.0	6.3	7.9	8.8
NF_3	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	24,611.9	23,876.0	24,349.1	24,609.2	25,479.0	24,400.2	24,622.3	23,756.4
Total (with LULUCF)	18,743.8	18,135.6	18,920.1	19,198.4	20,601.7	19,177.1	19,268.8	18,450.6
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA

Figure ES2-2: Trend of GHG emissions, by gases
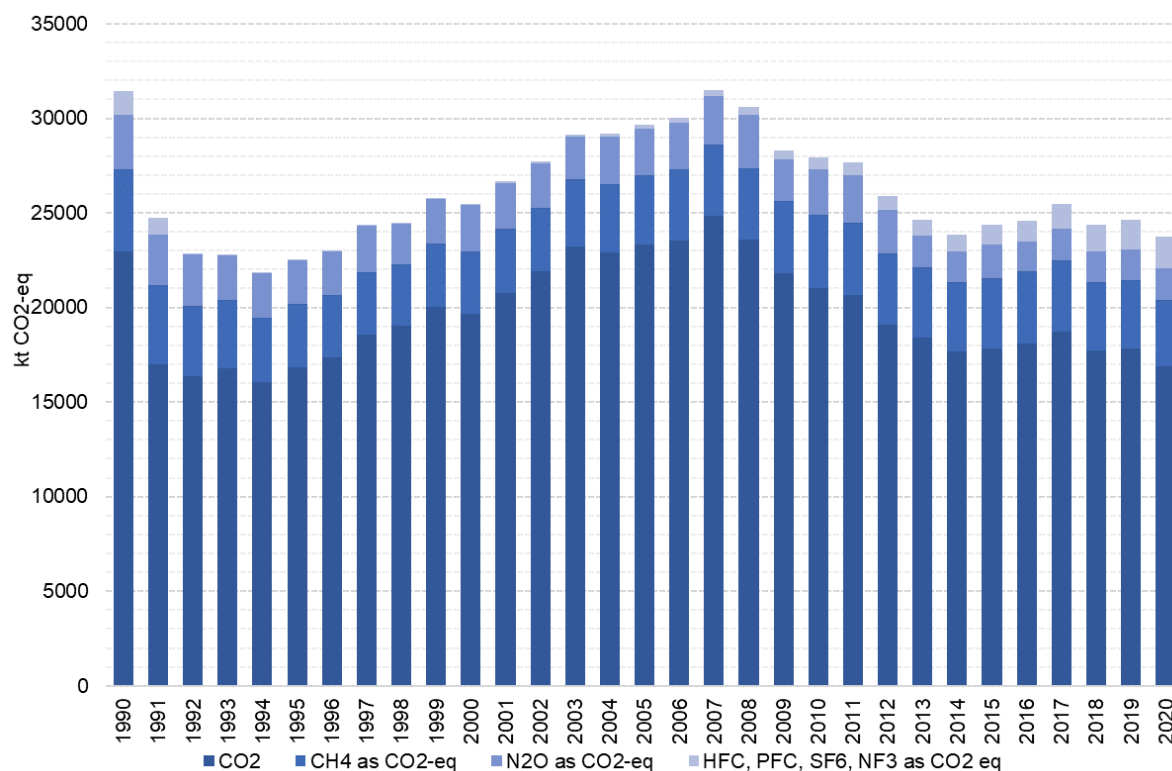
Tables ES.2-3, ES.2-4 and Figure ES.2-2 represents the contribution of the individual gasses to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2020 excluding LULUCF has CO_2 emission with 71.0 %, followed by CH_4 with 14.9 %, N_2O with 7.0 % and HFCs, PFCs and SF_6 with 7.1 %.

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 2020, the GHG emission from the Energy sector was 5.9 % lower in relation to 2019 and 27.6 % 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 70 % 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 95.3 % (in 2020). The contribution of energy in methane (CH_4) in total CO_2-eq emission is substantially smaller (3.3 % in 2020) while the contribution of energy in nitrous oxide (N_2O) in total CO_2-eq emission is quite small (1.4 % in 2020). 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: Energy subsectors total emissions by gases for the period 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1. Energy	21,439.5	15,972.4	18,217.1	21,564.5	19,708.3	16,591.2	16,998.6	17,380.3	16,437.3	16,496.1	15,516.6
A. Fuel comb.	20,437.2	14,846.4	17,275.1	20,558.7	18,909.4	16,147.9	16,566.7	16,875.0	15,974.9	16,042.7	15,074.6
1. Energy	7,088.6	5,278.0	5,833.4	6,837.5	5,903.4	4,742.6	4,875.3	4,493.2	3,937.9	3,915.8	3,695.8
2. Manufact. ind.	5,234.6	2,887.4	3,074.3	3,739.3	3,030.1	2,232.0	2,236.8	2,439.4	2,421.4	2,432.1	2,394.0
3. Transport	3,896.0	3,370.1	4,502.3	5,561.8	5,951.5	5,953.8	6,177.7	6,645.8	6,410.3	6,589.0	5,802.4
4. Other sectors	4,218.0	3,310.9	3,865.2	4,420.1	4,024.4	3,219.6	3,276.9	3,296.6	3,205.4	3,105.7	3,182.4
5. Other	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
B. Fugitive em.	1,002.3	1,126.0	942.0	1,005.8	798.9	443.3	431.9	505.3	462.4	453.5	442.0
1. Solid fuels	59.6	28.2	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
2. Oil and nat. gas	942.7	1,097.8	942.0	1,005.8	798.9	443.3	431.9	505.3	462.4	453.5	442.0
C. CO2 transport	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

The largest part (37.4 % in 2020) of the emissions are a consequence of fuel combustion in Transport, next is the combustion in Energy industries (23.8 % in 2020) and third is combustion in small stationary energy sources, such as Commercial/ Institutional, Residential and Agriculture/ Forestry/ Fishing (20.5 % in 2020). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 15.4 %, while Fugitive Emissions from Fuels contribute with about 2.9 %.

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 96.8 % in total sectoral emission in 2020. 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 2020 emissions from industrial processes were increased by 3.2 % regarding 2020 and decreased by 18.4 % regarding 1990. Industrial processes and product use contributed to total GHG emissions with 15.9 % in 2020. Emission of individual subsectors is presented in the Table ES.3-2.

Table ES.3-2: Industrial processes subsectors total emissions by gases for the period 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2. Industrial processes and product use	4,617.6	2,403.7	3,038.0	3,474.9	3,519.3	3,290.3	3,098.8	3,483.8	3,463.8	3,644.7	3,760.7
A. Mineral industry	1,302.7	741.7	1,428.9	1,813.8	1,401.8	1,306.4	1,201.3	1,425.6	1,358.4	1,324.9	1,359.3
B. Chemical industry	1,510.8	1,438.9	1,401.3	1,304.1	1,383.1	883.6	657.2	665.4	563.2	644.7	600.4
C. Metal industry	1,580.5	41.1	30.2	12.7	14.7	9.3	1.1	1.9	9.0	4.9	4.9
D. Non-energy products	176.2	111.3	75.7	111.5	89.7	68.7	73.9	70.8	80.1	93.1	87.2
E. Electronic Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Product uses as ODS	NO	21.8	52.9	186.7	593.3	996.6	1,139.3	1,293.3	1,428.5	1,551.0	1,680.2
G. Other prod. manuf.	47.4	48.8	49.1	46.1	36.7	25.7	26.0	26.8	24.6	26.1	28.7
H. Other	NA	NA	NA	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 36.2 % of sectoral CO_2-eq emission. The number of cattle showed a continuous decrease in the period from 1990 to 2000. 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 2019, in 2020 CO_2-eq emission from Enteric fermentation decreased by 1.9 %. As for Manure management emissions, CO_2-eq emission decreased by 4.7 % in 2020 compared to 2019. 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 increased in 2020 compared to 2019 by 1.9 %. Overall, in the year 2020, the GHG emission from the Agriculture sector decreased by 0.2 % in comparison with 2019. Emission of individual subsectors is presented in the Table ES.3-3.

Table ES.3-3: Agriculture subsectors total emissions by gases for the period 1990-2020 (kt CO$_2$-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
3. Agriculture	4,353.0	3,042.4	3,018.3	3,277.0	3,028.8	2,689.9	2,702.4	2,789.2	2,696.6	2,696.8	2,692.3
A. Enteric fermentation	2,121.2	1,330.0	1,169.0	1,271.1	1,134.1	1,039.1	1,091.0	1,052.2	988.8	994.7	975.5
B. Manure management	756.2	577.3	592.2	638.8	655.8	584.3	582.4	572.9	538.6	533.4	508.1
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	1,425.7	1,088.7	1,196.2	1,281.7	1,150.8	997.1	952.8	1,083.0	1,096.9	1,093.1	1,113.6
E. Presc. burning of sav.	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming	NO	NO	NO	14.5	21.5	12.1	11.2	10.9	4.6	2.1	6.9
H. Urea application	50.0	46.3	60.9	71.0	66.6	57.2	65.0	70.2	67.6	73.6	88.3
I. Other carbon-cont.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
J. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

LULUCF

The Act on Forest (Official Gazette No. NN 68/18, 115/18, 98/19) 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 Forest Management Area Plan of the Republic of Croatia (2006-2018), 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, for 2006, 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 28.8 % to the total emissions of CO$_2$ eq in Croatia including LULUCF in the year 2020.

Table ES.3-4: Removal trends in LULUCF sector from 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
LULUCF removals	-5,971.9	-8,178.0	-6,383.3	-7,700.7	-6,871.9	-5,429.0	-5,410.8	-4,877.3	-5,223.1	-5,353.5	-5,305.7

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 that sector.

Emissions from solid waste disposal account 68.3 % of sectoral emissions in 2020, compared to 32.6 % in 1990. An increase in generated and disposed of solid waste exists during the entire 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 30.1 % of sectoral emissions in 2020, compared to 65.2 % 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 7.5 % in 2020. Emission of individual subsectors is presented in the Table ES.3-5.

Table ES.3-5: Waste subsectors total emissions by gases for the period 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
5. Waste	1,006.1	1,081.2	1,216.1	1,346.9	1,674.	1,777.	1,809.	1,825.8	1,802.5	1,784.7	1,786.7
A. Solid waste disposal	328.0	419.5	560.0	713.7	1,040.	1,186.	1,211.	1,254.7	1,246.7	1,222.2	1,220.2
B. Biol.treatment of solid waste	NO,IE	0.8	1.2	1.9	6.3	8.0	11.2	10.7	12.8	15.9	21.9
C. Incineration of waste	22.4	14.2	17.0	10.1	11.0	9.4	8.7	7.8	8.1	7.5	7.5
D. Waste water treatment	655.8	646.7	637.9	621.2	617.2	573.7	578.3	552.5	534.8	539.1	537.2
E. Other	NO	NO	NO	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 1990-2020 (kt CO_2)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Energy	20,362.9	15,121.5	17,356.8	20,656.7	18,806.6	15,798.6	16,208.6	16,597.8	15,691.4	15,764.3	14,788.6
Industrial processes	2,566.3	1,649.3	2,238.7	2,601.6	2,121.6	1,956.7	1,824.2	2,065.1	1,960.6	2,017.5	1,986.7
Agriculture	50.0	46.3	60.9	85.5	88.0	69.3	76.2	81.1	72.2	75.7	95.2
LULUCF	-6,021.2	-8,232.5	-6,584.7	-7,770.9	-6,977.8	-5,573.8	-5,547.2	-5,116.5	-5,346.5	-5,479.3	-5,482.3
Waste	0.54	0.54	6.15	0.16	0.05	0.05	0.05	NO,NA	NO,NA	NO,NA	NO,NA
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total CO_2 emission without LULUCF	22,979.8	16,817.7	19,662.5	23,343.9	21,016.3	17,824.7	18,109.0	18,744.0	17,724.2	17,857.4	16,870.5
Total CO_2 emission with LULUCF	16,958.6	8,585.2	13,077.8	15,573.1	14,038.5	12,250.9	12,561.8	13,627.5	12,377.7	12,378.1	11,388.3

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 87.7 % 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 1990-2020 (kt CO_2)

GHG source categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Energy Indust.	7,065.8	5,261.6	5,810.9	6,810.0	5,877.3	4,718.8	4,846.8	4,464.8	3,907.8	3,880.4	3,659.3
Manuf.Ind.	5,208.6	2,874.4	3,061.7	3,724.0	3,015.8	2,222.7	2,228.7	2,429.6	2,411.0	2,421.1	2,381.7
Transport	3,787.1	3,292.9	4,354.4	5,467.7	5,865.8	5,887.8	6,106.4	6,570.3	6,340.8	6,516.9	5,732.1
Other sectors	3,719.0	2,856.9	3,418.4	3,898.2	3,506.2	2,719.8	2,790.1	2,821.6	2,747.1	2,658.9	2,727.2
Fugitive Em.	582.5	835.8	711.4	756.7	541.5	249.5	236.7	311.6	284.6	286.9	288.2
Total CO_2 em.	20,362.9	15,121.5	17,356.8	20,656.7	18,806.6	15,798.6	16,208.6	16,597.8	15,691.4	15,764.3	14,788.6

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 2020, the CO_2 emission from the Transport sector contributed with 34.0 % to the national total CO_2 emission. The largest part of the CO_2 emission from the Transport sector arises from road transport (96.8 % of CO_2 emission from the transport sector in 2020) 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 1990-2020 (kt CO_2)

GHG source categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Mineral industry	1,302.7	741.7	1,428.9	1,813.8	1,401.8	1,306.4	1,201.3	1,425.6	1,358.4	1,324.9	1,359.3
Chemical	751.1	756.0	704.4	663.6	615.4	572.3	547.9	566.8	513.1	594.6	535.3
Metal industry	336.4	40.3	29.7	12.7	14.7	9.3	1.1	1.9	9.0	4.9	4.9
Non-energy	176.2	111.3	75.7	111.5	89.7	68.7	73.9	70.8	80.1	93.1	87.2
Total CO_2	2,566.3	1,649.3	2,238.7	2,601.6	2,121.6	1,956.7	1,824.2	2,065.1	1,960.6	2,017.5	1,986.7

The most significant CO_2 industrial processes emission sources are the production of cement, ammonia and lime. In 2020, the mineral industry contributes to total sectoral CO_2 emission with 68.4 % and chemical industry with 26.9 %. 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 2020 CO_2 emissions from industrial processes decreased by 1.5 %, regarding the year 2019.

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 1990-2020 (kt CH_4)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Energy	33.33	26.82	23.38	26.82	26.72	23.44	23.11	22.71	21.44	20.67	20.37
Industrial processes	0.37	0.23	0.14	0.15	0.11	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA
Agriculture	101.93	67.66	62.77	68.83	64.86	58.95	60.67	58.79	55.25	55.24	53.66
LULUCF	0.05	0.30	3.88	0.11	0.07	0.56	0.36	2.77	0.05	0.11	1.30
Waste	37.36	40.21	45.48	50.53	63.49	67.38	68.57	69.26	68.34	67.55	67.51
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total CH_4	173.05	135.23	135.65	146.43	155.25	150.34	152.71	153.53	145.08	143.57	142.85

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. Of the total amount of MSW generated in 2020, 41 % (694,160 tonnes) was separately collected fractions. The largest separately collected fractions were paper and cardboard waste (29 %), bulky waste (19 %) and biowaste (17 %), followed by plastic (10 %), glass (6 %), metal waste (6 %), electrical and electronic waste (5 %), wood (3 %), textile (1 %), and other waste (4 %). 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.

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$_2$O emission in Croatia for the period from 1990-2020 (kt N$_2$O)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Energy	0.82	0.61	0.93	0.80	0.78	0.69	0.71	0.72	0.70	0.72	0.73
Industrial processes	2.65	2.40	2.45	2.24	2.66	1.11	0.43	0.40	0.23	0.23	0.29
Agriculture	5.89	4.38	4.66	4.94	4.43	3.85	3.72	4.16	4.17	4.16	4.21
LULUCF	0.16	0.16	0.35	0.23	0.35	0.44	0.43	0.57	0.41	0.41	0.48
Waste	0.24	0.25	0.24	0.28	0.29	0.31	0.32	0.32	0.32	0.32	0.33
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total N$_2$O emission	9.76	7.79	8.63	8.48	8.51	6.40	5.61	6.16	5.83	5.85	6.05

In the Agricultural sector, three N$_2$O emission sources are determined: direct N$_2$O emission from agricultural soils, direct N$_2$O emission from livestock farming and indirect N$_2$O 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$_2$O emission occurs in nitric acid production, which is used as a raw material in nitrogen mineral fertilizers. In the framework of the N$_2$O reduction measure analysis, the possibility for application of non-selective catalytic reduction device was considered, whereby the nitric acid production influence on N$_2$O 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$_2$O emission in the Energy sector is the use of three-way catalytic converters in road transport motor vehicles.

N$_2$O emission from the Waste sector indirectly occurs from human sewage. It is calculated on the basis of 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.

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 1990-2020 (kt CO$_2$-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Emissions of HFC, PFC	1,240.24	21.85	52.89	186.71	593.30	996.63	1,139.26	1,293.31	1,428.50	1,551.03	1,680.18
Emissions of SF$_6$	10.73	12.08	12.34	14.26	9.83	5.58	6.60	7.02	6.27	7.85	8.76
NF$_3$ emission	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	1,251.0	33.9	65.2	201.0	603.1	1,002.2	1,145.9	1,300.3	1,434.8	1,558.9	1,688.9

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 2020 Submission to the Convention on Long-range Transboundary Air Pollution'.The calculations of aggregated results for the emissions of indirect gases in the period 1990-2020 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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
NOx Emission	110.60	82.21	94.03	89.61	72.55	58.01	58.47	62.15	52.72	52.05	49.60
Energy	97.55	72.02	80.54	78.53	63.24	49.44	49.98	49.52	44.55	43.59	40.85
Industrial Processes	2.66	2.53	2.53	2.29	1.52	1.03	0.92	1.16	0.89	0.75	0.94
Agriculture	10.35	7.43	7.91	8.67	7.70	6.87	6.54	7.26	7.08	7.12	7.12
LULUCF	0.04	0.23	3.05	0.13	0.09	0.67	1.03	4.21	0.20	0.59	0.69
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA
CO Emission	552.14	449.82	555.76	417.52	327.37	275.77	264.64	313.46	229.92	216.49	218.84
Energy	511.49	415.59	435.39	397.57	325.60	265.16	256.99	251.31	228.56	215.24	214.16
Industrial Processes	39.91	27.26	30.12	17.37	0.18	0.21	0.00	0.01	0.23	0.12	0.08
Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
LULUCF	0.74	6.96	90.24	2.58	1.59	10.40	7.65	62.13	1.13	1.12	4.60
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA
NMVOC Emission	162.03	114.46	106.57	109.39	87.84	68.90	70.05	72.19	67.06	71.80	68.35
Energy	67.22	55.81	58.95	53.42	43.65	33.97	32.72	31.49	29.60	27.86	27.21
Industrial Processes	83.67	49.08	30.58	45.89	33.82	23.91	26.52	24.94	27.56	33.73	31.07
Agriculture	10.83	8.67	8.71	9.42	9.56	9.34	9.33	9.35	9.01	9.30	9.02
LULUCF	0.10	0.63	7.94	0.21	0.15	0.92	0.71	5.62	0.10	0.13	0.29
Waste	0.21	0.27	0.38	0.45	0.66	0.75	0.77	0.80	0.79	0.77	0.77
SO2 Emission	170.10	76.82	59.99	58.33	35.02	15.51	14.39	12.29	9.84	7.36	5.87
Energy	169.37	76.55	59.54	57.92	35.01	15.50	14.39	12.29	9.83	7.35	5.87
Industrial Processes	0.72	0.27	0.44	0.41	0.01	0.01	NO,NE, NA	0.00	0.01	0.00	0.00
Agriculture	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LULUCF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO

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$_2$O emissions arising from sources other than those in the agriculture and LULUCF sectors.

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 2020. 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 fourteen reviews so far, in-country review in 2004, 2007,

2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016 and 2020. 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. Background information on supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol

MESD, as the UNFCCC focal point, initiated intensive and continuous consultation and knowledge sharing with relevant national institutions responsible for the forestry sector in Croatia. The overall goal of this effort was to establish procedural arrangements necessary for streamlined data flow needed for reporting of information related to accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol.

In Croatia, there is a long tradition of forest management and a comprehensive national system for monitoring, data collection and reporting on the condition and activities in the forestry sector. In that respect, the main effort was directed in the harmonization of current system with the KP-LULUCF requirements. In the beginning of 2010, MESD commissioned a preparation of Action plan for implementation of Article 3, paragraphs 3 and 4 of the Kyoto Protocol which should facilitate the process of data collection and preparation of information related to accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol. Terms of reference for this Action plan included harmonization of definitions and their appliance to national circumstances, identification of lands subject to activities under Article 3.3 and elected activity under Article 3.4, data collection for estimation of carbon stock change and non-CO_2 greenhouse gas emissions and uncertainty assessment and verification.

The Ministry of Agriculture and MESD agreed that preparation of the annual GHG Inventory in respect of the LULUCF sector should be based on forest management plans. As for the first Croatian National Forest Inventory (CRONFI), it is still not official. Once CRONFI becomes official and published, it could be used to fill the gaps in reporting.

1.1.4. Information on Kyoto units

Assigned Amount Units (AAUs)

Pursuant to Article 3(7bis), (8) and (8bis) of the Kyoto Protocol and Paragraph 2 of Annex I to document FCCC/SBSTA//2015/L.13, the assigned amount for the second commitment period is equal to the percentage inscribed in the third column of Annex B of the Annex to the Doha Amendment of the

aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases in the base year multiplied by eight, taking into account Article 3(7bis) of the Kyoto Protocol and paragraph 2 of the Annex to document FCCC/SBSTA/2015/L.13.

The amount of the Assigned amount units (AAUs) for Croatia for the period from 2013 till 2020 is 162,271,086 t CO_2-eq.

Commitment period reserve

Parties are required by decision 11/CMP.1 under the Kyoto Protocol and Paragraph 18 of Decision 1/CMP.8 to establish and maintain a commitment period reserve as part of their responsibility to manage and account for their assigned amount. The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8. Table 1.1-1 provides a calculation using both methods to calculate the commitment period reserve. The last column presents the commitment period reserve applicable for the second commitment period for Croatia.

Table 1.1-1: Commitment period reserve

	t CO_2-eq
Assigned amount for second commitment period	162,271,086
90 % of assigned amount	146,043,977
Emission from last submitted inventory	23,758,399
100% of most recently reviewed* inventory multiplied by 8	190,050,817
Commitment period reserve	146,043,977

*emission from last submitted inventory used for calculation

Information from national registry

Changes to the national registry of HR in 2021 are presented in Table1.1-2.

Table 1.1-2: Information on Kyoto Protocol units

Reporting Item	Description
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2021 has been submitted to the UNFCCC Secretariat electronically.
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2021.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2021.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2021.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2021.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.
15/CMP.1 annex I.E	The public website of Croatian National registry can be found at https://unionregistry.ec.europa.eu/euregistry/HR/index.xhtml in English and

Reporting Item	Description
Publicly accessible information	Croatian language and at http://www.haop.hr/hr/tematska-podrucja/zrak-klima-tlo/klimatske-promjene in Croatian language.
15/CMP.1 annex I.E paragraph 18 CPR Calculation	The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8 (Table 1.1-1).

There has not been any issuance, acquisition, holding, transfer, cancellation, retirement and/or carry-over of CP2 AAUs, RMUs, ERUs, CERs, tCERs and lCERs in 2021.

Croatia has performed issuance and cancellation of CP1 ERUs in 2015 to account for the LULUCF activities in the first commitment period of the Kyoto protocol. Pursuant to Commission Delegated Regulation (EU) 2015/1844, CP1 AAUs have been exchanged in return for the CER and ERU units exchanged by the operators pursuant to Article 60 of the Regulation (EU) No 389/2013. Retirement transactions have been performed in 2015 to account for the CP1 emissions.

SEF report which is submitted together with this report contains the information on the transactions in the reporting period, the year 2021. Croatia did not have any holdings or performed any transactions involving CP2 Kyoto units in the reporting period.

Croatia did not conclude any transfers of its annual emission allocation to other Member States pursuant to Decision 406/2009/EC.

1.1.5. Changes in the national system

There were no changes in the national system from the last report.

1.1.6. Changes in national registry

Changes in national registry are given in the table 1.1-3.

Table 1.1-3: Changes in national registry

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change of name or contact occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	There was a change in the cooperation arrangement during the reported period as the United Kingdom of Great Britain and Northern Ireland no longer operate their registry in a consolidated manner within the Consolidated System of EU registries, CS EUR.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been 6 new EUCR releases (versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2) after version 11.5 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The changes that have been introduced with versions 12.4, 13.0.2, 13.2.1, 13.3.3, 13.5.1 and 13.5.2 compared with version 11.5 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include

Reporting Item	Description
	thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security were introduced.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.
1/CMP.8 paragraph 23 PPSR account	Previous period surplus reserve (PPSR) account will be established in the Consolidated System of European Registries (CSEUR).

The Annexes A and B are submitted together with this report. They are considered as confidential and are available upon request.

1.2. A description of the national inventory arrangements

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 on a mechanism for monitoring and reporting greenhouse gas emissions in the European Union and its Member States (Regulation (EU) No 525/2013.)

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 2022 inventory submission.

1.2.1. Institutional, legal and procedural arrangements

MESD, as the UNFCCC focal point, initiated intensive and continuous consultation and knowledge sharing with relevant national institutions responsible for the forestry sector in Croatia. The overall goal of this effort was to establish procedural arrangements necessary for streamlined data flow needed for reporting of information related to accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol.

1.2.2. Overview of 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.

1.2.3. 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 - Documentation revision and supplement	QA/QC coordinator (MESD)
Approval of the QA/QC plan	MESD
Implementation of QC procedures - Internal audit - Corrective and preventive activities - Reporting on performed internal audit	QA/QC coordinator (MESD) Sectoral experts (MESD), Project leader in NIR preparation (MESD) Project Coordinator (Authorized Institution) Sectoral experts (Authorized Institution) 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 2020 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.

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

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 2022 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.

1.2.5. 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.

   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.

1.3. Inventory preparation, and data collection, processing and storage

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 fourteen reviews so far, in-country review in 2004, 2007, 2008, 2012 and 2018, centralized reviews in 2005, 2006, 2009, 2010, 2011, 2013, 2014, 2016 and 2020. 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.

1.4. 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 draft emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020 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 1.4-1, but more detailed information is given in sectoral chapters.

Table 1.4-1: 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 Interior
	Fuel consumption and fuel characteristic data for thermal power plants	- Pollution Emission Register MESD - Verified reports of CO_2 emission - Voluntary survey of Power Utility Company

CRF Sector/Sub-sector	Type of data	Source of data
	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 - MESD - 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* 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 Data on cement and lime production	- Survey of ammonia manufacturer - Survey of cement and lime manufacturers - 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 2020* Submission to the Convention on Long-range Transboundary Air Pollution'
Agriculture	Livestock number	- CBS - 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 Activity data on crop production	- Ministry of Agriculture with the assistance of public company "Hrvatske šume" - MESD - CBS
Waste	Activity data on solid waste disposal	- MESD

CRF Sector/Sub-sector	Type of data	Source of data
	Activity data on biological treatment of solid waste - composting	- Composting facilities
	Activity data on biological treatment of solid waste - anaerobic digestion at biogas facilities	- Biogas facilities
	Activity data on open-burned waste	- Ministry of Agriculture - CBS
	Activity data on wastewater treatment and discharge	- State company Croatian Water (Hrvatske vode) - CBS - FAOSTAT

1.4.1. 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. Majoriti of installations were included on the basis of the combustion activity. Other installations were included in the trading system primarily on the basis of 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 2020 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.

1.5.   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 1.5-1.

Table 1.5-1: Key categories summary table for 2020

Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, year = 2020)							
A	B	C	D				E
IPCC Source Categories	GHG	Key	If Column C is Yes, Criteria for Identification				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	
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	Yes	L1e	T1e	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	
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	T2e			
1.A.4 Other Sectors - Biomass	CH_4	Yes	L1e L2e	T2e	L1i L2i		
1.A.4 Other Sectors - Biomass	N_2O	Yes	L2e	T2e			
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		T1i	
1.B.2.a Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO_2	Yes		T2e		T1i T2i	
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				
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	Yes	L1e L2e	T2e	L1i L2i	T1i T2i	
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	L1e	T1e	L1i		
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		T1e		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		L1i		
3.B Manure Management	N_2O	Yes	L1e	T1e T2e		T1i	
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	Yes	L1e L2e	T2e	L1i L2i	T2i	
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	Yes	L1e L2e		L1i L2i	T2i	
4. Land use land use change and forestry							
4(III).Direct N2O emissions from N mineralization/immobilization	N_2O	Yes				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		
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	T1i T2i	
4.B.2 Land Converted to Cropland	CO_2	Yes			L2i	T1i 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		L1i L2i		
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

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.

1.6. 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 23,756.35 kt CO_2-eq for the year 2020 and 31,416.28 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 2020 (24,388,69 kt CO_2-eq) according to simulation varies between 22,973.34 kt CO_2-eq (2.5 percentile) and 25,986.76 kt CO_2-eq (97.5 percentile). Figure A2.2-1 shows the distribution of total CO_2-eq emission for year 2020 with a corresponding probability density function (red line) that best matches the simulation results.

Monte Carlo analysis shows that with a certainty of 95% total simulated emissions of all categories excluding LULUCF for the year 1990 (32,311.65 kt CO_2-eq) varies between 30,445.91 kt CO_2-eq (2.5 percentile) and 34,383.13 kt CO_2-eq (97.5 percentile).

Uncertainty in the trend excluding LULUCF

The Inventory trend excluding LULUCF is -24.52%, simulated trend is -24.45 % and the 95% probability range of the trend is -30.81% (2.5 percentile) to -17.62% (97.5 percentile).

Uncertainty in the emissions including LULUCF

The estimations of CO_2-eq emissions were 18,450.62 kt CO_2-eq for the year 2020 and 25,444.41 kt CO_2-eq for the year 1990 with removals from LULUCF included.

Monte Carlo analysis shows that with a certainty of 95% total emissions of categories for the year 2020 (21,858.72 kt CO_2-eq) according to simulation varies between 16,466.54 kt CO_2-eq (2.5 percentile) and 27,797.59 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 (28,566.37 kt CO_2-eq) varies between 23,623.85 kt CO_2-eq (2.5 percentile) and 33,871.08 kt CO_2-eq (97.5 percentile).

Uncertainty in the trend including LULUCF

The Inventory trend including LULUCF is -27.49%, simulated trend is -22.83% and the 95% probability range of the trend is -44.66% (2.5 percentile) to 3.59% (97.5 percentile), so the uncertainty introduced in trend varies from -17.17% to 31.05% with respect to the base year emissions.

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

Croatian inventory consists of the emission estimates for the period from 1990-2020.

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.

Chapter 2: Trends in greenhouse gas emissions

2.1 Description and interpretation of emission trends for aggregated GHG emissions

The total GHG emissions in 2020, excluding removals by sinks, amounted 23,756.4 mil. t CO_2-eq (equivalent CO_2 emissions), which represents a 24.4 % 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 and for the period from 2017 to 2019. 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 2020. 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 from 1990 to 2012 (kt CO_2-eq)

Greenhouse gas source and sink categories	1990	1995	2000	2005	2010	2011	2012
1. Energy	21,439.5	15,972.4	18,217.1	21,564.5	19,708.3	19,453.0	18,035.2
2. Industrial processes and product use	4,617.6	2,403.7	3,038.0	3,474.9	3,519.3	3,402.5	3,187.1
3. Agriculture	4,353.0	3,042.4	3,018.3	3,277.0	3,028.8	3,082.2	2,959.1
4. Land use, land-use change and forestry	-5,971.9	-8,178.0	-6,383.3	-7,700.7	-6,871.9	-5,608.6	-5,172.7
5. Waste	1,006.1	1,081.2	1,216.1	1,346.9	1,674.9	1,707.7	1,703.4
6. Other	NO	NO	NO	NO	NO	NO	NO
Total (with LULUCF)	25,444.4	14,321.7	19,106.2	21,962.6	21,059.3	22,036.8	20,712.1
Total (without LULUCF)	31,416.3	22,499.7	25,489.5	29,663.4	27,931.3	27,645.4	25,884.8

54

Table 2.1-2: Emissions/removals of GHG by sectors for the period from 2013-2020 (kt CO_2-eq)

Greenhouse gas source and sink categories	2013	2014	2015	2016	2017	2018	2019	2020
1. Energy	17,286.7	16,344.0	16,591.2	16,998.6	17,380.3	16,437.3	16,496.1	15,516.6
2. Industrial processes and product use	2,942.9	3,183.2	3,290.3	3,098.8	3,483.8	3,463.8	3,644.7	3,760.7
3. Agriculture	2,693.4	2,617.9	2,689.9	2,702.4	2,789.2	2,696.6	2,696.8	2,692.3
4. Land use, land-use change and forestry	-5,868.1	-5,740.3	-5,429.0	-5,410.8	-4,877.3	-5,223.1	-5,353.5	-5,305.7
5. Waste	1,688.9	1,730.9	1,777.7	1,809.4	1,825.8	1,802.5	1,784.7	1,786.7
6. Other	NO	NO	NO	NO	NO	NO	NO	NO
Total (with LULUCF)	18,743.8	18,135.6	18,920.1	19,198.4	20,601.7	19,177.1	19,268.8	18,450.6
Total (without LULUCF)	24,611.9	23,876.0	24,349.1	24,609.2	25,479.0	24,400.2	24,622.3	23,756.4

Figure 2.1-1: Trend of GHG emissions, by sectors
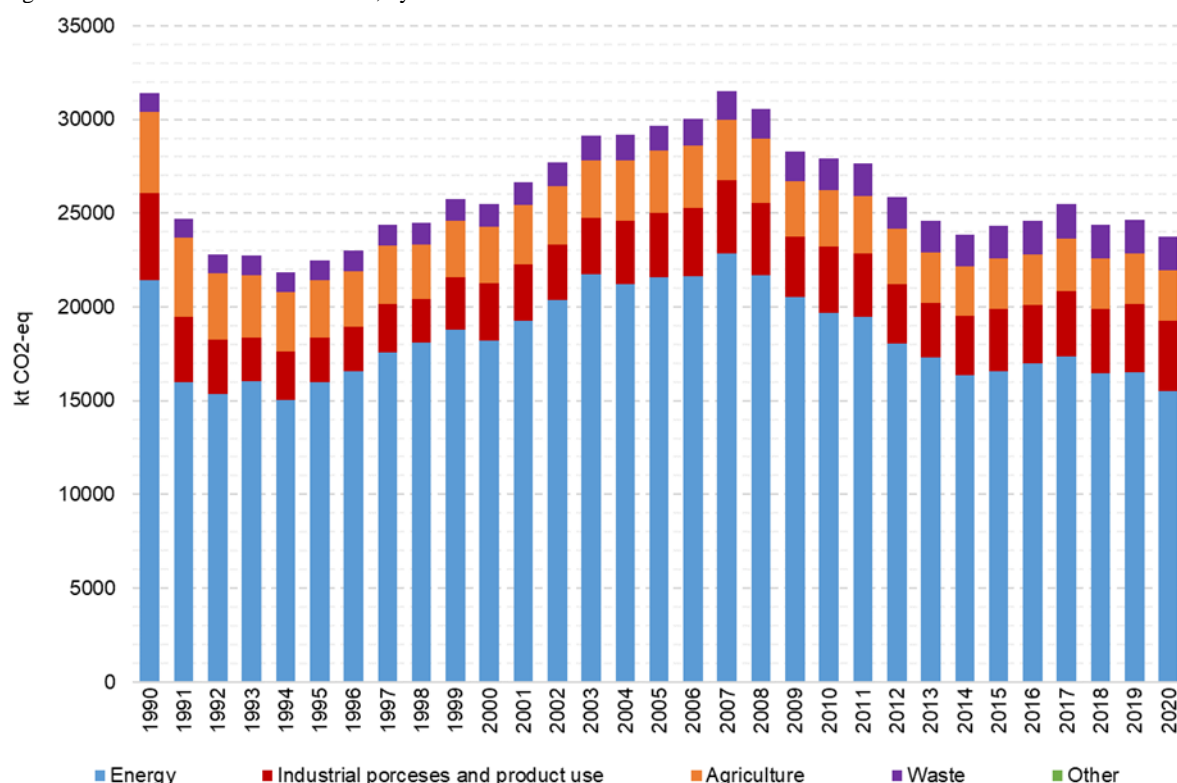
Tables 2.1-1, 2,1-2 and Figure 2.1-1 represents the contribution of the individual sectors to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2020 excluding LULUCF has the Energy sector with 65.3 %, followed by Industrial Processes and product use with 15.9 %, Agriculture with 11.3 % and Waste with 7.5 %. This structure is with minor changes consistent through all the observed period from 1990 to 2020. In the year 2020, the total GHG emissions in Croatia was 23,756.4 kt CO_2-eq excluding LULUCF sector while the total emission was 18,450.6 kt CO_2-eq including the LULUCF sector which represents removals by sink from 22.3 % in that year.

Table 2.1-3: Emissions/removals of GHG by gases for the every five years from 1990 to 2012 (kt CO_2-eq)

Greenhouse gas emissions	1990	1995	2000	2005	2010	2011	2012
CO_2 emissions without net CO_2 from	22,979.8	16,817.7	19,662.5	23,343.9	21,016.3	20,649.6	19,087.4
CO_2 emissions with net CO_2 from	16,958.6	8,585.2	13,077.8	15,573.1	14,038.5	14,896.7	13,728.1
CH_4 emissions without CH_4 from	4,324.9	3,373.1	3,294.2	3,658.1	3,879.4	3,832.0	3,785.4
CH_4 emissions with CH_4 from	4,326.2	3,380.6	3,391.2	3,660.8	3,881.1	3,850.6	3,824.3
N_2O emissions without N_2O from	2,860.6	2,275.0	2,467.5	2,460.4	2,432.5	2,492.7	2,263.2
N_2O emissions with N_2O from	2,908.7	2,322.0	2,572.0	2,527.8	2,536.6	2,618.3	2,410.9
HFCs	NO	21.8	52.9	186.7	593.3	660.8	737.9
PFCs	1,240.2	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO
SF_6	10.7	12.1	12.3	14.3	9.8	10.3	11.0
NF_3	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	31,416.3	22,499.7	25,489.5	29,663.4	27,931.3	27,645.4	25,884.8
Total (with LULUCF)	25,444.4	14,321.7	19,106.2	21,962.6	21,059.3	22,036.8	20,712.1
Total (without LULUCF, with	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA

Table 2.1-4: Emissions/removals of GHG by gases for the period from 2013-2020 (kt CO_2-eq)

Greenhouse gas emissions	2013	2014	2015	2016	2017	2018	2019	2020
CO_2 emissions without net CO_2 from	18,432.2	17,681.6	17,824.7	18,109.0	18,744.0	17,724.2	17,857.4	16,870.5
CO_2 emissions with net CO_2 from	12,439.8	11,819.8	12,250.9	12,561.8	13,627.5	12,377.7	12,378.1	11,388.3
CH_4 emissions without CH_4 from	3,686.2	3,649.9	3,744.4	3,808.7	3,769.1	3,625.7	3,586.4	3,538.7
CH_4 emissions with CH_4 from LULUCF	3,688.1	3,650.2	3,758.4	3,817.6	3,838.3	3,627.0	3,589.2	3,571.2
N_2O emissions without N_2O from	1,678.6	1,638.8	1,777.7	1,545.7	1,665.6	1,615.6	1,619.6	1,658.2
N_2O emissions with N_2O from LULUCF	1,801.0	1,760.0	1,908.5	1,673.1	1,835.5	1,737.6	1,742.6	1,802.2
HFCs	807.8	898.1	996.6	1,139.3	1,293.3	1,428.5	1,551.0	1,680.2
PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	7.2	7.7	5.6	6.6	7.0	6.3	7.9	8.8
NF_3	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	24,611.9	23,876.0	24,349.1	24,609.2	25,479.0	24,400.2	24,622.3	23,756.4
Total (with LULUCF)	18,743.8	18,135.6	18,920.1	19,198.4	20,601.7	19,177.1	19,268.8	18,450.6
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA

Figure 2.1-2: Trend of GHG emissions, by gases
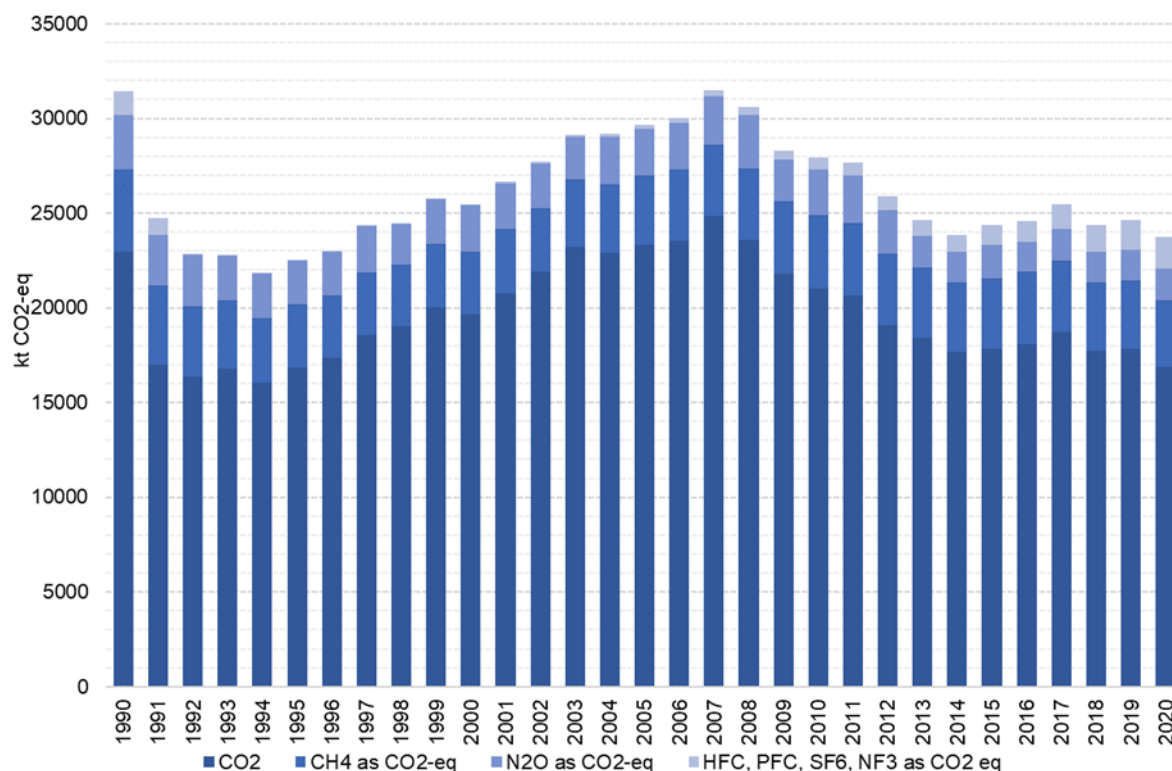
Tables 2.1-3, 2.1-4 and Figure 2.1-2 represents the contribution of the individual gasses to total emissions and removals of the GHGs. The largest contribution to the GHGs emission in 2020 excluding LULUCF has CO_2 emission with 71.0 %, followed by CH_4 with 14.9 %, N_2O with 7.0 % and HFCs, PFCs and SF_6 with 7.1 %.

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 2020, the GHG emission from the Energy sector was 5.9 % lower in relation to 2019 and 27.6 % 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 70 % 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 95.3 % (in 2020). The contribution of energy in methane (CH_4) in total CO_2-eq emission is substantially smaller (3.3 % in 2020) while the contribution of energy in nitrous oxide (N_2O) in total CO_2-eq emission is quite small (1.4 % in 2020). 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 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
1. Energy	21,439.5	15,972.4	18,217.1	21,564.5	19,708.3	16,591.2	16,998.6	17,380.3	16,437.3	16,496.1	15,516.6
A. Fuel comb.	20,437.2	14,846.4	17,275.1	20,558.7	18,909.4	16,147.9	16,566.7	16,875.0	15,974.9	16,042.7	15,074.6
1. Energy	7,088.6	5,278.0	5,833.4	6,837.5	5,903.4	4,742.6	4,875.3	4,493.2	3,937.9	3,915.8	3,695.8
2. Manufact. ind.	5,234.6	2,887.4	3,074.3	3,739.3	3,030.1	2,232.0	2,236.8	2,439.4	2,421.4	2,432.1	2,394.0
3. Transport	3,896.0	3,370.1	4,502.3	5,561.8	5,951.5	5,953.8	6,177.7	6,645.8	6,410.3	6,589.0	5,802.4
4. Other sectors	4,218.0	3,310.9	3,865.2	4,420.1	4,024.4	3,219.6	3,276.9	3,296.6	3,205.4	3,105.7	3,182.4
5. Other	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
B. Fugitive em.	1,002.3	1,126.0	942.0	1,005.8	798.9	443.3	431.9	505.3	462.4	453.5	442.0
1. Solid fuels	59.6	28.2	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
2. Oil and nat. gas	942.7	1,097.8	942.0	1,005.8	798.9	443.3	431.9	505.3	462.4	453.5	442.0
C. CO2 transport	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

The largest part (37.4 % in 2020) of the emissions are a consequence of fuel combustion in Transport, next is the combustion in Energy industries (23.8 % in 2020) and third is combustion in small stationary energy sources, such as Commercial/ Institutional, Residential and Agriculture/ Forestry/ Fishing (20.5 % in 2020). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 15.4 %, while Fugitive Emissions from Fuels contribute with about 2.9 %.

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 96.8 % in total sectoral emission in 2020. 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 2020 emissions from industrial processes were increased by 3.2 % regarding 2020 and decreased by 18.4 % regarding 1990. Industrial processes and product use contributed to total GHG emissions with 15.9 % in 2020. 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 1990-2020 (kt CO_2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
2. Industrial processes and product use	4,617.6	2,403.7	3,038.0	3,474.9	3,519.3	3,290.3	3,098.8	3,483.8	3,463.8	3,644.7	3,760.7
A. Mineral industry	1,302.7	741.7	1,428.9	1,813.8	1,401.8	1,306.4	1,201.3	1,425.6	1,358.4	1,324.9	1,359.3
B. Chemical industry	1,510.8	1,438.9	1,401.3	1,304.1	1,383.1	883.6	657.2	665.4	563.2	644.7	600.4
C. Metal industry	1,580.5	41.1	30.2	12.7	14.7	9.3	1.1	1.9	9.0	4.9	4.9
D. Non-energy products	176.2	111.3	75.7	111.5	89.7	68.7	73.9	70.8	80.1	93.1	87.2
E. Electronic Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Product uses as ODS	NO	21.8	52.9	186.7	593.3	996.6	1,139.3	1,293.3	1,428.5	1,551.0	1,680.2
G. Other prod. manuf.	47.4	48.8	49.1	46.1	36.7	25.7	26.0	26.8	24.6	26.1	28.7
H. Other	NA	NA	NA	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 36.2 % of sectoral CO_2-eq emission. The number of cattle showed a continuous decrease in the period from 1990 to 2000. 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 2019, in 2020 CO_2-eq emission from Enteric fermentation decreased by 1.9 %. As for Manure management emissions, CO_2-eq emission decreased by 4.7 % in 2020 compared to 2019. 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 increased in 2020 compared to 2019 by 1.9 %. Overall, in the year 2020, the GHG emission from the Agriculture sector decreased by 0.2 % in comparison with 2019. 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 1990-2020 (kt CO_2-eq)

GHG source and sink categorieses	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
3. Agriculture	4,353.0	3,042.4	3,018.3	3,277.0	3,028.8	2,689.9	2,702.4	2,789.2	2,696.6	2,696.8	2,692.3
A. Enteric fermentation	2,121.2	1,330.0	1,169.0	1,271.1	1,134.1	1,039.1	1,091.0	1,052.2	988.8	994.7	975.5
B. Manure management	756.2	577.3	592.2	638.8	655.8	584.3	582.4	572.9	538.6	533.4	508.1
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	1,425.7	1,088.7	1,196.2	1,281.7	1,150.8	997.1	952.8	1,083.0	1,096.9	1,093.1	1,113.6
E. Presc. burning of sav.	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming	NO	NO	NO	14.5	21.5	12.1	11.2	10.9	4.6	2.1	6.9
H. Urea application	50.0	46.3	60.9	71.0	66.6	57.2	65.0	70.2	67.6	73.6	88.3
I. Other carbon-cont.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
J. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

LULUCF

The Act on Forest (Official Gazette No. NN 68/18, 115/18, 98/19) 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 Forest Management Area Plan of the Republic of Croatia (2006-2018), 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, for 2006, 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 2.2-4 shows the CO_2 removal trend in the forestry sector. Removals arisen in the LULUCF sector contribute with 28.1 % to the total emissions of CO_2 eq in Croatia including LULUCF in the year 2020.

Table 2.2-4: Emission trends in LULUCF sector from 1990-2020 (kt CO2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
LULUCF removals	-5,971.9	-8,178.0	-6,383.3	-7,700.7	-6,871.9	-5,429.0	-5,410.8	-4,877.3	-5,223.1	-5,353.5	-5,305.7

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 that sector.

Emissions from solid waste disposal account 68.3 % of sectoral emissions in 2020, compared to 32.6 % in 1990. An increase in generated and disposed of solid waste exists during the entire 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 30.1 % of sectoral emissions in 2020, compared to 65.2 % 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 7.5 % in 2020. Emission of individual subsectors is presented in the Table2.2.5.

Table 2.2-5: Waste subsectors total emissions by sectors for the period 1990-2020 (kt CO2-eq)

GHG source and sink categories	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
5. Waste	1,006.1	1,081.2	1,216.1	1,346.9	1,674.9	1,777.7	1,809.4	1,825.8	1,802.5	1,784.7	1,786.7
A. Solid waste disposal	328.0	419.5	560.0	713.7	1,040.4	1,186.6	1,211.2	1,254.7	1,246.7	1,222.2	1,220.2
B. Biol.treatment of solid waste	NO,IE	0.8	1.2	1.9	6.3	8.0	11.2	10.7	12.8	15.9	21.9
C. Incineration of waste	22.4	14.2	17.0	10.1	11.0	9.4	8.7	7.8	8.1	7.5	7.5
D. Waste water treatment	655.8	646.7	637.9	621.2	617.2	573.7	578.3	552.5	534.8	539.1	537.2
E. Other	NO	NO	NO	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 2020 National energy balance was used.

Institutional arrangement for creating national energy data balance is defined in the Ordinance on Energy balance (OG 68/2001). 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 2020.

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, 1995, 2000, 2005, 2010 and period from 2015 to 2020 is presented in the Table 3.1-1.

Table 3.1-1: Primary energy production

PJ	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Coal and coke	4.21	1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel wood	45.77	46.54	41.97	52.27	56.20	64.19	64.15	64.67	63.06	62.79	64.34
Crude oil	104.54	62.81	51.35	40.11	30.69	28.62	31.47	31.79	31.26	30.13	26.98
Natural gas	74.27	69.12	59.40	79.76	93.88	61.61	57.52	51.76	43.07	36.13	29.89
Hydro power	40.08	55.86	62.53	69.20	87.24	61.63	65.63	53.81	66.98	51.54	51.62
Heat				0.22	0.63	0.62	0.66	0.67	0.63	0.61	0.61
Renewables				0.20	2.63	10.79	12.68	16.10	16.21	19.51	22.64
Total	**268.88**	**236.30**	**215.25**	**241.77**	**271.26**	**227.46**	**232.11**	**218.79**	**221.21**	**200.71**	**196.08**

Figure 3.1-1 presents the trends in the primary energy production from 1990 to 2020.

Figure 3.1-1: Trends in primary energy production for the period from 1990 to 2020
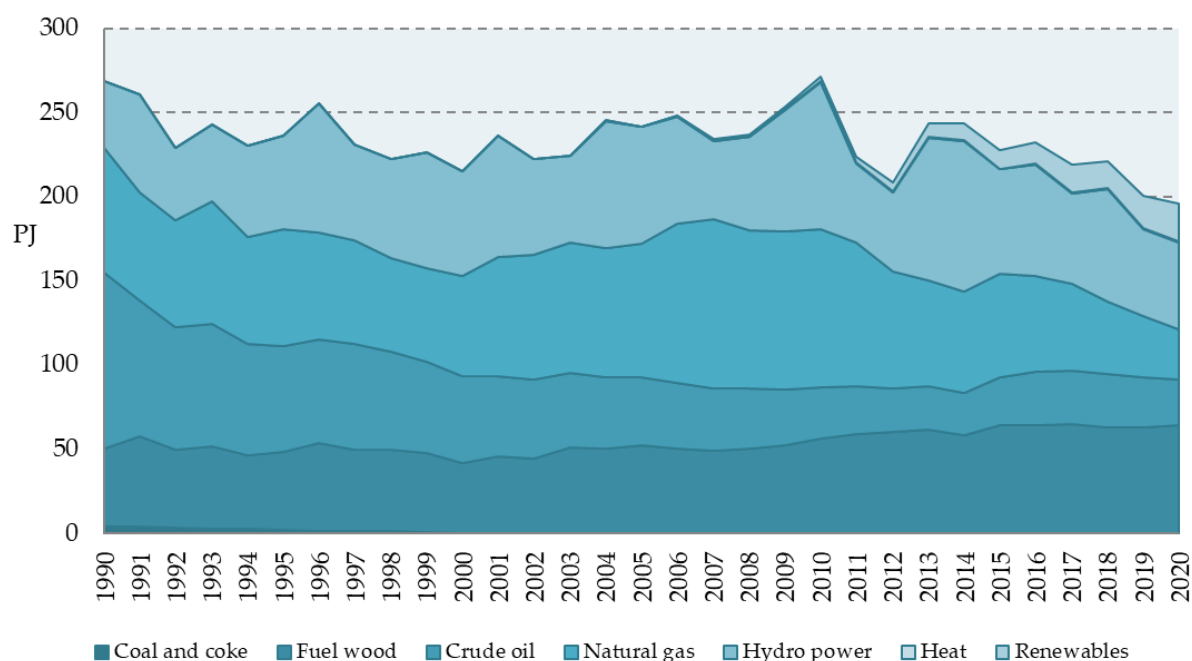
In 1990 primary energy production was about 268.9 PJ, which is 27.1 % higher comparing to 2020. In 2020, the total primary energy production decreased by 2.3 % with relation to 2019. Comparing to 2019, the energy production from renewable sources increased by 16.2 % in 2020. The production of natural gas decreased by 17.3 % as well as production of crude oil (10.5 %). Hydropower production increased by 0.2 % as well as fuelwood production (2.5 %).

While in 1990 the share of crude oil in primary energy production was the highest one with 38.9 %, in 2020 its' share was only 13.8 %. In 2020, the share of fuelwood (32.8 %) was the highest one. It was followed by hydro power with a share of 26.3 %. The comparison of shares in primary energy productions for the 1990 and 2020 are presented in Figure 3.1-2.

Figure 3.1-2: Shares of individual energy forms in the total production for the 1990 and 2020
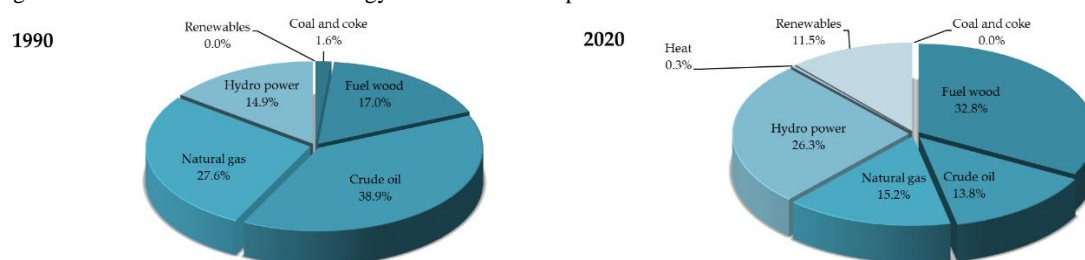
Primary energy supply

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 and period from 2010 to 2020 is presented in the Table 3.1-2.

Table 3.1-2: Primary energy supply

PJ	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Coal and coke	34.07	7.42	17.15	32.95	30.92	29.86	32.14	21.65	20.36	20.77	18.25
Fuel wood	45.77	46.54	41.97	52.27	52.29	52.69	52.47	52.09	53.20	54.18	55.98
Liquid fuels	188.57	146.03	160.52	181.88	152.54	130.92	130.78	139.83	134.52	133.21	112.85
Natural gas	98.22	82.77	94.98	101.06	111.37	87.16	91.08	104.67	96.43	101.22	106.10
Hydro power	40.08	55.86	62.53	69.20	87.24	61.63	65.63	53.81	66.98	51.54	51.62
Electricity	24.09	11.08	12.32	15.88	14.28	24.44	19.91	25.03	19.40	22.08	16.70
Heat	0.00	0.00	0.00	0.22	0.63	0.62	0.66	0.67	0.63	0.61	0.61
Renewables	0.00	0.00	0.00	0.20	2.24	11.16	12.68	16.11	17.32	22.12	25.33
Total	**430.81**	**349.71**	**389.46**	**453.66**	**451.50**	**398.48**	**405.34**	**413.86**	**408.84**	**405.73**	**387.44**

Figure 3.1-3 presents the trends in the primary energy supply from 1990 to 2020.

Figure 3.1-3: Trends in primary energy supply for the period from 1990 to 2020
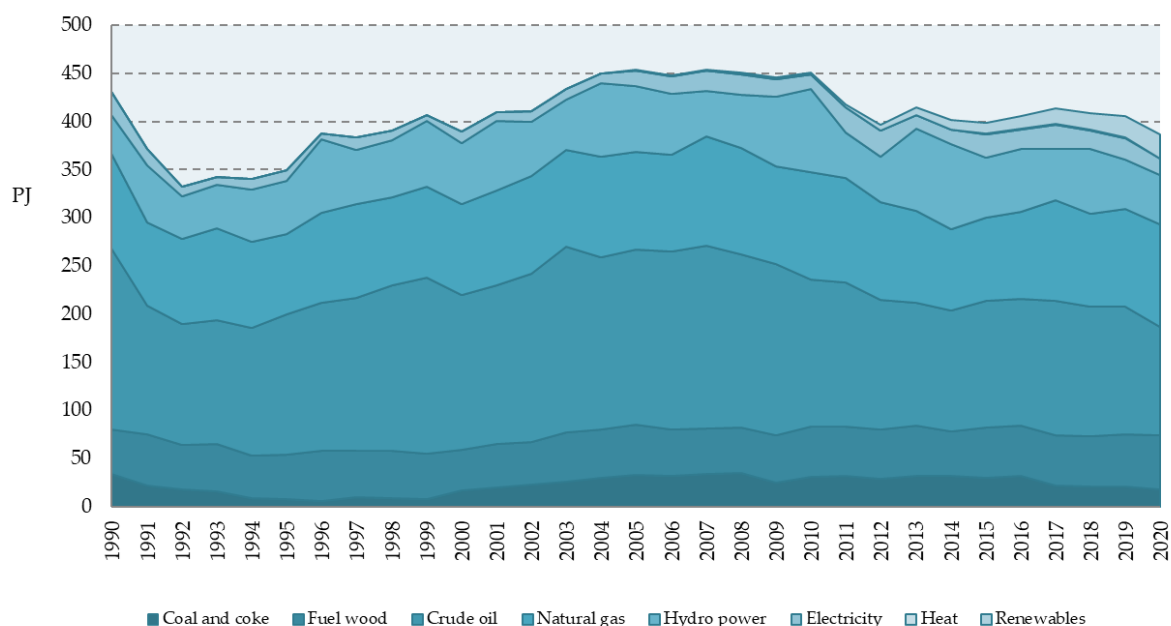
In 1990 the primary energy supply was about 430.8 PJ, which is 10.1 % higher comparing to 2020. In 2020, the total primary energy supply decreased by 4.5 % in relation to the previous year. There was an increase in renewable energy sources, fuelwood and natural gas while consumption of coal and coke and liquid fuels decreased. Hydropower energy supply increased by 0.2 % with relation to 2019. Figure 3.1-4 presents a comparison of the shares of individual energy forms in the total primary energy supply for the 1990 and 2020.

Figure 3.1-4: Comparison of the shares of individual energy forms for the 1990 and 2020
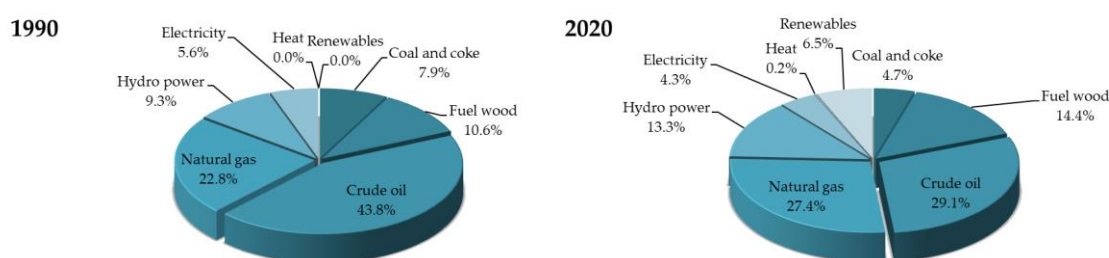
Liquid fuels had the largest share in total primary energy supply in 1990 as well as in 2020 (43.8 % in 1990 and 29.1 % in 2020). It was followed by the natural gas with a share of approximately 27.4 %. Figure 3.1-5 presents the difference between total primary energy production (P) given in Table 3.1-1 and total primary energy supply (S) given in Table 3.1-2.

Figure 3.1-5: Total primary energy supply (S) and production (P)
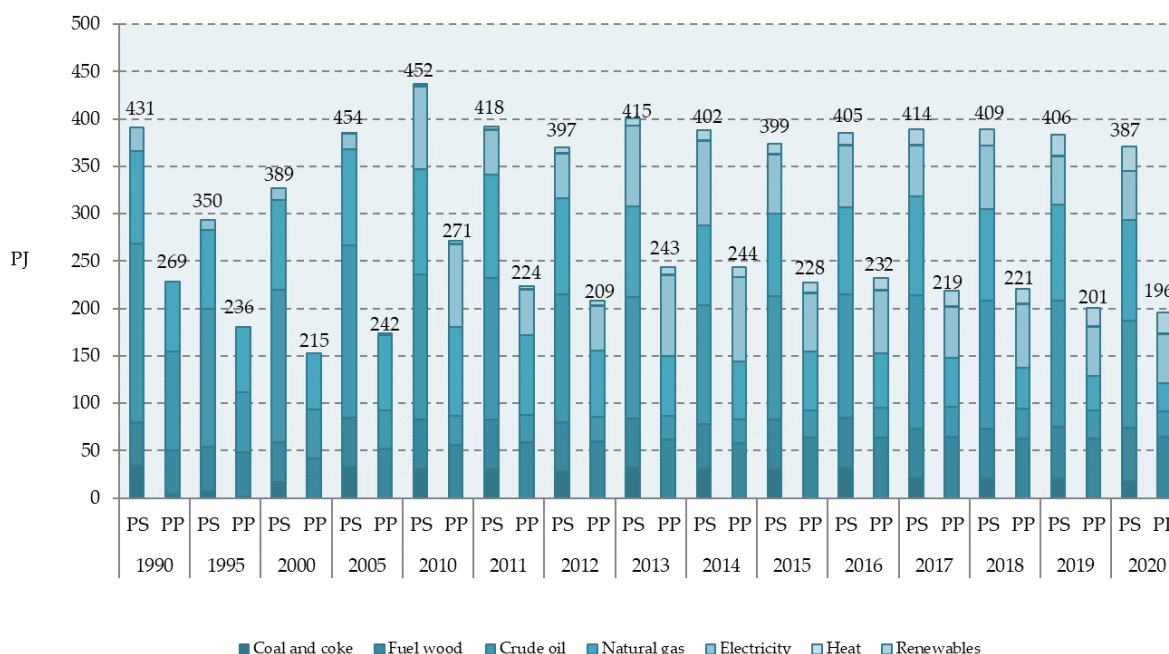
The difference between the supply and the production presents the balance of energy export and import to Croatia. The relation between the produced and consumed energy constitutes own supply which in 2020 amounted 50.6 %. Total hydropower and fuelwood supply were fully covered from the territory of Croatia. The production of solid fuels stopped in 2000, thus all needs for coke and coal were satisfied from import.

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 2020 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 2020

Gorivo / Fuel		DOV (GJ/t(10^{3}m^3)) 2020		CO$_2$ Emisijski faktor (t CO2/TJ)	Oksidacijski faktor (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	27.0000	94.60	1
Kameni ugljen-*Termoelektrane*	Other bituminous coal *Thermal power plant*	GJ/t	24.5720	94.60	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	18.4300	96.10	1
Lignit	Lignite	GJ/t	11.2000	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^{3}m^3	34.7700	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 2020 is shown in Figure 3.1-6.

Figure 3.1-6: Structure of energy consumption
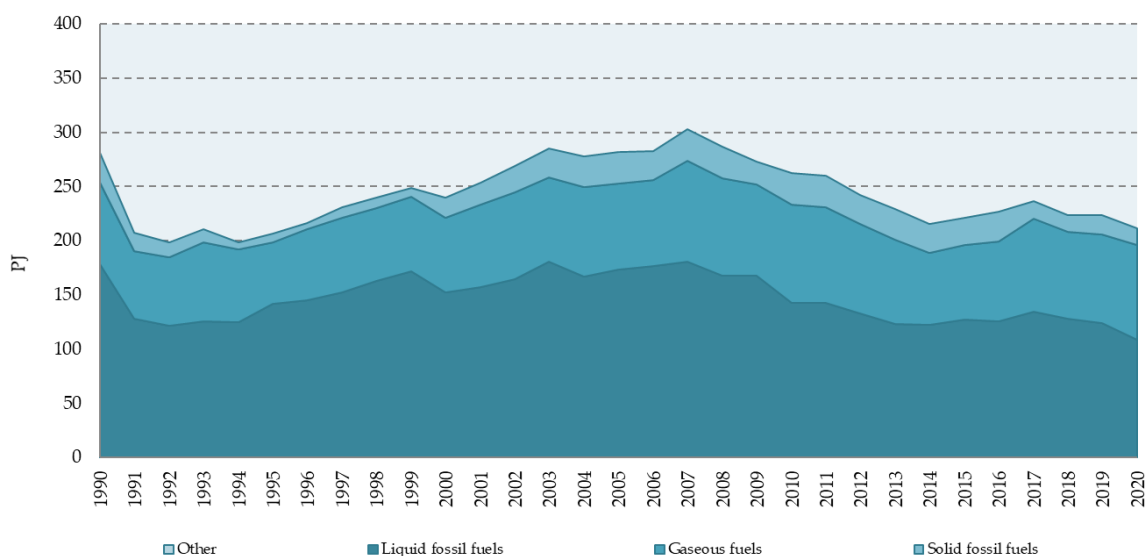
Liquid fossil fuels are mainly used with a share between 50 to 65 %, and natural gas with approximately 30 %, while the share of solid fossil fuels is between 3 to 11 %. Fuelwoods and biomass-based fuels are neutral regarding CO_2 emission, therefore are not shown in the Figure 3.1-6.

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 95 % in 2020. The contribution of energy in methane (CH_4) emission is substantially smaller (3 %) while the contribution of energy in nitrous oxide (N_2O) emission is quite small (about 1 %) in 2020.

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 90 %) of energy-related emissions. Contribution of individual subsectors to the emission of greenhouse gases, for the last

estimated year (2020), is presented in the Table 3.1-4 while contribution of individual subsectors to GHG emission for the period 1990-2020 is presented in Figure 3.1-7.

Table 3.1-4: Contribution of individual subsectors to emission of greenhouse gases, for 2020

GHG categories	kt			Total	
	CO_2	CH_4	N_2O	CO_2-eq (kt)	%
ENERGY	14,788.60	20.37	0.73	15,516.58	100.00
A. Fuel combustion activities	14,500.42	14.23	0.73	15,074.62	97.15
1. Energy industries	3,659.32	0.42	0.09	3,695.84	23.82
a) Electricity and heat production	2,621.72	0.40	0.08	2,656.82	17.12
b) Petroleum refining	835.52	0.02	0.00	836.74	5.39
c) Manufacture of solid fuels	202.08	0.00	0.00	202.28	1.30
2. Manufacturing ind. and constr.	2,381.74	0.18	0.03	2,394.01	15.43
3. Transport	5,732.11	0.37	0.20	5,802.43	37.40
a) Civil aviation	16.65	0.00	0.00	16.79	0.11
b) Road transport	5,546.03	0.36	0.18	5,609.98	36.15
c) Railways	42.09	0.00	0.02	46.98	0.30
d) Navigation (domestic)	127.34	0.01	0.00	128.67	0.83
4. Other sectors	2,727.25	13.25	0.42	3,182.35	20.51
5. Other	NO	NO	NO	NO	NO
B. Fugitive emissions from fuels	288.18	6.14	0.00	441.95	2.85
1. Solid fuels	NO	NO	NO	NO	NO
2. Oil and natural gas	288.18	6.14	0.00	441.95	2.85
C. CO_2 transport and storage	NO	NO	NO	NO	NO

Figure 3.1-7: CO$_2$-eq emissions from Energy sector by subsectors in 1990-2020
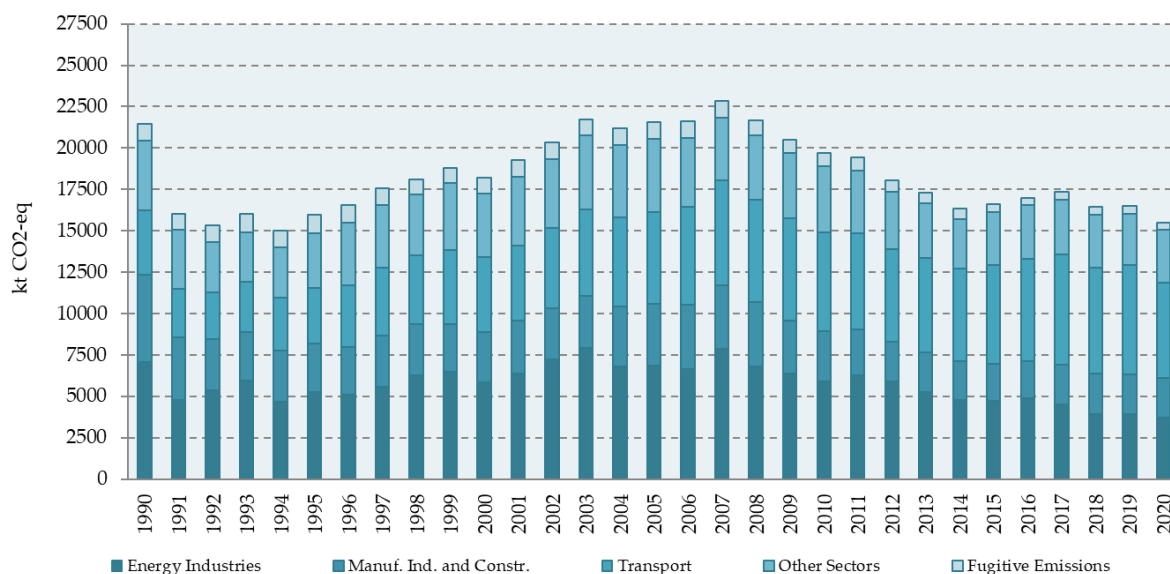
The largest part (37.4 %) of the emissions are a consequence of fuel combustion in Transport, then the combustion in Energy industries (23.8 % in 2020) and the combustion in small stationary energy sources, such as Commercial/Institutional, Residential and Agriculture/Forestry/Fishing (20.5 % in 2020). Manufacturing Industries and Construction contribute to total emission from the Energy sector with 15.4 %, while Fugitive Emissions from Fuels contribute about 2.9 %. The majority of energy-related GHG emissions belong to CO$_2$ (91 to 95 %), then follows CH$_4$ (3 to 9 %) and N$_2$O (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 2020

Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, year = 2020)							
A **IPCC Source Categories**	**B** **GHG**	**C** **Key**	**D** **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	
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	Yes	L1e	T1e	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	T2e			
1.A.4 Other Sectors - Biomass	CH_4	Yes	L1e, L2e	T2e	L1i, L2i		
1.A.4 Other Sectors - Biomass	N_2O	Yes	L2e	T2e			
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, T2i	
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				
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	Yes	L1e, L2e	T2e	L1i, L2i	T1i, T2i	

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

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 2020 was set up according to the EMEP/CORINAIR methodology. Emissions were obtained from the emission inventory report 'Republic of Croatia Informative Inventory Report for 2020, 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).

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.

The emission of NO_X from the Energy sector (Fuel Combustion Activities) in 2020 was 40.7 kt which is 6.3% lower than the year before and 48.7% lower compared to 1990. The NO_X emissions from Energy sector contribute with approximately 95% to national total NO_X emission. The structure of NO_X emission

in the Energy sector has not changed significantly in the period from 1990 to 2020 (Figure 3.1-8). The main source of NO_X emission is transport (57.5% of total emission in the energy sector in 2020).

Figure 3.1-8: NO_X emissions from Energy sector in the period 1990-2020
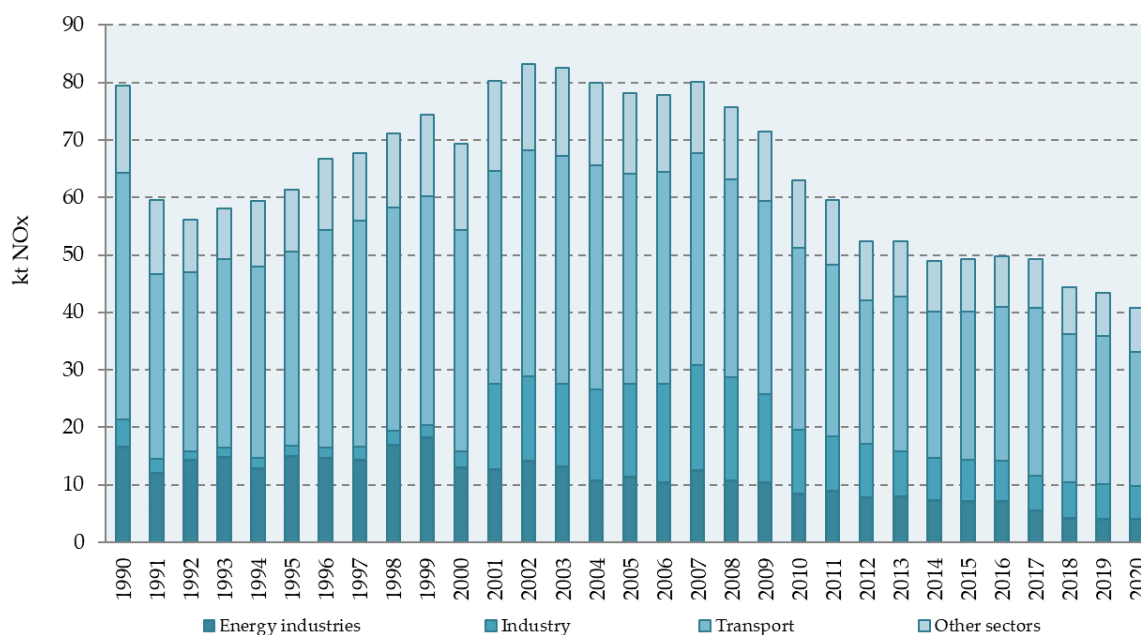
CO emissions

In 2020, the emission of CO from Fuel Combustion Activities was 197.7 kt which is 1.0 % higher than in the year before and 55.3 % lower compared to 1990, the year with maximum emission (442.3 kt) of CO in the observed period. The CO emissions from Energy sector in 2020 contribute with approximately 90% to national total CO emission. 81.6 % of CO emission in the Energy sector in 2020 was the result of incomplete fossil fuel combustion in Commercial and Residential sector and 14.0 % in Road transport sector (Figure 3.1-9). Large combustion plants have automatic regulation of air throughput and combustion control, so CO emissions are low (about 0.6% of national total emission).

Figure 3.1-9: CO emissions from Energy sector in the period 1990-2020
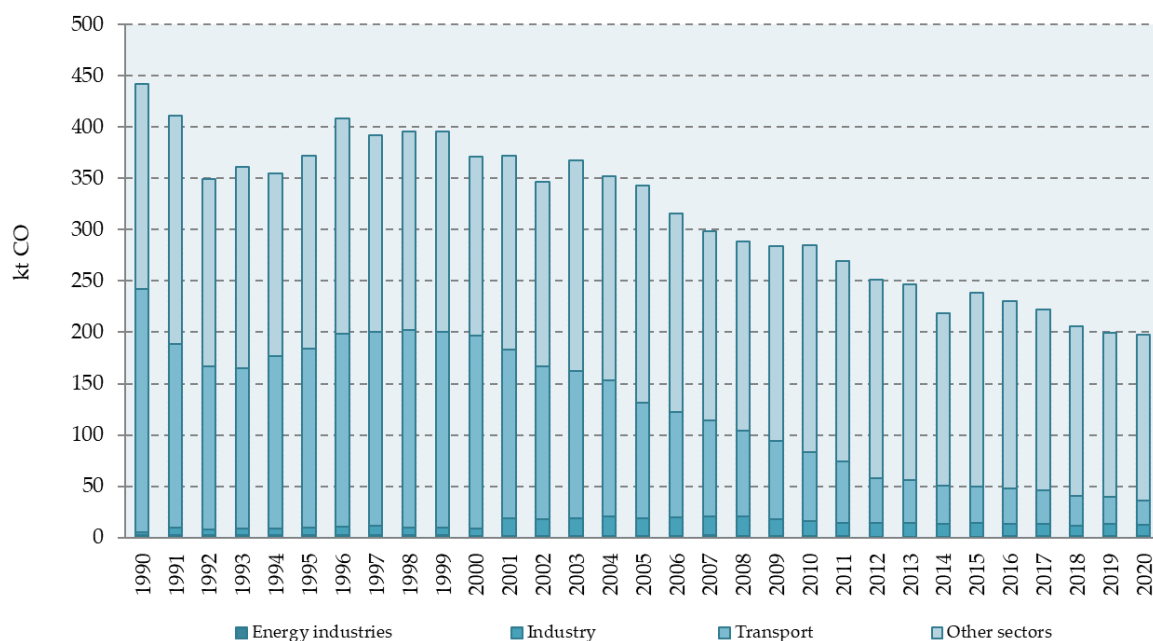
NMVOC emissions

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. Anthropogenic NMVOCs emissions from the Energy sector (Fuel Combustion Activities) were 24.5 kt in 2020 which was 1.3% lower than the year before and 57.3 % lower than in 1990.

The structure of NMVOC emission from the Energy sector has not changed significantly in the period from 1990 to 2020 (Figure 3.1-10). The main source of NMVOC emission is stationary combustion sectors, mainly from the Commercial and Residential sector.

Figure 3.1-10: NMVOC emissions from Energy sector in the period 1990-2020
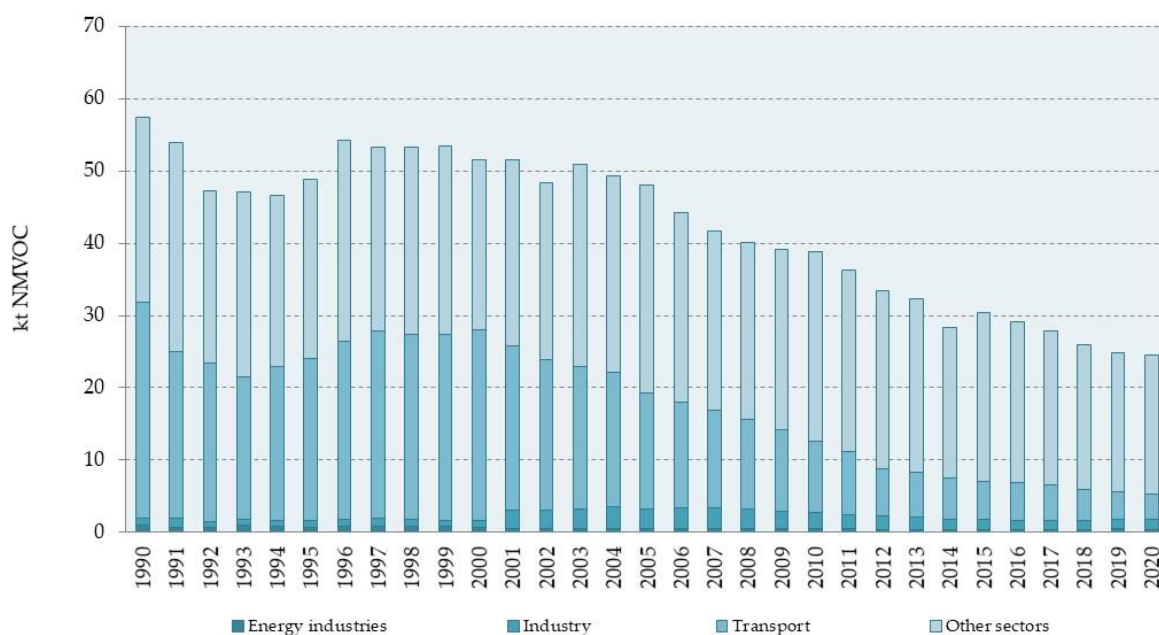
SO₂ emissions

In accordance with the calculated results, the level of SO$_2$ emission from Fuel Combustion Activities in 2020 reached 3.9 kt which is approximately 91% of total national SO$_2$ emission. The trend shows that emissions of SO$_2$ have decreased by 19.8% compared to the emission in 2019 and decreased by 97.0% since 1990. Since 1990, SO$_2$ emission has an overall decreasing trend due to the consumption of fossil fuel with lower sulphur content. The outstanding high level of SO$_2$ emission in 1990 is a result of fossil fuel consumption with high sulphur content in Energy Industries and Manufacturing Industries and Construction sectors. In years ahead, emissions from these two sectors were reduced by 50%. During the period from 1990 to 2020, the decrease of SO$_2$ emissions was achieved in almost all sectors and the greatest decrease of SO$_2$ emission was in the Energy Industries sector. Emission trend for SO$_2$ in the period of 1990 to 2020 in the Energy sector 1990 and 2020 is presented in Figure 3.1-11.

Figure 3.1-11: SO$_2$ emissions from Energy sector in the period 1990-2020
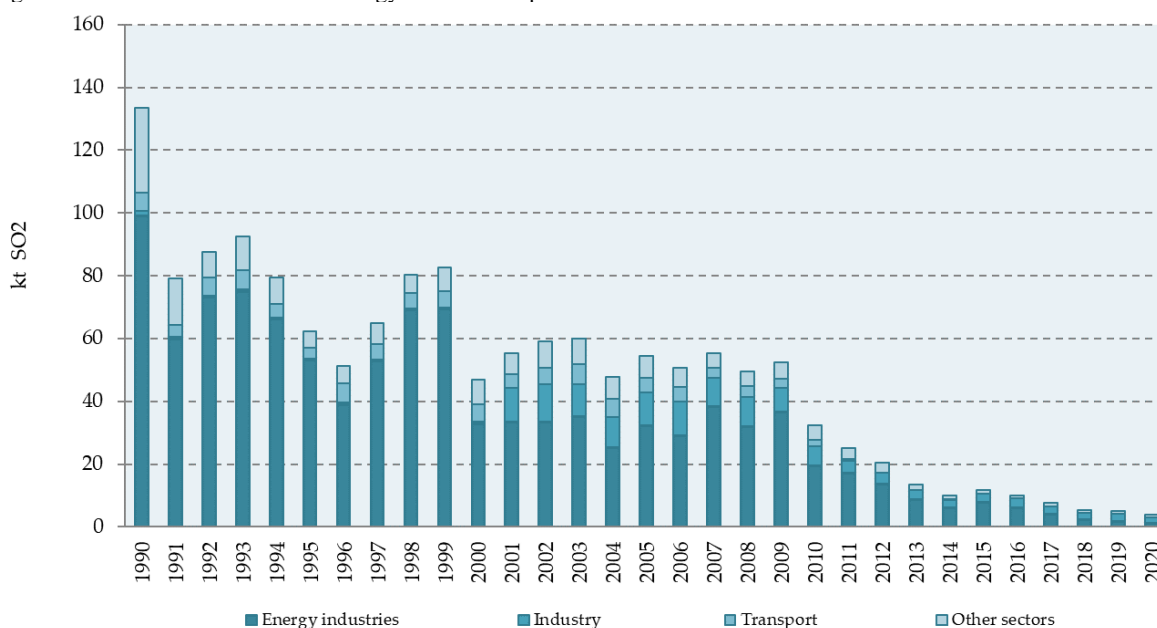
3.2 Fuel combustion (CRF 1.A)

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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Fuel consumption (PJ)											
SA	280.92	206.51	239.86	281.78	262.82	221.67	227.38	237.48	224.29	224.74	213.24
Appar. consum.	286.87	208.36	235.45	280.13	262.61	220.06	227.96	236.82	223.96	224.48	212.72
Dif.(%)	2.12	0.89	-1.84	-0.58	-0.08	-0.72	0.26	-0.28	-0.15	-0.12	-0.24
CO2 emission (kt)											
RA	20164.7	14538.8	16689.6	19977.3	18439.4	15749.4	16432.9	16703.2	15705.0	15835.0	14556.3
SA	19780.4	14285.8	16645.3	19899.9	18265.1	15549.1	15971.9	16286.2	15406.7	15477.3	14500.4
Diff.(%)	1.9	1.8	0.3	0.4	1.0	1.3	2.9	2.6	1.9	2.3	0.4

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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Liquid fuel consumption (PJ)											
SA	178.04	142.13	152.33	173.22	142.97	127.43	126.12	134.67	128.37	123.96	108.85
Apparent. consum.	181.52	144.45	147.92	172.01	142.94	125.84	126.70	134.01	128.04	123.69	108.36
Dif.(%)	1.95	1.63	-2.90	-0.70	-0.02	-1.25	0.46	-0.49	-0.26	-0.21	-0.47
CO₂ emission (kt)											
RA	13080.7	10646.4	11077.1	12840.7	10626.7	9497.3	9697.2	10289.6	9686.7	9424.5	8008.7
SA	12903.5	10366.2	11049.3	12743.3	10444.1	9291.0	9231.8	9872.5	9384.2	9056.9	7942.4
Diff.(%)	1.4	2.7	0.3	0.8	1.7	2.2	5.0	4.2	3.2	4.1	0.8

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 2020 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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Other fuel consumption (PJ)											
SA	NO	NO	NO	NO	0.32	0.39	0.41	0.48	0.82	1.13	1.63
Apparent. consum.	NO	NO	NO	NO	0.32	0.39	0.41	0.48	0.82	1.13	1.63
Dif.(%)	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2 emission (kt)											
RA	NO	NO	NO	NO	45.63	55.77	59.12	69.03	116.93	161.43	233.13
SA	NO	NO	NO	NO	46.07	59.67	63.70	69.11	121.25	171.46	243.63
Diff.(%)	NO	NO	NO	NO	-0.95	-6.54	-7.20	-0.13	-3.56	-5.85	-4.31

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, from 1990 to 2020

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Liquid fuel consumption (TJ)											
Aviation bunkers	6945.7	3428.9	2813.4	3604.7	4132.2	4884.0	5182.9	6194.0	7719.4	8356.9	2259.5
Marine bunkers	1936.8	1356.8	757.4	1047.8	255.0	144.4	175.6	266.8	872.8	1042.8	852.7
Total bunkers	8882.5	4785.7	3570.8	4652.5	4387.2	5028.5	5358.5	6460.8	8592.2	9399.7	3112.2
CO2-eq emission (kt)											
Aviation bunkers	500.8	247.3	202.9	259.9	298.0	357.1	378.9	452.8	564.3	610.9	165.2
Marine bunkers	148.7	104.1	58.2	80.6	19.8	11.1	13.3	20.3	65.9	78.7	64.4
Total bunkers	649.6	351.4	261.1	340.6	317.8	368.1	392.3	473.1	630.3	689.7	229.6

Total CO_2-eq from the international bunker in 2020 amounted to 229.6 kt which is 66.7 % lower than in 2019 as a result of lower fuel consumption in the Aviation and Marine bunkers.

Marine bunkers

International marine bunkers are included in the Croatian energy balance for the period from 1994 to 2020, 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 2013

Gas-Diesel Oil

DataType	Product	Item1	Flow	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
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

DataType	Product	Item1	Flow	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
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

Gas-Diesel Oil

DataType	Product	Item1	Flow	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
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

DataType	Product	Item1	Flow	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Public Electr. and Heat Prod.	3,745.3	3,019.3	3,806.5	4,751.1	3,989.3	3,116.8	3,373.0	2,921.4	2,412.9	2,678.5	2,656.8
Petroleum Refining	2,430.2	1,817.7	1,687.3	1,733.8	1,452.7	1,390.1	1,301.2	1,353.2	1,319.6	992.4	836.7
Other Ener. Industries	913.1	441.1	339.6	352.5	461.5	235.7	201.1	218.6	205.4	244.9	202.3
Total Ener. Industries	7,088.6	5,278.0	5,833.4	6,837.5	5,903.4	4,742.6	4,875.3	4,493.2	3,937.9	3,915.8	3,695.8

Figure 3.2-1: CO_2-eq emissions from Energy Industries
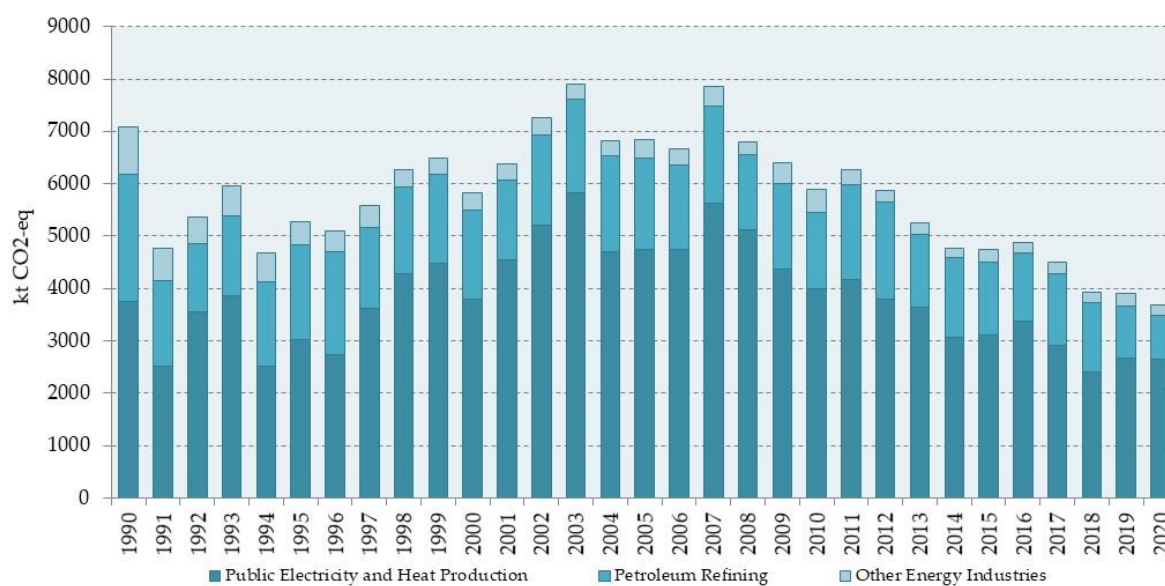
It should be stressed out that approximately 46-53 % of the electricity is generated in hydropower plants; therefore the emission from the Energy Industries sector is relatively small, 29-36 % of emission from the total Energy sector. The largest part (51-75 %) of the emission is a consequence of fuel 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 2020 electricity generation capacities in Croatia encompassed 17 locations with large hydropower plants, 7 locations 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 are gas-fired, coal-fired and fuel oil-fired. 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 2020 amount to 4661.8 MW. Out of this amount, 1552.6 MW is placed in thermal power plants, 2199.4 MW in hydro power plants, 801.3 in wind power plants, 108.5 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	2199.4	-
NPP Krško*	348	uranium oxide (UO_2)
TPP Plomin 1	-	coal
TPP Plomin 2**	199	coal
TPP Rijeka	303	fuel oil
CHP Sisak	229	fuel oil / natural gas
CHP Zagreb (east)	300	fuel oil / natural gas
CHP Zagreb (west)	50	fuel oil / natural gas / extra light oil
CPP Osijek	89	fuel oil / natural gas / extra light oil
KTE Jertovec	76	fuel oil / natural gas / extra light oil
Other biogas plants	55.1	biogas
Other biomass plants	8.2	biomass
Geothermal plants	10.0	
CHP in Industry	157.3	coal / natural gas / fuel oil/ wood
Other small CHP	4.3	natural gas
Total (HPP+NPP+TPP)	4100.3	
* 50% of NPP Krško is owned by HEP, ** TPP Plomin 2 Ltd. (HEP and RWE Power Co-ownership – share 50% : 50%)		

During the observed period between 1990 and 2020 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 2020, the import of electricity was about 39% of the total electricity consumption in Croatia. Electricity supply for the period from 1990 to 2020 is presented in Figure 3.2-2.

Figure 3.2-2: Electricity supply for the period from 1990 to 2020
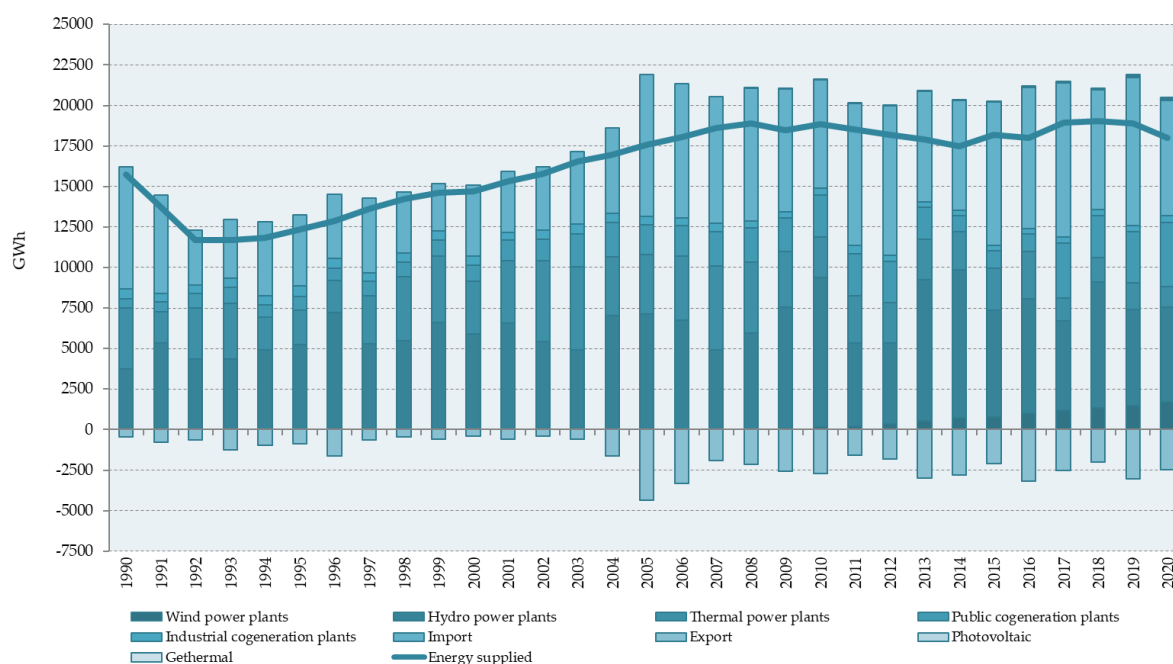
In this subsector there are few types of plants:

- 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 2020.

Figure 3.2-3: CO$_2$-eq emissions from Public Electricity and Heat Production subsectors
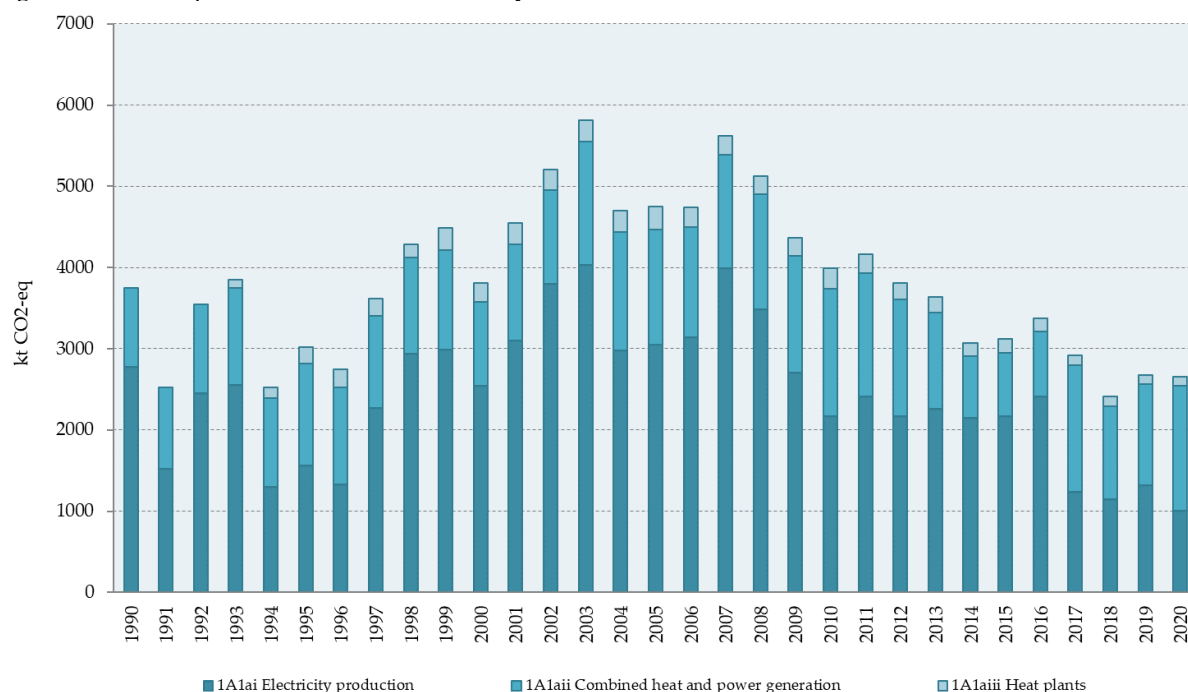
Production of electricity has increasing trend through the years, from 8 TWh (1990) to 15 TWh (2010) but CO$_2$ emission does not follow this trend. Approximately 51 % of electricity is generated in hydropower plants (HPP), but this per cent depends on hydrological conditions during the year. If hydrological 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 2020 is presented in Figure 3.2-4. In 2020, the total electricity production was 4.9 % higher than in the former year (Table 3.2-8).

Table 3.2-8: Differences between electricity production in 2019 and 2020

ENERGY BALANCE	Electricity, GWh		Difference 2020-2019	Difference %
	2019	2020		
Production	12,760.3	13,385.3	625.0	4.9
Hydro power plants	5,932.6	5,810.4	-122.2	-2.1
Wind power plants	1,467.3	1,720.7	253.4	17.3
Photovoltaic	83.1	95.5	12.4	14.9
Thermal power plants	1,666.6	1,270.8	-395.8	-23.7
Public cogeneration plants	3,149.3	3,995.0	845.7	26.9
Industrial cogeneration plants	369.5	399.2	29.7	8.0
Import	9,158.3	7,090.6	-2,067.7	-22.6
Export	-3,025.3	-2,451.3	574.0	-19.0
Total consumption	**18,893.3**	**18,024.6**	**-868.7**	**-4.6**

Figure 3.2-4: Domestic production of electricity by sources for the period from 1990 to 2020
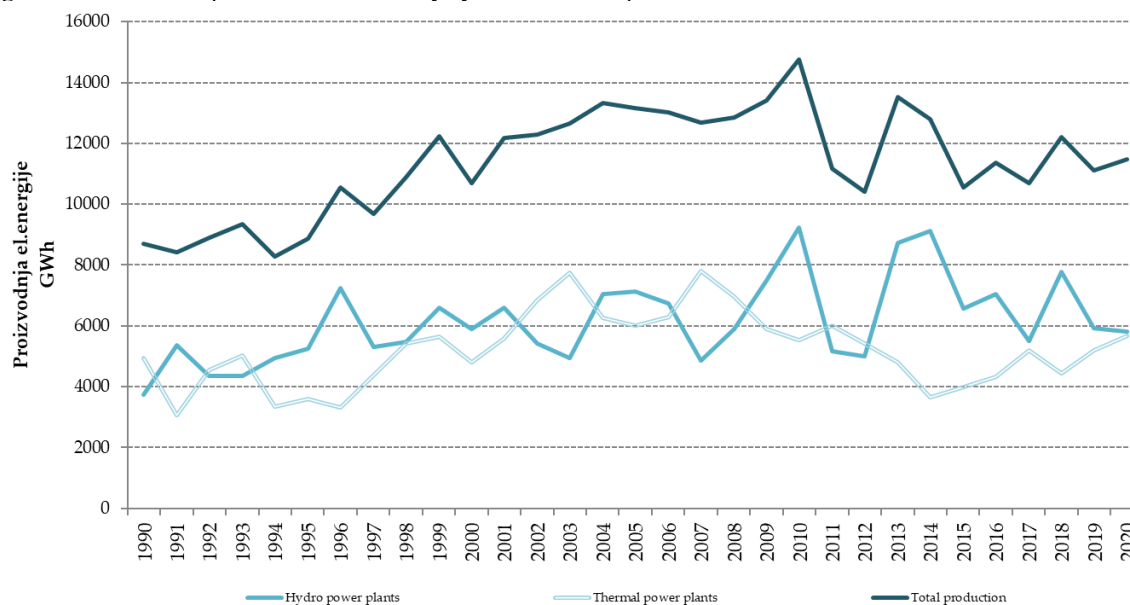
Fuel consumption, net calorific values and emission factors used for estimating GHG emissions are presented in Tables A3-1 to A3-3 of the Annex 3.

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

Processing Capacities	Installed (1000 t/year)
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 2020
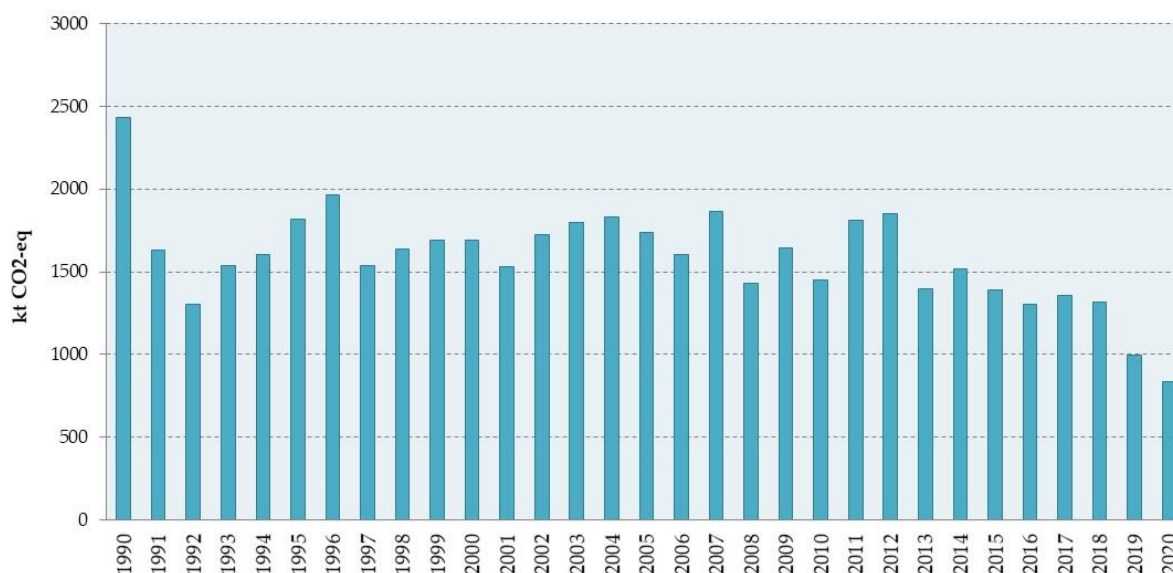
Manufacturing of Solid Fuels and Other Energy Industries (CRF 1.A.1.c)

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 2020. 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 2020 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 2020

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

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 2013-2020 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 $\pm 40\%$; 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 2022 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 2020 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 2020.

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 CO₂-eq emissions (kt) from Manufacturing Industries and Construction

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Iron and Steel Industry	1,067.5	193.9	109.0	89.2	93.1	51.7	34.0	37.0	54.4	41.3	33.9
Non-Ferrous Metals	17.2	10.7	16.9	21.5	14.0	10.9	10.7	20.7	26.9	27.0	25.6
Chemicals	739.8	671.3	706.5	581.7	450.2	294.7	296.7	332.8	279.9	292.3	336.5
Pulp, Paper and Print	304.3	183.9	153.5	175.0	162.1	70.2	105.6	96.8	93.2	110.9	115.9
Food Proc., Bev. and Tobac.	732.2	580.4	432.5	594.2	515.4	351.8	377.8	359.7	335.4	337.0	295.9
Non-metallic minerals	1,937.6	1,082.5	1,422.4	1,857.1	1,409.5	1,153.5	1,122.0	1,302.0	1,316.1	1,287.6	1,266.5
Other	436.0	164.8	233.5	420.6	385.8	299.2	290.0	290.3	315.4	336.0	319.8
Total Manuf. Ind. and Cons.	5,234.6	2,887.4	3,074.3	3,739.3	3,030.1	2,232.0	2,236.8	2,439.4	2,421.4	2,432.1	**2,394.0**

Figure 3.2-7: CO₂-eq emissions from Manufacturing Industries and Construction
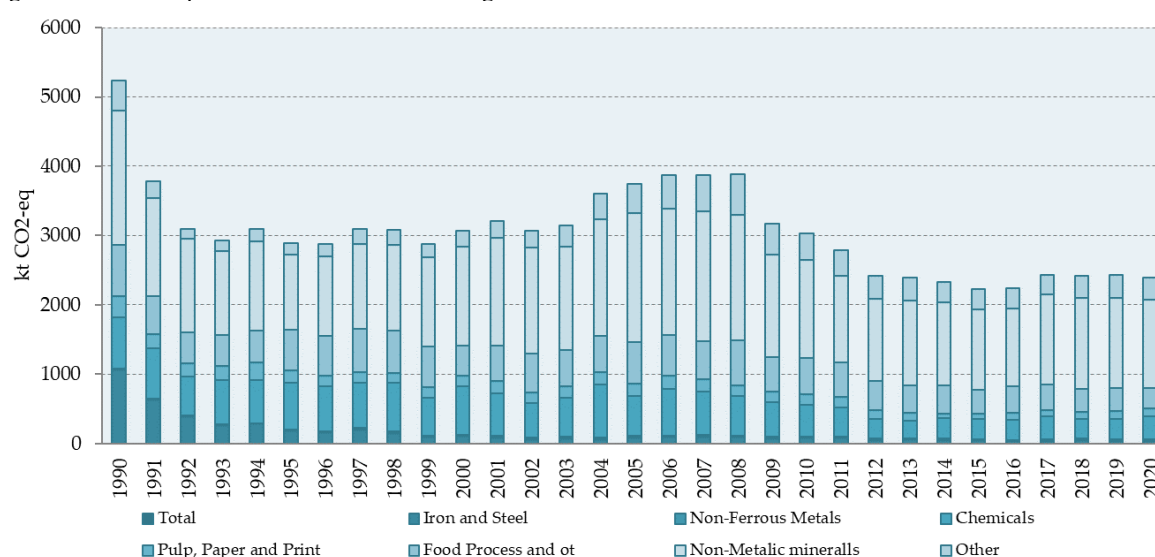
The emissions from this subsector contribute 16-27 % of the total emission from the Energy sector. The largest contributor to emissions is fuel combustion in industry of construction materials and petrochemical production (subsector: Other in Figure 3.2-7), followed by food processing industry, chemical industry, paper industry, iron and steel industry and non-ferrous metal industry.

3.2.5.2.   Methodological issues

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 1990-2020 (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 2022 cycle there were no recalculations in this category.

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 3.2-11 and Figure 3.2-8.

Table 3.2-11: The CO_2-eq emissions (kt) from sector Transport

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Civil	6.7	23.1	25.7	38.0	31.7	31.1	31.4	31.7	32.0	32.3	16.8
Road	3,600.0	3,128.0	4,292.6	5,314.2	5,701.5	5,729.0	5,947.9	6,410.1	6,175.3	6,349.1	5,610.0
Railways	153.5	118.6	96.4	107.7	100.7	61.8	64.6	62.2	51.9	50.5	47.0
Navigation	135.9	100.5	87.6	101.8	117.7	131.9	133.8	141.8	151.1	157.1	128.7
Total	**3,896.0**	**3,370.1**	**4,502.3**	**5,561.8**	**5,951.5**	**5,953.8**	**6,177.7**	**6,645.8**	**6,410.3**	**6,589.0**	**5,802.4**

Figure 3.2-8: The CO$_2$-eq emissions from Transport
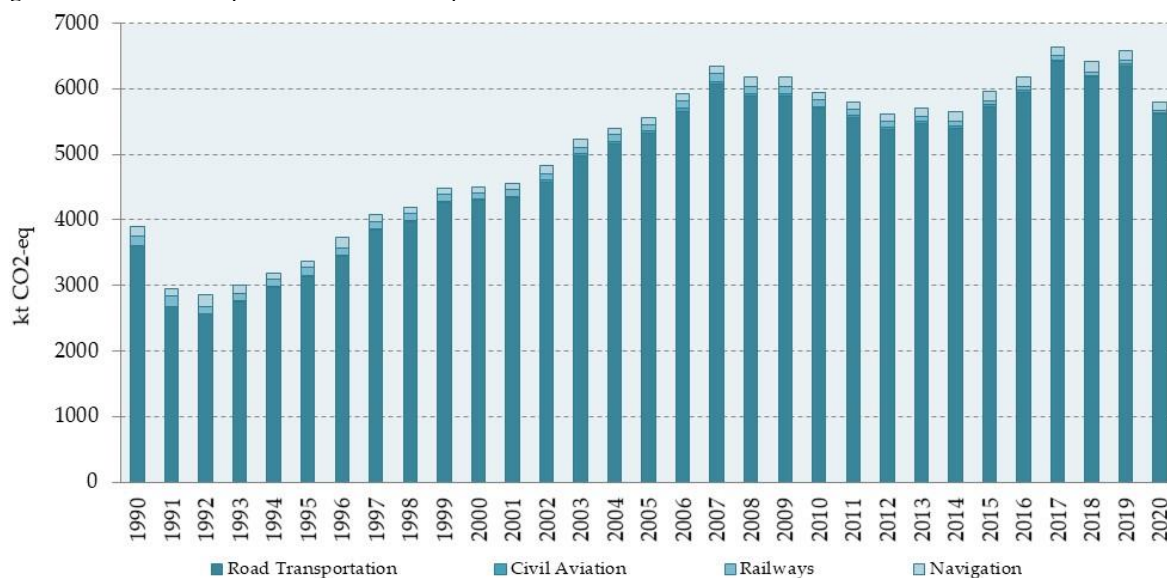
The contribution from the Transport sector to the total CO$_2$-eq emissions from Energy sector in 2020 was 37.4 %. CO$_2$-eq emissions from the transport sector in 2020 amounted to 5,802.43, which is 11.9 % lower than in 2019 as a result of lower fuel consumption in road transport. Specifically, the 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 2020 and contributed to the CO$_2$-eq emissions from the transport sector with 96.7 %. In 2020, the Navigation sector was contributed to the CO$_2$-eq emissions with 2.2 %, Railways with 0.8 % and Civil aviation (domestic) with 0.3 % and (Figure 2.3-8). In comparison with 1990, CO$_2$-eq emissions from the transport sector were increased by 55.8 % 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 2020 amounted 16.8 kt, which is 47.9% lower than in 2019, as a result of jet kerosene consumption decrease. In comparison with 1990, CO$_2$-eq emission was 2.5 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 23.6 % in 2020 and 11.5 % in 1990. In the period from 1990 to 2020 emissions from road transportation raised by 55.9 % 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 National Action plan for energy efficiency for the period from 2017 to 2019.

The CO$_2$-eq from the sub-sectors Road transport in 2020 amounted to 5610.0 kt, which is 11.6 % lower than in 2019 as a result of decrease in fuel consumption. In comparison with 1990, CO$_2$-eq increased by 55.8 % as a result of growing in diesel fuel consumption (by 3.6 times compared to 1990). At the same time, gasoline consumption was decreased by 50.3 %.

Trends of CO_2-eq emissions for fossil fuel type consumed in road transport for the period from 1990 to 2020 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
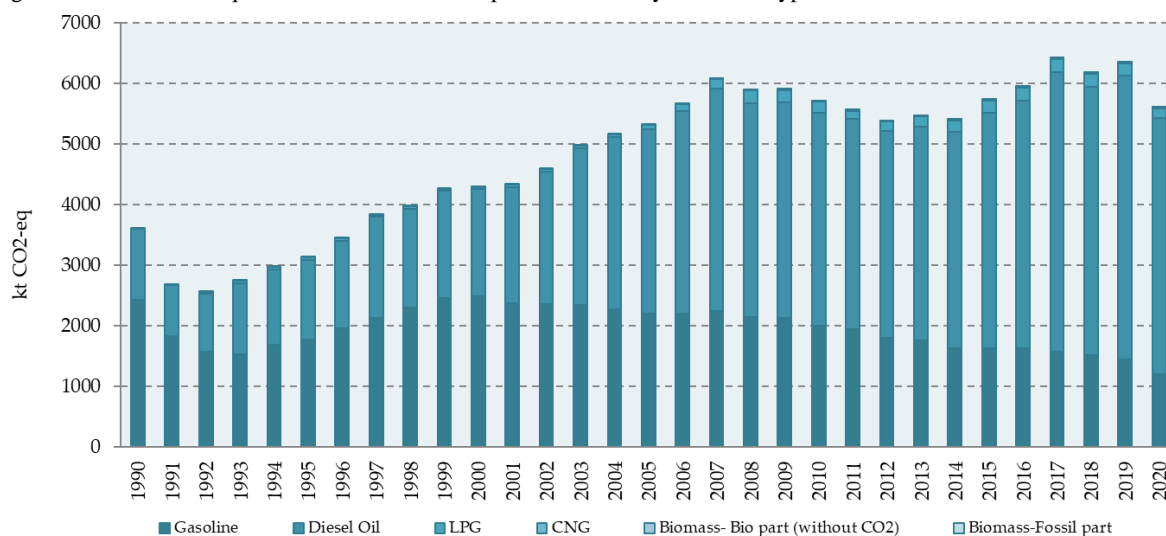
Railways (CRF 1.A.3.c)

The CO_2-eq from the sub-sectors Railways in 2020 amounted to 47.0 kt, which is 7.5 % lower than in 2019 as a result of a decrease in diesel consumption. In comparison with 1990, CO_2-eq was decreased by 69.4% 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 2020 amounted to 128.7 kt, which is for 18.1% lower than in 2019 as a result of increase in fuel consumption. In comparison with 1990, CO_2-eq increased by 5.3% as a result of decrease in navigation traffic and consequently decrease in fuel consumption.

3.2.6.2. Methodological issues

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 practise 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 and for period 2011 - 2020 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 guidance. Amounts of all types of liquid and gaseous fuels consumed for the whole period from 1990 to 2020 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 and for period 2011 – 2020 are presented in the Table A2-10 of the Annex 3.

Comparing the total number of vehicles in 2020 with the number of vehicles in 1990 it can notice the increase of 70.3 %. The increase was largely the result of increase in the number of passenger cars by 60.9 %, constituting 82.7 % of the total number of road vehicles in 2020. Other classes of vehicles were also increased in this period: the number of Light Duty vehicles increased by 123.3%, Heavy Duty vehicles included buses increased by 36.5%, motorcycles and mopeds for 3.4 times. It is important to emphasize that number of registered vehicles gradually decreased in the period 2008-2014 due to economic crisis, where the number of passenger cars which have the highest share in total number of vehicles decreased by 3.5 %.

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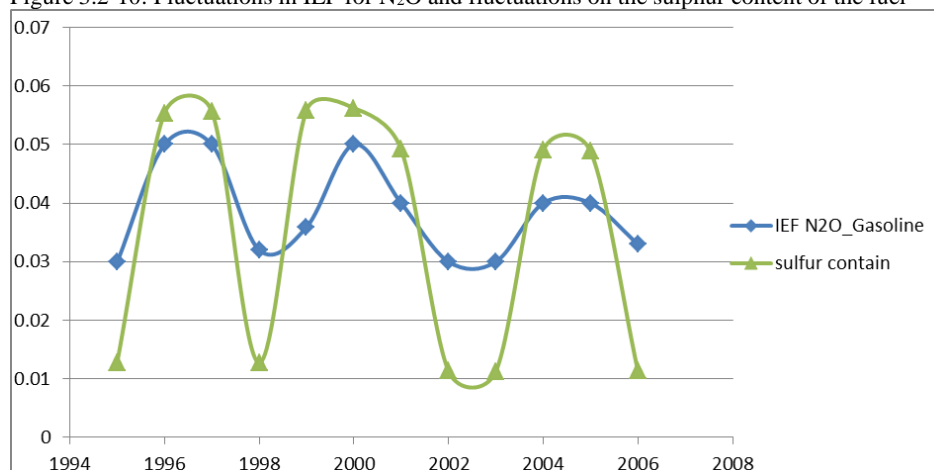
For confirmation of this statement, N_2O emission calculation with constant sulfur contain for Passenger Euro I Gasoline vehicles was performed. Obtained IEF for N_2O did not have fluctuations (see figure 3.2-11).

Figure 3.2-11: IEF for N_2O when sulphur content is constant
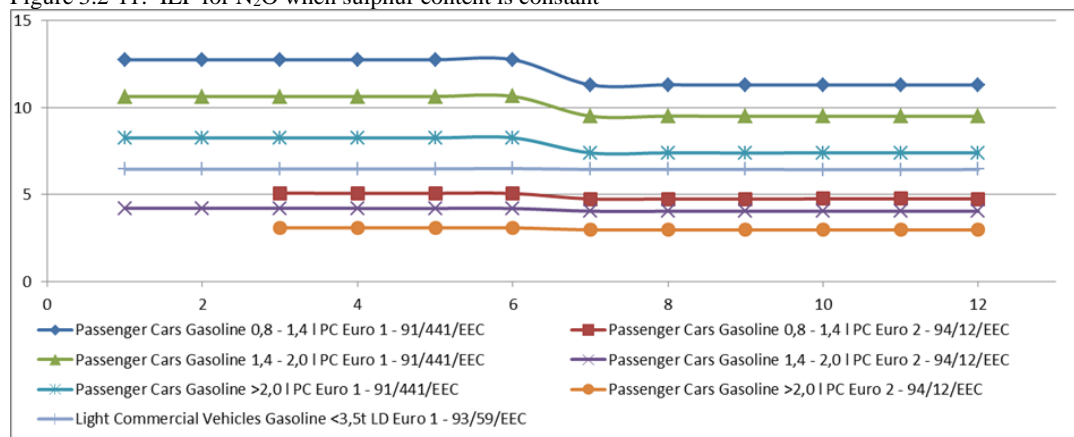
Amounts of fuels consumed, their net calorific values and appropriate GHG emission factors and GHG emissions in the sub-sector Road transport are shown in Table A3-12 Annex 3.

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 2020 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 A2-15 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 2020. 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 practise 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

New version of COPERT 5 model was used for fuel distribution by subcategories. The model estimated the mileage differently, so consumed fuels were redistributed differently within the subcategories. At the sector level (1A3b) fuel consumption as well as CO_2 emission stayed the same.

New version of COPERT 5 model was used to calculate CH_4 and N_2O emissions. In some categories EF for CH_4 and N_2O changed so emissions were changed as well. Due to this update emissions changed les then 0.1%.

Differences between NIR 2021 and NIR 2022 for CO_2-eq emissions from Transport sector for the period 1990-2019 is given in Table 3.2-12 and on Figure 3.2-12.

Table 3.2-12: Differences between NIR 2021 and NIR 2022 for CO_2-eq emissions from Road transport sector for the period 1990-2019

	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001
NIR 2021	3896.11	2951.12	2850.14	3001.71	3184.24	3370.62	3728.12	4087.63	4196.73	4475.43	4500.21
NIR 2022	3,896.0	2,951.5	2,850.2	3,001.3	3,183.9	3,370.1	3,728.2	4,088.1	4,196.7	4,476.8	4,502.3

Diff., kt	-0.09	0.33	0.10	-0.41	-0.30	-0.53	0.09	0.48	-0.07	1.38	2.08
Diff., %	**0.00%**	**0.01%**	**0.00%**	**-0.01%**	**-0.01%**	**-0.02%**	**0.00%**	**0.01%**	**0.00%**	**0.03%**	**0.05%**

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NIR 2021	4824.2	5222.9	5398.4	5561.0	5916.8	6340.8	6170.8	6180.7	5951.7	5800.7	5620.1
NIR 2022	4,824.8	5,223.7	5,400.5	5,561.8	5,918.0	6,342.2	6,172.2	6,182.0	5,951.5	5,800.3	5,617.0
Diff., kt	0.54	0.80	2.10	0.70	1.17	1.36	1.38	1.25	-0.27	-0.40	-3.16
Diff., %	**0.01%**	**0.02%**	**0.04%**	**0.01%**	**0.02%**	**0.02%**	**0.02%**	**0.02%**	**0.00%**	**-0.01%**	**-0.06%**

	2013	2014	2015	2016	2017	2018	2019
NIR 2021	5705.46	5648.44	5957.01	6178.28	6646.45	6413.66	6593.84
NIR 2022	5,702.8	5,645.2	5,953.8	6,177.7	6,645.8	6,410.3	6,589.0
Diff., kt	-2.69	-3.29	-3.23	-0.59	-0.68	-3.41	-4.81
Diff., %	**-0.05%**	**-0.06%**	**-0.05%**	**-0.01%**	**-0.01%**	**-0.05%**	**-0.07%**

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 abovementioned 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	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Comm./Instit.	858.9	664.7	644.0	792.7	674.4	587.8	611.4	631.8	633.0	618.5	577.4
Residential	2,437.5	2,025.2	2,304.3	2,862.8	2,578.7	1,930.9	1,960.7	1,968.8	1,862.0	1,772.7	1,854.3
Agr./For./Fishing	921.5	621.0	916.9	764.6	771.3	700.9	704.8	696.0	710.4	714.5	750.7
Total	**4,218.0**	**3,310.9**	**3,865.2**	**4,420.1**	**4,024.4**	**3,219.6**	**3,276.9**	**3,296.6**	**3,205.4**	**3,105.7**	**3,182.4**

Figure 3.2-12: The CO_2-eq emissions from Small Stationary Energy Sources
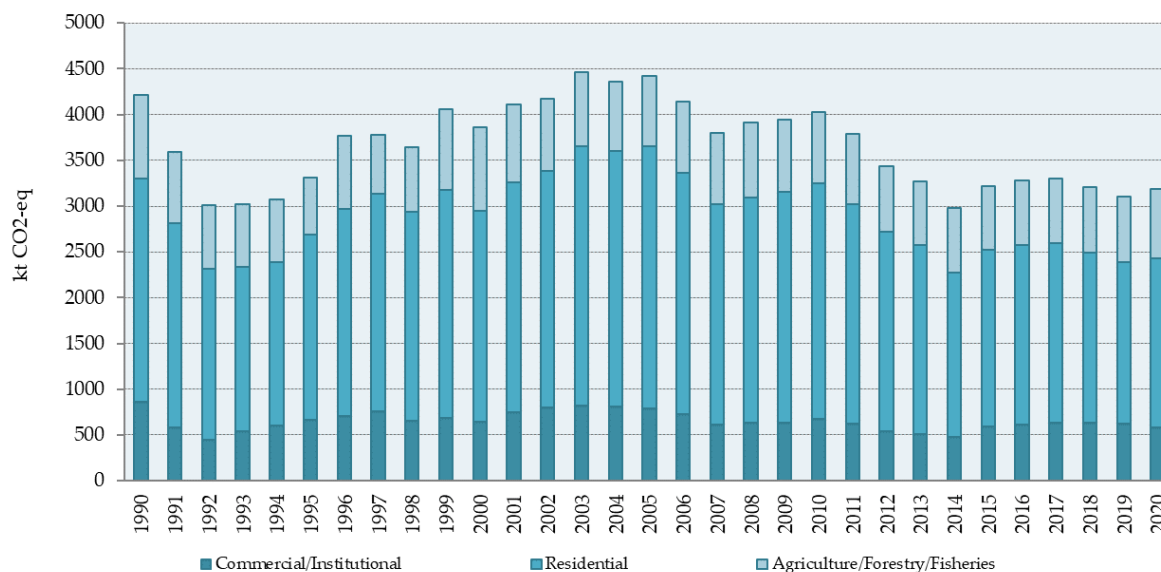
The CO_2-eq emissions from these subsectors were about 16-20 % of the total emissions from the Energy sector. The most of the emission comes from small household furnaces and boiler rooms (54-62 %), then from the service sector (17-22 %), while the combustion of fuel in agriculture, forestry and fishing accounts for 18 to 25 % for the period from 1990 to 2020.

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 2022.

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

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 0.07% (in 2020) to total emissions of Croatia while navigation contributes with 0.20 % (in 2020). 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 1A3b 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
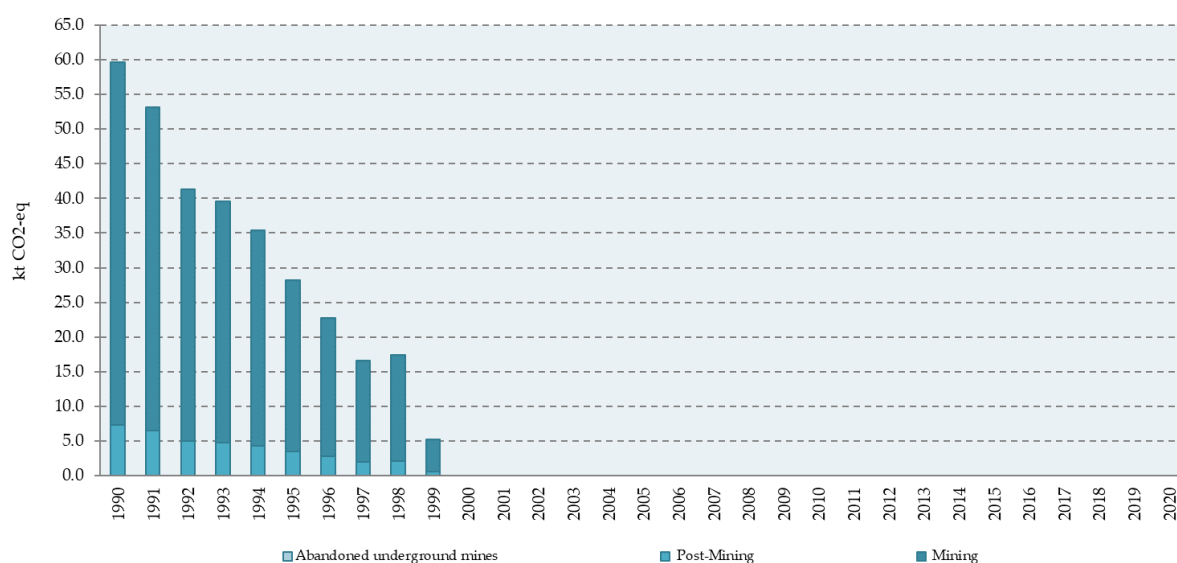
3.3.1.2. Methodological issues

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 2020. 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 1901-2020

Period	Number of abandoned underground mines	Closing technology		CH₄ 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	-	-
2000-2020	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 3.2-8.

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 (CO2 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 800-900ºC 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.

104

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 kt CO_2 from scrubbing process	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 kt CO_2 from scrubbing process	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
Central Gas Station Molve	429.19	409.38	397.08	192.35	157.07	232.16	207.05	157.76	173.72
Ivanić Grad fraction facility	0.00	0.02	1.61	10.05	29.19	29.26	29.26	83.28	73.69
TOTAL kt CO_2 from scrubbing process	429.19	409.40	398.69	202.40	186.26	261.42	236.30	241.04	247.40

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) 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.
	UMS Etan, Ivanić Grad / INA - d.d.
	UMS PS Ferdinandovac / INA - d.d.
	UMS PS Gola / INA - d.d.
	UMS PS Hampovica / INA - d.d.
	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 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 3.3-4 and Figure 3.3-2.

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

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Oil activities	378.3	211.3	171.8	135.0	102.6	95.4	105.0	106.3	104.8	100.1	89.6
Gas activities	563.2	886.0	769.7	870.3	696.0	347.6	326.7	398.7	357.4	353.2	352.1
Venting and Flaring	1.2	0.5	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Total	**942.7**	**1,097.8**	**942.0**	**1,005.8**	**798.9**	**443.3**	**431.9**	**505.3**	**462.4**	**453.5**	**442.0**

Figure 3.3-2: The fugitive emissions from oil and gas activities
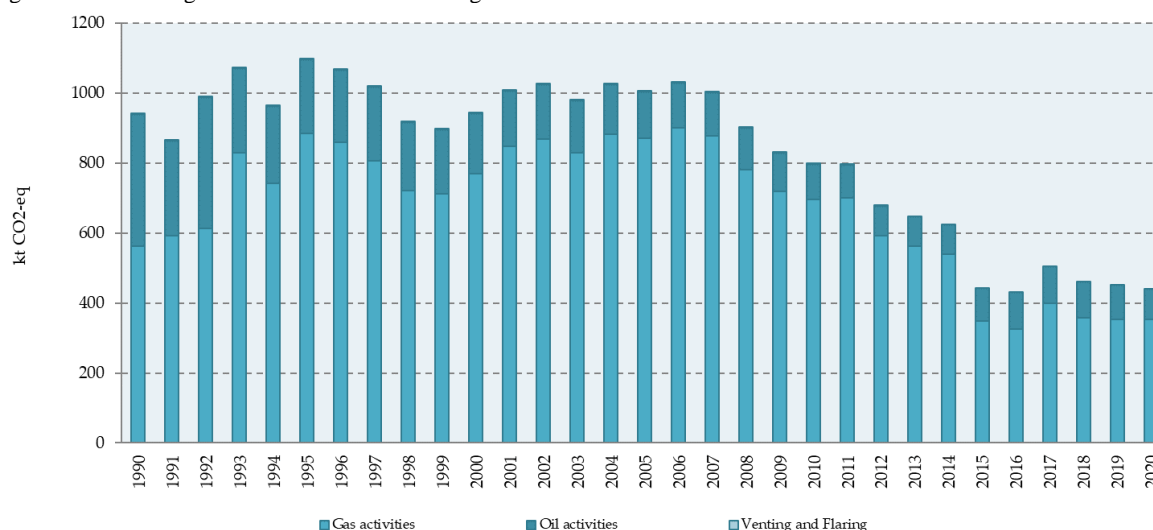
The CO_2-eq emissions from this sub-sector were 2.9 % of the total emissions from Energy sector in 2020. From 2006 oil and gas production is continuously decreasing consequently CO_2-eq emission is

decreasing too. In 1990 39% of total fugitive emission arises from oil activities while in 2020 only 20% 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 (1990-2020) was set up according to the EMEP/CORINAIR methodology. Emissions were obtained from the emission inventory report 'Republic of Croatia Informative Inventory Report for 2020, 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).

A summary of estimated results of the fugitive emissions of CO, NO_X, NMVOC and SO_2 are illustrated in the Table 3.3-5 and Figure 3.3-3.

Table 3.3-6: The fugitive emissions of ozone precursors and SO2 from fugitive emissions sector

Emissions (kt)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
CO emission	50.62	34.76	54.33	54.66	40.26	26.16	26.22	29.22	22.37	15.47	16.47
NO_x emission	0.33	0.23	0.33	0.33	0.24	0.18	0.19	0.18	0.16	0.11	0.11
NMVOC emission	6.44	5.03	5.67	5.41	4.79	3.57	3.60	3.63	3.70	3.03	2.71
SO_2 emission	2.42	1.72	3.57	3.54	2.72	3.66	4.26	4.75	4.39	2.44	1.93

Figure 3.3-3: The fugitive emissions of CO, NOX, NMVOC and SO_2
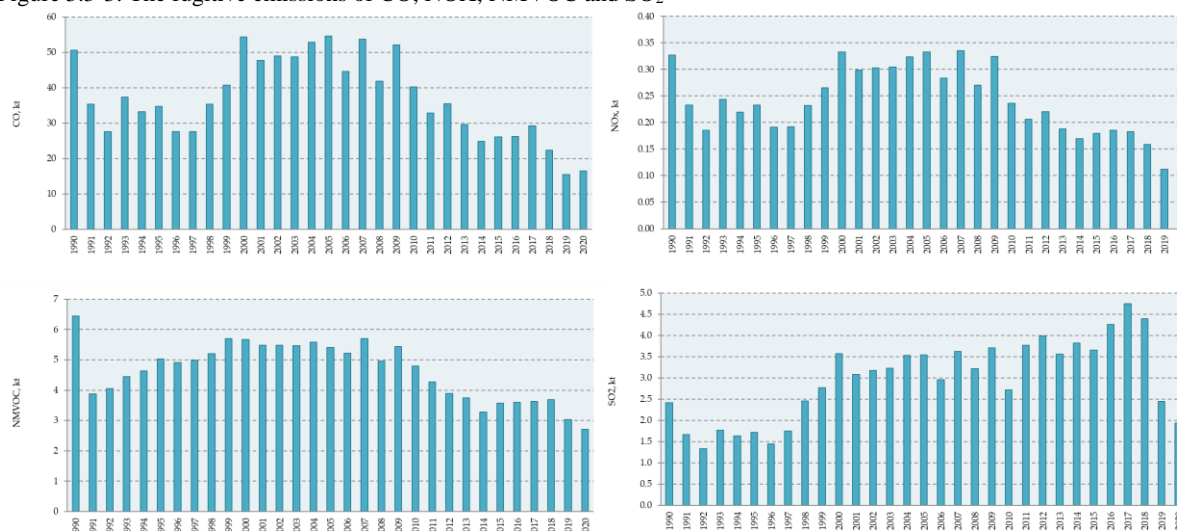
3.3.2.2.   Methodological issues

Fugitive emission of CH$_4$

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 2020.

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 A2-19, 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

For the category 1B2 Fugitive Emissions from Natural Gas CO_2 emission from Ivanić Grad fraction facility has been added. In addition to Molve, gas has been processed since 2013 at the Ivanić Grad faction facility as well. CO_2 emission data were obtained directly from the operator via a questionnaire. Recalculation is performed for the period 2013 -2019.

Table 3.3-7: Differences between NIR 2022 and NIR 2021 for CO2-eq emissions from Fugitive emissions sector for the period 2013-2019

	2013	2014	2015	2016	2017	2018	2019
NIR 2022	648.69	624.08	443.26	431.92	505.25	462.37	453.47
NIR 2021	648.68	622.47	433.20	402.73	476.00	433.11	370.19
Diff, kt	0.02	1.61	10.05	29.19	29.26	29.26	83.28
Diff, %	**0.002**	**0.258**	**2.321**	**7.249**	**6.147**	**6.755**	**22.496**

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, for the period 1990-2020 are shown in Figure 4.1-1.

Figure 4.1-1: Emissions of GHGs from Industrial Processes and Product Use
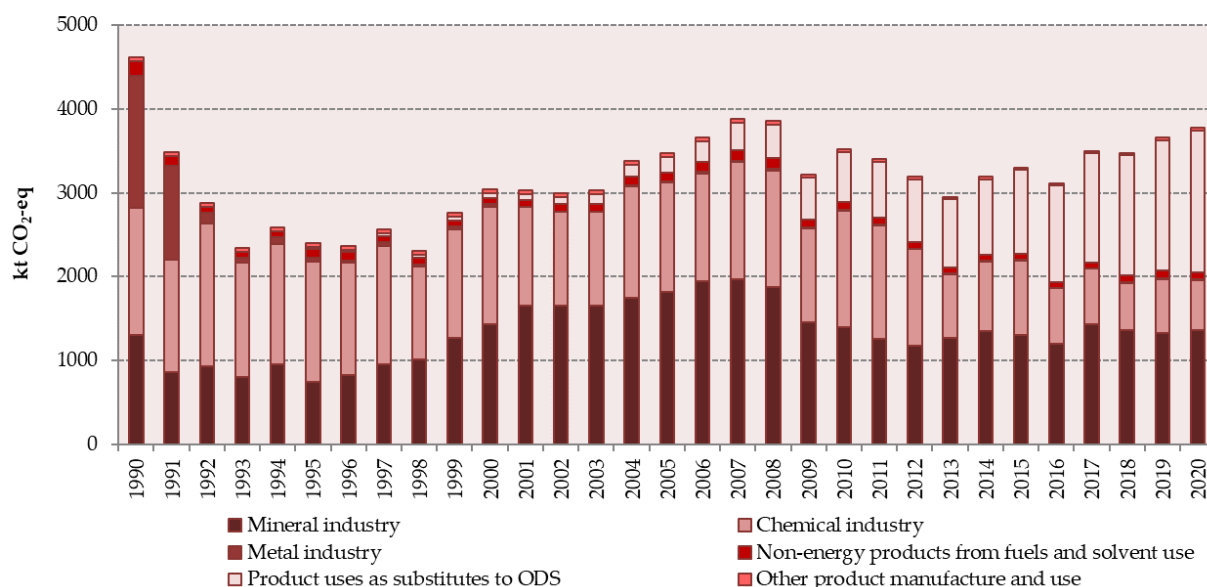
Regarding emissions trends in this sector, it is necessary to point out a few general facts. The Republic of Croatia was the federal unit of SFR Yugoslavia until 1991. After the breakup of Yugoslavia and Croatian independence, the transition from a socialist economy into a system based on private ownership 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 2020[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	L1e	T1e	L1i		
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		T1e		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 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

[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 (1990-2020). 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 1998-2020, 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 2013-2020 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 (2013-2020)

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.

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

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

- PS (1990-2020 – 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.

Non-carbonate sources of CaO and MgO are at this time only partially included in the calculations. Currently, this applies only to one factory and to the period since 2000[4]. For this plant, the rest of the time series, i.e, the CaO and MgO contribution from non-carbonate sources for 1990-2000, was estimated on the basis of the arithmetic mean (average) of the available data for the years after 2000.

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

For the factories and years for which data on non-carbonate sources (dry mass and content of CaO and MgO) are (currently) not included, only the total content of CaO and MgO in clinker is included in the above-given formula. At this time, it is assumed that these factories did not use non-carbonate sources for clinker production in the period 1990-2012.

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.

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

---

[4] The analysis of non-carbonate CaO and MgO content in the raw material is performed by an external accredited laboratory once a year.

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[5].

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[6].

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[7] (includes six factories); and the programme: CO_2 Emission Reduction Programme for Istra cement plant[8] (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.

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.

The most prevalent carbonate raw materials for clinker production in Croatia are limestone, marl and bauxite, while most commonly used non-carbonate CaO and MgO sources are slag, quartz sand, fly ash and certain types of waste (e.g. ceramics, brick and tile waste).

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	1,093.5
1991	1,337.1	708.4
1992	1,566.3	832.0
1993	1,305.1	687.1
1994	1,583.7	840.4
1995	1,197.6	626.8
1996	1,306.3	686.0
1997	1,533.8	805.9
1998	1,649.1	865.6
1999	2,151.0	1,133.9

---

[5] 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.

[6] 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.

[7] The study was made on the initiative of the Croatia Cement g.i.u. association (prepared by EKONERG Ltd.).

[8] Programme was ordered by Istra cement Plc. and prepared by EKONERG Ltd.

Year	Total clinker production (kt)	Total process CO$_2$ emission (kt)
2000	2,382.1	1,262.8
2001	2,739.2	1,449.7
2002	2,698.6	1,429.2
2003	2,692.1	1,432.7
2004	2,852.2	1,516.7
2005	2,926.6	1,549.7
2006	3,104.4	1,642.3
2007	3,160.5	1,668.8
2008	2,995.1	1,572.5
2009	2,439.1	1,250.3
2010	2,320.5	1,212.6
2011	2,071.7	1,085.9
2012	1,996.5	1,040.9
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

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

Recalculations were not performed for this source category.

4.2.1.6. Category-specific planned improvements

A project which will include additional investigation and collection of all available consistent AD regarding non-carbonate sources of CaO and MgO for the whole time series is currently being prepared. All data gaps will be estimated in collaboration with experts from cement industry. The results of this project will include revised emission estimates, which will be presented in future submissions, and all revised information on AD, EFs, methods and assumptions used for estimating emissions will be included in the NIR 2023.

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

Methodology

Lime factories

- T2 (1990-2012)

- T3 (2013-2020)

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[9], 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.

Emission factors

- PS (1990-2020 – 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:

$$EF_{ql} = CaO_{ql} \text{ x } 0.785$$
$$EF_{dl} = CaO*MgO_{dl} \text{ x } 0.913$$

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

---

[9] 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

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.

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[10] (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

[10] 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)
1997	100.9	55.2	NO	156.0
1998	105.3	53.4	NO	158.6
1999	90.8	52.7	NO	143.5
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

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

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)
2008	0.75	0.90	*	0.79	232.6
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

* There was no production in the given year

Average annual EFs for lime produced in lime factories (both quicklime and dolomitic lime) generally declined since 2013 due to the application of higher tier after inclusion into EU ETS. In 2011 and 2012, average EF for quicklime was also somewhat low because only two factories were in operation in 2011 and only one in 2012, and that factory generally has very low CaO content of lime (on average about 88%).

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[11].

4.2.3.2. Methodological issues

Methodology

- T3 (1990-2020)

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.

Emission factors

- PS (1990-2020)

---

[11] 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.

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. 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

Year	Total carbonates consumption (kt)	Total emissions from glass production (kt)
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
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

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, which were in operation since 2008 and 2012, respectively.

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 (1990-2020)

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 (2000-2020)

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 (1990-2020)

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[12].

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 (2000-2020)

Thermal power plant used limestone since 2000. One rock wool factory used dolomite since 2008 and the second factory since 2012.

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.

Activity data

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

---

[12] 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.

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.

Other (2.A.4.d)

Data on carbonates consumed in the period 2000-2012 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.

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

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

Year	Total carbonates consumption (kt)	Total emissions from ceramics production (kt)
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
2017	17.9	8.0
2018	25.9	11.5
2019	9.6	4.2
2020	10.5	4.6

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)
2000	*	2.7
2001	*	3.6
2002	*	5.1
2003	*	6.1
2004	*	5.6
2005	*	5.0
2006	*	5.1
2007	*	4.7
2008	18.2	8.1
2009	13.4	6.1
2010	18.9	8.7
2011	30.4	13.8
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

*Confidential data

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 are no category-specific recalculations in this category.

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

Methodology

- T3 (1990-2020)

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:

$$E_{CO2} = (TFR_{NG} \times CCF_{NG} \times COF_{NG} \times 44/12) - R_{CO2}$$

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]

Emission factors and activity data

-   PS (1990-2020)

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[13].

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[14]. Data are collected in the DCS during the 24-hour work regime and stored on an annual basis.

Total annual consumption and average annual composition of natural gas and emissions from Ammonia Production are shown in Table 4.3-1.

---

[13] 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.

[14] Dall tube, the accuracy of the measurement: ± 3%

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

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 IPCC 2006 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.[15]

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 have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020; 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, 2019). 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.

---

[15] 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 (1990-2020)

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.

Emission factors

- PS (1990-2020)

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[16]. 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
2004	287.6	2.2
2005	280.7	2.1
2006	277.6	2.1

---

[16] 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$_2$O emission - TOTAL (kt)
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

In addition, emissions of NO$_x$ have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020; Submission to the Convention on Long-range Transboundary Air Pollution'. Emissions were calculated using Tier 2 EMEP/EEA methodology.

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 2019, 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.

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)

139

- 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
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

Year	Carbon black (kt)	Ethylene (kt)	Ethylene dichloride (kt)	Methanol (kt)
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

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
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

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)
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

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 2020; 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 are/were possibly more iron foundries not covered by the EU ETS, which is currently being investigated.

4.4.1.2. Methodological issues

Methodology

Steel (2.C.1.a)

- T2 (1990-2012)

- T3 (2013-2020)

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:

$$E_{CO2} = \left[\sum_a (MI_a \times C_a) - \sum_b (MO_b \times C_b) \right] \times 44/12$$

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 (1997-2020)

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 (2013-2020)

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 (1997-2020)

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
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

Emissions of NO_x, CO, NMVOC and SO_2 have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020; 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 2020. Uncertainty estimate associated with emission factors amounts to 10 % for 1990 and 5 % for 2020, according to values from the 2006 IPCC Guidelines.

For pig iron, uncertainty for activity data amounts to 2 % and 5 % for EF (1990). For cast iron, uncertainty for activity data and EF amounts to 5 (2020).

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 2019; 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 (1990-2020)

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 (1990-2020)

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[17], 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
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

---

[17]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.

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 (1990-2020)

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 (1990-2020)

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
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

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 (1990-2020)

Emissions of NMVOC have been taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020; 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)[18]

- Coating applications (NFR 2.D.3.d)[19]

- Degreasing (NFR 2.D.3.e)[20]

- Dry cleaning (NFR 2.D.3.f)

- Chemical products (NFR 2.D.3.g)[21]

- Printing (NFR 2.D.3.h)

---

[18] 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.

[19] Refers to paints used within the industrial and domestic sectors.

[20] 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.

[21] 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.

- Other solvent use (NFR 2.D.3.i)[22]

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, 2019).

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 (1990-2020)

Emissions of NMVOC are taken from the emission inventory report 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020; 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 2019 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 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 2020; Submission to the Convention on Long-range Transboundary Air Pollution'.

Urea based catalytic converters

- T1 (2000-2020)

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.

---

[22] 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.

Emission factors

Solvent use

-   D (1990-2020)

Default emission factors (EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2019), taking into account the implementation of abatement technology where applicable, were applied for the 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 (1990-2020)

The recommended Tier 1/Tier 2 emission factors from the EMEP/EEA 2019 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 (2000-2020)

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	134.6	0.015	0.009	NO
1991	85.1	0.011	0.006	NO
1992	51.7	0.003	0.005	NO
1993	48.8	0.002	0.005	NO
1994	51.1	0.019	0.005	NO
1995	90.7	0.020	0.006	NO
1996	82.1	0.025	0.007	NO

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)
1997	57.9	0.038	0.002	NO
1998	56.5	0.037	0.004	NO
1999	51.2	0.040	0.005	NO
2000	52.2	0.036	0.009	2.7
2001	53.2	0.028	0.004	2.9
2002	64.8	0.054	0.004	3.3
2003	66.4	0.084	0.009	3.9
2004	79.0	0.099	0.009	4.2
2005	83.1	0.089	0.017	4.6
2006	93.0	0.082	0.028	5.0
2007	93.7	0.081	0.018	5.5
2008	96.6	0.106	0.010	5.3
2009	67.6	0.080	0.009	5.3
2010	63.5	0.054	0.007	5.2
2011	58.4	0.063	0.006	5.2
2012	55.7	0.062	0.004	5.1
2013	48.4	0.068	0.006	5.3
2014	43.3	0.057	0.005	5.3
2015	42.7	0.053	0.015	5.8
2016	46.3	0.054	0.007	6.1
2017	42.9	0.053	0.011	6.9
2018	53.0	0.063	0.006	6.6
2019	65.2	0.065	0.007	7.0
2020	61.1	0.058	0.007	6.3

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.

Since NMVOC emissions data for this inventory are taken from the IIR, and CO_2 emissions from this source category are calculated based on NMVOC emissions, changes in IIR result in recalculations of CO_2 emissions within GHG inventory.

In the IIR 2022, for Chemical products sub-category, revised emissions are included for the entire reporting period. Therefore, within the category 2.D.3 recalculations of CO_2 emissions were performed for the period 1990-2019. Emissions from other sub-categories were not recalculated.

4.5.3.6.   Category-specific planned improvements

There are no planned category-specific improvements.

4.6. Electronics industry (CRF 2.E)

This category does not exist in Croatia.

4.7. Product uses as substitutes for ODS (2.F)

For source category 2.F, an improvement project was carried out, which included extensive research and collection of revised activity data. The results of this project include revised emissions estimates for the whole time series.

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.

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

Methodology

Commercial refrigeration (2.F.1.a)

- T2a (1995-2020)

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 (1995-2020)

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 (1995-2020)

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 (1995-2020)

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 (1995-2020)

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 (1995-2020)

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). Only after the adoption of the European Regulation 517/2014 on Fluorinated Greenhouse Gases and the shortage and increase in the price of HFCs did the situation improve. 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. Until 2005, it can be assumed that there was no collection of HFCs at disposal. Only after the adoption of the Regulation on ODS and Fluorinated Greenhouse Gases (OG 120/2005), collection of fluorinated greenhouse gases during the final decommissioning is prescribed. 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 10% 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 2011-2020 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.

Activity data

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.

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. 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.

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 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. 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, but they are exclusively 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. 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.

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	1789.4	284.3	290.0	18693.2	NO	599.7
1996	3852.8	568.0	487.2	18490.9	501.1	1156.7
1997	6417.3	851.2	626.4	18288.5	1598.7	1785.6
1998	9678.3	1133.8	993.8	18086.2	3388.2	2499.8
1999	13659.8	1415.9	1302.2	17883.9	5932.1	3312.6
2000	18408.5	1661.4	1665.6	17681.5	9141.0	4225.6
2001	24374.3	1901.5	2192.0	17479.2	13237.5	5414.6
2002	35957.3	2135.9	4884.2	17778.3	18951.2	6293.0
2003	45062.8	2478.7	6343.0	18935.2	26401.8	7591.1
2004	52453.0	2803.1	6887.1	20092.1	35668.5	9341.6
2005	62237.9	3142.9	7930.7	21677.9	46855.2	33283.6
2006	72545.5	3504.1	8995.1	22834.8	60103.0	64111.5
2007	87527.6	3808.5	12365.3	23422.4	76160.2	107157.6
2008	99495.4	4029.8	13760.5	25433.2	93709.0	148597.9
2009	118414.8	4282.8	15023.8	25650.5	110193.7	194156.2
2010	138723.7	18301.9	16492.8	28766.7	125321.8	233091.5
2011	152362.5	18242.2	18712.6	29253.9	140375.9	271789.2
2012	174984.1	11279.3	25261.3	29633.1	152472.0	311312.0
2013	185139.2	11229.3	26459.5	30763.5	166665.2	351040.5
2014	203558.9	11192.8	32990.5	31383.6	185971.9	394582.3
2015	215687.8	10037.9	43893.4	32898.7	205920.8	446269.1
2016	262499.3	9666.0	54397.4	34497.5	232293.5	505190.5
2017	293804.6	9299.5	66878.2	35376.9	256732.5	591659.3
2018	297799.8	11698.9	70402.9	37173.6	294242.0	678660.9
2019	303525.6	10926.4	73865.4	37975.7	333253.6	753642.1
2020	309229.0	10991.8	74503.7	58176.9	368953.5	822157.2

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

For source category 2.F, an improvement project led by the Ministry of Economy and Sustainable Development was carried out. The project included extensive research and collection of revised activity data as well as revision of the methodology and emission factors used in previous submissions, in line with national conditions and the availability of activity data. The results of this project include revised emission estimates of all subcategories within 2.F source category, for the whole time series.

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 (2003-2020 – 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 (1995-2020 – fixed systems)

- T2 (2003-2020 – 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 (2003-2020)

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 on imports, exports and production are included for the years from 2003 to 2020 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

Data	XPS	PUR	Reference
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.

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.

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	NO	193.2	NO
1996	NO	123.6	NO
1997	NO	118.7	NO
1998	NO	114.0	NO
1999	NO	109.4	NO
2000	NO	105.0	NO
2001	NO	197.4	NO
2002	NO	158.6	NO
2003	1616.8	471.8	5214.3
2004	3407.7	622.9	5627.0
2005	4660.7	869.8	6053.1
2006	6636.1	1383.1	6600.3
2007	9054.6	2249.1	7226.0
2008	11927.8	2415.9	5868.5
2009	14009.0	2894.3	8371.9
2010	19628.0	3311.5	9658.7
2011	16807.1	3988.6	9266.7
2012	18712.2	4966.1	9260.5
2013	20548.0	5983.2	9931.2
2014	22150.6	5937.7	10284.3
2015	24460.7	6570.5	10886.8
2016	23398.5	6426.2	10892.6
2017	22383.0	6416.8	10761.6
2018	21412.2	6281.0	10827.4
2019	20483.8	6307.9	11049.4
2020	19596.3	6199.9	10376.3

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

For source category 2.F, an improvement project led by the Ministry of Economy and Sustainable Development was carried out. The project included extensive research and collection of revised activity data as well as revision of the methodology and emission factors used in previous submissions, in line with national conditions and the availability of activity data. The results of this project include revised emission estimates of all subcategories within 2.F source category, for the whole time series.

4.7.2.6. Category-specific planned improvements

Category-specific improvements are not planned.

4.8. Other product manufacture and use (CRF 2.G)

For source category 2.G, an improvement project was carried out, which included extensive research and collection of revised activity data. The results of this project include revised emission estimates for the whole time series.

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

Methodology

- T2 (1990-2020)

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 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	10725.9
1991	10608.5
1992	10692.9
1993	10806.6
1994	11599.2
1995	12076.0
1996	12511.2
1997	12150.0
1998	13003.8
1999	12950.2
2000	12337.7
2001	12424.7

Year	SF$_6$ (kt CO$_2$-eq)
2002	12755.0
2003	13093.9
2004	13538.2
2005	14262.6
2006	14134.6
2007	14152.8
2008	12990.7
2009	9341.3
2010	9830.8
2011	10259.2
2012	10962.1
2013	7178.3
2014	7674.8
2015	5576.1
2016	6598.6
2017	7017.3
2018	6270.6
2019	7852.2
2020	8763.4

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

For source category 2.G, an improvement project led by the Ministry of Economy and Sustainable Development was carried out. The project included extensive research and collection of revised activity data as well as revision of the methodology and emission factors used in previous submissions, in line with national conditions and the availability of activity data. The results of this project include revised emission estimates of all subcategories within 2.G source category, for the whole time series.

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$_2$O 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 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 2018, 2019 and 2020 is estimated by linear extrapolation.

Total N$_2$O emissions from product uses are shown in Table 4.8-2.

Table 4.8-2: N$_2$O emission from product uses

Year	N$_2$O (kt)
1990	0.123
1991	0.123
1992	0.123
1993	0.123

Year	N$_2$O (kt)
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
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

4.8.3.3.   Uncertainties and time-series consistency

For estimation of N$_2$O 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

For source category 2.G, an improvement project led by the Ministry of Economy and Sustainable Development was carried out. The project included extensive research and collection of revised activity data as well as revision of the methodology and emission factors used in previous submissions, in line with national conditions and the availability of activity data. The results of this project include revised emission estimates of all subcategories within 2.G source category, for the whole time series.

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 2020; Submission to the Convention on Long-range Transboundary Air Pollution.

Emissions estimate is based on the Tier 2 of EMEP/EEA 2019 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 2019 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 2020; Submission to the Convention on Long-range Transboundary Air Pollution'.

Emissions estimate is based on the Tier 2 of EMEP/EEA 2019 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 2019 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 2020 caused by agricultural activities was 2,692.3kt CO_2-eq, which represents 11,3 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
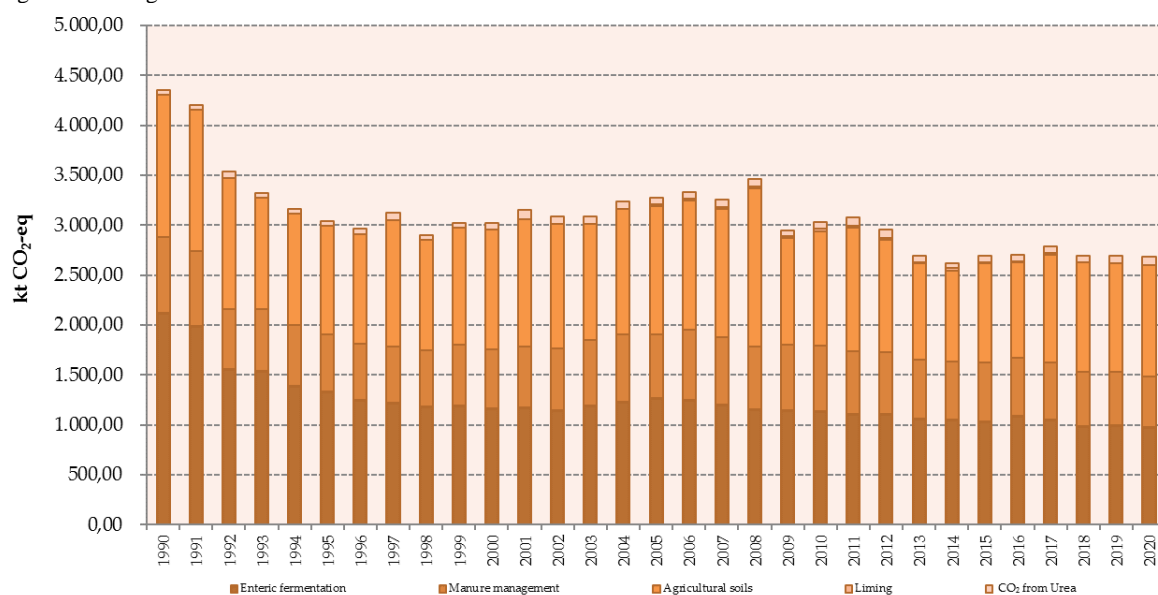
Greenhouse gas emission decreased from 1990-1996 due to the war which highly influenced the animal population, crop production, consumption of mineral fertilizers and the overall agricultural practice in Croatia. In the post-war period, the sector began to revitalize and emission trend stabilized due 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 1990-2020.

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	84.85	17.08	101.93	1.104	4.78	5.89	0.00	50.02	50.02
1991	79.69	17.43	97.12	1.05	4.74	5.80	0.00	50.95	50.95
1992	62.52	14.02	76.53	0.82	4.40	5.22	0.00	65.51	65.51
1993	61.62	14.84	76.46	0.82	3.76	4.57	0.00	52.14	52.14
1994	55.71	15.04	70.75	0.77	3.76	4.53	0.00	47.57	47.57
1995	53.20	14.46	67.66	0.72	3.65	4.38	0.00	46.29	46.29
1996	49.83	14.50	64.33	0.68	3.69	4.37	0.00	52.44	52.44
1997	48.79	14.71	63.50	0.67	4.25	4.92	0.00	68.39	68.39
1998	47.42	14.89	62.31	0.65	3.70	4.35	0.00	44.25	44.25
1999	47.63	16.39	64.02	0.67	3.94	4.62	0.00	50.49	50.49
2000	46.76	16.02	62.77	0.64	4.01	4.66	0.00	60.87	60.87
2001	47.13	16.53	63.66	0.65	4.29	4.94	0.00	92.09	92.09
2002	45.96	16.96	62.92	0.64	4.19	4.83	0.00	80.76	80.76
2003	47.94	18.18	66.12	0.65	3.93	4.58	0.00	71.79	71.79
2004	49.14	19.26	68.40	0.67	4.21	4.88	0.00	75.94	75.94
2005	50.84	17.98	68.83	0.63	4.30	4.94	14.49	70.97	85.46
2006	50.08	20.45	70.53	0.65	4.33	4.99	17.48	63.19	80.67
2007	48.17	19.72	67.90	0.62	4.30	4.92	16.60	72.72	89.32
2008	46.24	18.19	64.43	0.58	5.32	5.90	20.78	75.83	96.60
2009	45.84	19.49	65.33	0.59	3.58	4.17	11.92	65.04	76.96
2010	45.40	19.50	64.90	0.57	3.86	4.43	21.46	66.58	88.04
2011	44.29	18.75	63.04	0.54	4.17	4.71	21.32	83.86	105.18
2012	44.59	18.34	62.92	0.53	3.79	4.32	14.38	86.85	101.23
2013	42.69	17.36	60.06	0.50	3.25	3.75	14.23	60.39	74.61
2014	41.97	17.34	59.31	0.51	3.07	3.58	19.99	49.47	69.47
2015	41.57	17.39	58.95	0.50	3.35	3.85	12.09	57.25	69.34
2016	43.64	17.03	60.67	0.53	3.20	3.72	11.20	64.96	76.17
2017	42.09	16.70	58.79	0.52	3.63	4.16	10.92	70.21	81.13
2018	39.55	15.70	55.25	0.49	3.68	4.17	4.62	67.62	72.24
2019	39.79	15.45	55.24	0.49	3.67	4.16	2.07	73.59	75.66
2020	39.02	14.64	53.66	0.48	3.74	4.21	6.89	88.29	95.18

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	2121.15	427.11	2548.26	329.05	1425.69	1754.74	0.00	50.02	50.02	4353.02
1991	1992.20	435.87	2428.07	313.75	1413.42	1727.18	0.00	50.95	50.95	4206.20
1992	1562.96	350.38	1913.34	245.46	1311.32	1556.78	0.00	65.51	65.51	3535.63
1993	1540.48	371.10	1911.58	243.74	1119.17	1362.90	0.00	52.14	52.14	3326.63
1994	1392.68	376.03	1768.71	230.65	1119.68	1350.33	0.00	47.57	47.57	3166.61
1995	1330.03	361.43	1691.46	215.90	1088.70	1304.60	0.00	46.29	46.29	3042.35
1996	1245.87	362.44	1608.30	203.95	1098.65	1302.60	0.00	52.44	52.44	2963.35
1997	1219.73	367.74	1587.46	199.91	1265.55	1465.46	0.00	68.39	68.39	3121.31
1998	1185.49	372.27	1557.76	193.35	1103.51	1296.86	0.00	44.25	44.25	2898.87
1999	1190.78	409.81	1600.60	200.90	1174.40	1375.30	0.00	50.49	50.49	3026.38
2000	1168.97	400.39	1569.36	191.86	1196.21	1388.07	0.00	60.87	60.87	3018.30
2001	1178.20	413.21	1591.40	192.76	1278.21	1470.97	0.00	92.09	92.09	3154.46
2002	1149.05	423.98	1573.02	189.46	1248.86	1438.32	0.00	80.76	80.76	3092.10
2003	1198.59	454.38	1652.98	194.58	1170.10	1364.68	0.00	71.79	71.79	3089.45
2004	1228.58	481.52	1710.09	200.29	1255.18	1455.47	0.00	75.94	75.94	3241.50
2005	1271.09	449.61	1720.70	189.20	1281.68	1470.88	14.49	70.97	85.46	3277.04
2006	1252.01	511.13	1763.13	194.90	1290.82	1485.72	17.48	63.19	80.67	3329.52
2007	1204.31	493.11	1697.42	185.29	1280.31	1465.60	16.60	72.72	89.32	3252.34
2008	1155.97	454.83	1610.80	172.82	1584.44	1757.26	20.78	75.83	96.60	3464.66
2009	1146.02	487.16	1633.18	174.81	1067.06	1241.86	11.92	65.04	76.96	2952.00
2010	1135.00	487.42	1622.43	168.52	1151.14	1319.66	21.46	66.58	88.04	3030.12
2011	1107.21	468.80	1576.01	160.01	1242.55	1402.56	21.32	83.86	105.18	3083.75
2012	1114.64	458.43	1573.07	157.90	1128.58	1286.47	14.38	86.85	101.23	2960.78
2013	1067.33	434.08	1501.41	149.82	967.52	1117.35	14.23	60.39	74.61	2693.37
2014	1049.14	433.49	1482.63	150.70	915.11	1065.81	19.99	49.47	69.47	2617.91
2015	1039.13	434.65	1473.78	149.66	997.08	1146.73	12.09	57.25	69.34	2689.85
2016	1091.03	425.72	1516.75	156.72	952.80	1109.52	11.20	64.96	76.17	2702.43
2017	1052.18	417.53	1469.71	155.36	1083.02	1238.38	10.92	70.21	81.13	2789.22
2018	988.79	392.53	1381.32	146.12	1096.94	1243.06	4.62	67.62	72.24	2696.62
2019	994.72	386.20	1380.92	147.16	1093.09	1240.25	2.07	73.59	75.66	2696.83
2020	975.46	366.08	1341.54	142.00	1113.59	1255.60	6.89	88.29	95.18	2692.31

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 2020[23]

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	CH₄	Yes	L1e, L2e	T1e, T2e	L1i
3.B Manure Management	CH₄	Yes	L1e		L1i
3.B Manure Management	N₂O	Yes	L1e	T1e, T2e	
3.D.1 Direct N2O Emissions From Managed Soils	N₂O	Yes	L1e, L2e	T2e	L1i, L2i
3.D.2 Indirect N2O Emissions From Managed Soils	N₂O	Yes	L1e, L2e		L1i, L2i

L1e - Level excluding LULUCF Tier1   L2e - Level excluding LULUCF Tier 2
L1i - Level including LULUCF Tier1   L2i - Level including LULUCF Tier 2
T1e - Trend excluding LULUCF Tier1   T2e - Trend excluding LULUCF Tier2
T1i - Trend including LULUCF Tier1   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 39% of total CH_4 emission from Enteric fermentation in 2020, followed by dairy cattle with 36%. Cattle livestock in total is responsible for 81% of total CH_4 emission from Enteric fermentation.

Figure 5.2-1 shows the emission of methane from Enteric fermentation for the period from 1990-2020. The emission trend follows the trend of animal population which significantly decreased during the war period in the early 1990s (up to 1996). The decrease is recorded for each animal category (see Table 5.2-2).

---

[23] Data on key categories are taken from Annex 1 Key Categories.

Figure 5.2-1: CH$_4$ emission from Enteric fermentation
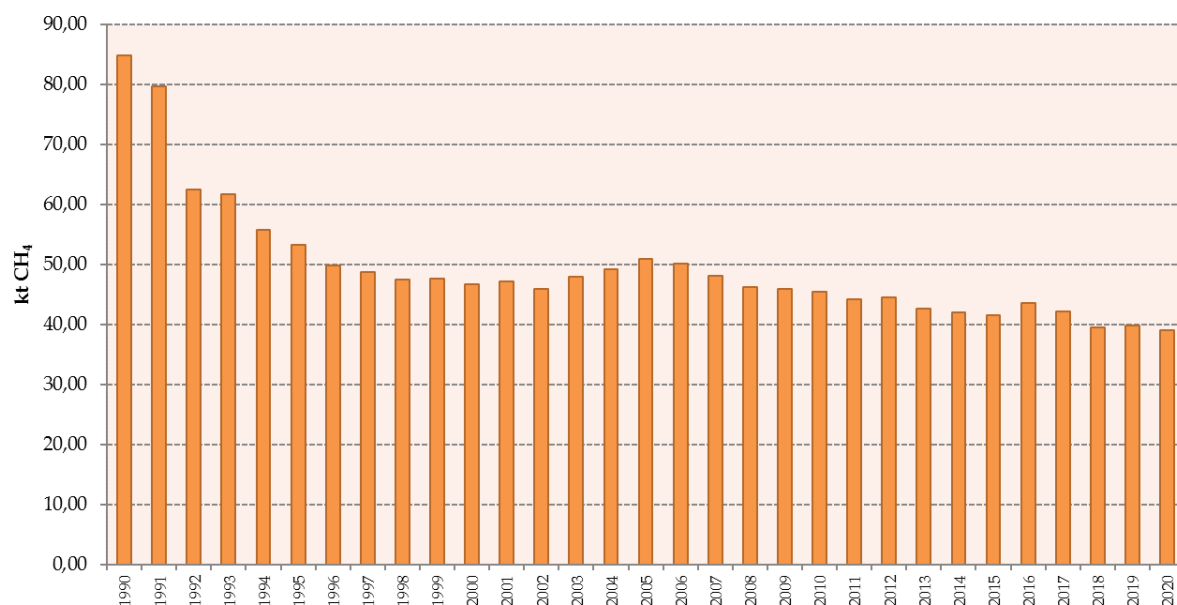
5.2.2. Methodological issues

The IPCC Tier 1 methodology has been used to calculate methane emission from enteric fermentation for all livestock categories except for poultry. Default emission factors for developed countries were used for the entire data series (Table 10.10 and 10.11, IPCC 2006 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.

IPCC Tier 2 methodology has been used to calculate emission estimates for cattle categories for the year 2005, 2016-2020 due to applied technical correction from the ESD comprehensive review 2020 (see chapter 5.2.5 for further explanation).

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 (Zaninović, M. et al).

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 5.2-1 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 2010-2020 was updated with 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 and 2016. 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 and for 2017-2020 available 2016 AD was used. Note that the time period 2017-2020 is a probable minor overestimate of the population, since the overall trend indicates a decrease of the animal numbers. However the trend was not extrapolated due to high variation of AD for known years, which could also lead to a possible underestimate. Decision was thus made to go with the conservative approach of using the "last good number" and revisit the AD extrapolation as more known datapoints become available. Further

investigation into the availability and accuracy of source data for some of the key historical years - in particular the 1990-1995 period - is required as well.

Activity data source for horses and mules and asses for the time period 2010-2020 was updated with values from the Ministry of Agriculture (MA) for increased accuracy of data.

Cattle, swine and poultry subcategorization into distinct cattle subcategories was provided by CBS.

Table 5.2-1: Sources of activity data regarding animal population

Animal category	CBS	FAO	Croatian Agricultural Agency	Ministry of Agriculture	Extrapolation / interpolation
Cattle	2008-2020				
Sheep	1990-2020				
Goats	1990-1991; 1999-2020	1992-1998			
Horses	1990-1994		1995-1999	2010-2020	
Mules/assess	1990-1991	1992-1994	1995-1999	2010-2020	
Swine	1990-2020				
Poultry	1990-2020				
Rabbits	2003, 2007, 2010, 2013, 2016				1990-2002*, 2004-2006, 2008-2009, 2014-2015, 2017-2020**

used AD from year 2003

**used AD fom year 2016*

Table 5.2-2: Number of animals produced annually in the period from 1990 – 2020

Year	Animal number / 1000 heads							
	Dairy cattle	Non-dairy	Sheep	Goats	Horses	Mules/asses	Swine	Total Poultry
1990	463	361	751	172	39	17	1573	17102
1991	444	313	753	133	36	13	1621	16512
1992	360	230	539	114	26	13	1182	13142
1993	347	242	525	105	22	12	1262	12697
1994	326	193	444	108	21	7	1347	12503
1995	317	176	453	107	5	2	1175	12024
1996	294	168	427	105	5	2	1197	10993
1997	284	168	453	100	6	2	1176	10945
1998	274	169	427	84	7	2	1166	9959
1999	268	170	488	78	7	2	1362	10871
2000	262	164	529	79	10	3	1234	11256
2001	254	184	539	93	11	3	1234	11747
2002	247	170	580	97	14	3	1286	11665
2003	252	192	587	86	15	3	1347	11778

Year	Animal number / 1000 heads							
	Dairy cattle	Non-dairy	Sheep	Goats	Horses	Mules/asses	Swine	Total Poultry
2004	226	240	722	126	17	3	1489	11185
2005	235	236	796	134	18	3	1205	10641
2006	233	250	680	103	19	3	1488	10088
2007	225	242	646	92	18	3	1348	10053
2008	213	241	643	84	20	4	1104	10015
2009	212	235	619	76	20	4	1250	10787
2010	207	238	629	75	21	4	1231	9469
2011	185	262	639	70	22	3	1233	9523
2012	181	271	679	72	22	3	1182	10160
2013	168	274	620	69	21	3	1111	9280
2014	159	281	605	61	21	2	1156	10268
2015	152	289	608	62	22	2	1167	10168
2016	147	298	619	76	23	3	1163	9835
2017	139	311	637	77	23	3	1121	10399
2018	136	278	636	80	24	4	1049	11413
2019	130	290	657	82	25	4	1022	12747
2020	110	313	662	86	26	5	1033	13057

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 1990-2020.

Cattle categorization

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 2000-2020. 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 2000-2020 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 2000-2020. This improved segregation and classification of cattle is part of the planned upgrade to new national Tier 2/3 calculation for CH4 emission from cattle (see planned improvements chapter, 5.2.6).

Table 5.2-3: Cattle classification into main IPPC subcategories

IPPC categories	CBS categories	
	1990-1999	2000-2019
Dairy cows	▪ Cows*	▪ Dairy cows
Mature non-dairy cattle	▪ Bovine over 2 years ▪ Heifers in calf	▪ Cattle of 2 years and over, heifers ▪ Cattle of 2 years and over, heifers for slaughter ▪ 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 ▪ Bovine from 3 months to 1 year	▪ Young cattle under 1-year-old, for slaughter ▪ Young cattle under 1-year-old, female ▪ Young cattle under 1-year-old, male
	▪ Bovine from 1 year to 2 years	▪ Cattle between 1 and 2 years old, heifers ▪ Cattle between 1 and 2 years old, heifers for slaughter ▪ 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 2000-2018 category AD trend.

5.2.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to minimal ±10% and maximum of ±30%, based on expert judgements. The expert judgement used for the uncertainty of the AD is based on the authority of the AD source (10% for high authority CBS source, 30% for FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty estimate associated with emission factors amounts to 20%.

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 (especially 1990-2020). 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 2010-2019 time period due to new AD for horses and mules/asses. Impact of recalculations on the total 3.A source emissions compared to the last submission is negligible (> ±0.1) and is presented in Table 5.2-4.

Table 5.2-4: Emission difference of CRF 3.A. source due to the recalculations

(CRF 3.A)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt CO$_2$ eq.	-0.862	-0.941	-1.007	0.018	0.001	0.001	0.005	0.001	0.001	0.027
%	-0.08	-0.09	-0.09	0.0017	0.0001	0.0001	0.0004	0.0001	0.0002	0.0028

5.2.6. Category-specific planned improvement

Planned improvements assumed to be short-term goals (under 1 year) are:

- Improvements and verifications of activity data parameters for historical years and development of Tier 2 / Tier 3 methodology for relevant animal categories (emphasized on cattle). Ministry of Economy and Sustainable Development had secured funds required for the launch of this project.

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Implementation of the developed national and introduction of Tier 2 / Tier 3 methodology for cattle in the inventory emission estimate, for all years.

- 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$_2$O) 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$_2$O 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$_2$O 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$_2$O 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 2020 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
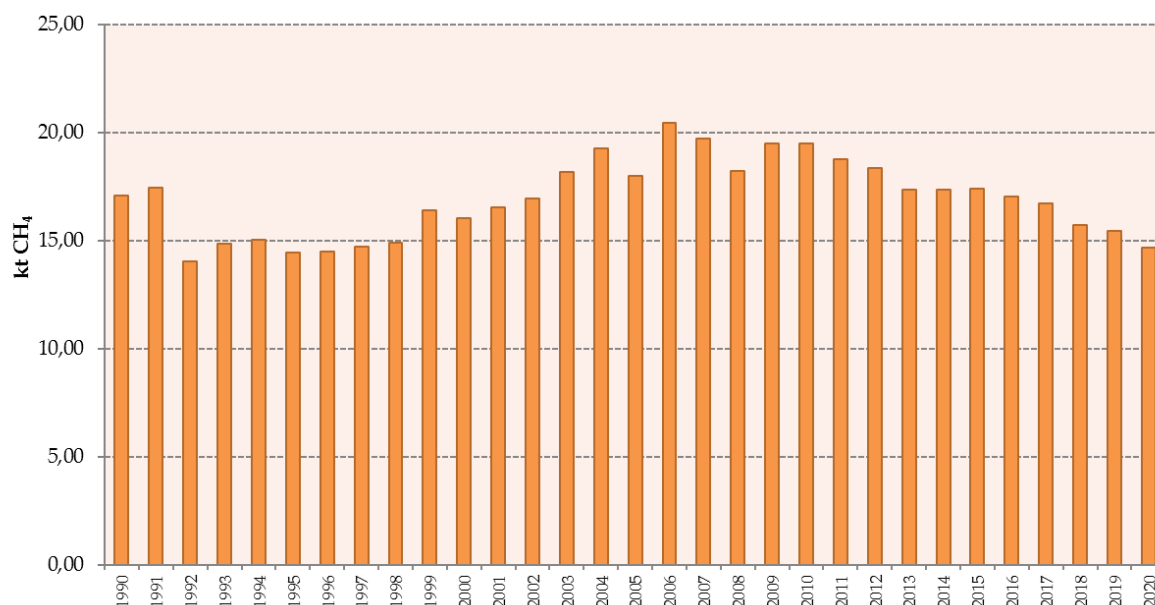
5.3.1.2. Methodological issues

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 typical animal mass (TAM) for cattle categories and default TAM from the 2006 IPCC Guidelinesfor 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 2020

	Typical Animal Mass (TAM), kg	VS	B0	CH4 emission, per head (FE)		MMS Distribution						
						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	550.00 (CS)	5.1	0.24	37.69		5.0%	49.9%	0.0%	33.1%	2.0%	9.0%	0.0%
Other mature cattle	529.06 (CS)	2.6	0.18	10.33		1.6%	36.5%	0.0%	46.9%	5.0%	9.0%	0.0%
Growing cattle	301.60 (CS)	2.7	0.18	10.33		1.6%	36.5%	0.0%	46.9%	5.0%	9.0%	0.0%
Sheep	48.50	0.4	0.19	0.22		0.0%	0.0%	0.0%	18.0%	82.0%	0.0%	0.0%
Market swine	38.50	0.3	0.45	6.16		2.0%	81.3%	0.0%	7.7%	0.0%	9.0%	0.0%
Breeding swine	377.00	0.46	0.45	8.48		2.0%	71.8%	0.0%	16.2%	1.0%	9.0%	0.0%
Goats	130.00	0.30	0.18	0.14		0.0%	0.0%	0.0%	5.0%	95.0%	0.0%	0.0%
Horses	50.00	2.13	0.3	2.03		0.0%	0.0%	0.0%	30.0%	70.0%	0.0%	0.0%
Mules and Asses	198.00	2.13	0.3	0.83		0.0%	0.0%	0.0%	10.0%	90.0%	0.0%	0.0%
Layers	1.80	0.02	0.39	0.07		0.0%	8.4%	0.0%	90.6%	1.0%	0.0%	0.0%
Broilers	1.80	0.01	0.36	0.02		0.0%	1.0%	0.0%	98.0%	1.0%	0.0%	0.0%
Turkeys	6.80	0.07	0.36	0.12		0.0%	0.0%	0.0%	98.0%	1.8%	0.0%	0.0%
Ducks	2.70	0.02	0.36	0.04		0.0%	1.0%	0.0%	93.0%	5.0%	0.0%	0.0%
Other	2.70	0.02	0.36	0.07		0.0%	10.0%	0.0%	80.0%	5.0%	0.0%	0.0%
Rabbits	1.60	-	-	0.08		0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%

CS   - country specific

5.3.1.3. Uncertainties and time-series consistency

Uncertainty estimate associated with activity data amounts to minimal ±10% and maximum of ±30%, based on expert judgements and values for default EF from 2006 IPCC Guidelines. The expert judgement used for the uncertainty of the AD is based on the authority of the AD source (10% for high authority CBS source, 30% for FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty estimate associated with emission factors amounts to 30% based on expert judgement.

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 2010-2019 time period due to new AD for horses and mules/asses. Impact of recalculations on the total 3.B.1 source emissions compared to the last submission is negligible (> ±0.1) and 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)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt CO_2 eq.	-0.862	-0.941	-1.007	0.018	0.001	0.001	0.005	0.001	0.001	0.027
%	-0.08%	-0.09%	-0.09%	0.0017%	0.0001%	0.0001%	0.0004%	0.0001%	0.0002%	0.0028%

5.3.1.6. Category-specific planned improvement

Planned improvements assumed to be short-term (1 year) are:

- Improvements and verifications of activity data parameters for Tier 2 emission calculation for relevant animal categories and MM systems. Ministry of Economy and Sustainable Development had secured funds required for the launch of this project. The project is under implementation

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Implementation of the developed national parameters for Tier 2 emission calculation for relevant animal categories and MM systems in the inventory emission estimate for all years. The project is under implementation
- 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 2018 are presented in Figure 5.3-2.

Figure 5.3-2: N₂O Emissions from Manure management

5.3.2.2. Methodological issues

Direct N₂O 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[24]. 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 data was developed with the assistance of experts from the Faculty of Agriculture, University of Zagreb for each year in the data series (calculated for key years and then interpolated for the time periods between key years). Default emission factors (Table 10.21 of the 2006 IPCC Guidelines) were used for the final calculation of direct N₂O emissions.

Indirect N₂O 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 N₂O emissions were the estimated using Equation 10.27 (2006 IPCC guidelines), using default emission factors (Table 11.3, 2006 IPCC guidelines).

For indirect N₂O 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_leachMS 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 N2O-N per kg N leaching/runoff (IPCC, 2006). The requirements regarding handling application of organic manure, size and water tightness of animal

---

[24] See Chapter 5.3.2.6 for details on planned improvement.

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 is based on the authority of the AD source (±10% for high authority CBS source, ±30% for FAO and other data), observing annual variation in AD and of periodic revisions of the AD. Uncertainty for N excretion rates is estimated to be ±25%. Uncertainty of emission factors is within the range -50% to +100%.

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 2010-2019 time period due to new AD for horses and mules/asses. Impact of recalculations on the total 3.B.2 source emissions compared to the last submission is negligible (> ±0.1) and 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)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt CO_2 eq.	-0.044854	-0.060328	-0.068844	0.005612	0.000012	0.000012	0.000072	0.000012	0.000024	0.001372
%	-0.000266	-0.000377	-0.000436	0.000037	0.000000	0.000000	0.000000	0.000000	0.000000	0.000009

Planned improvements assumed to be short-term (1 year) are:

- Improvements and verifications of activity data parameters for Tier 2 emission calculation for relevant animal categories and MM systems. Ministry of Economy and Sustainable Development had secured funds required for the launch of this project.

Planned improvements assumed to be mid-term or long-term goals (over 1 year) are:

- Implementation of the developed national parameters for Tier 2 emission calculation for relevant animal categories and MM systems in the inventory emission estimate for all years.

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 2018 are presented in Figure 5.6-1. 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 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 - 2014 again show a decline in their consumption, with an all-time low in 2014.

Figure 5.5-1: Total N₂O emissions from Agricultural soils
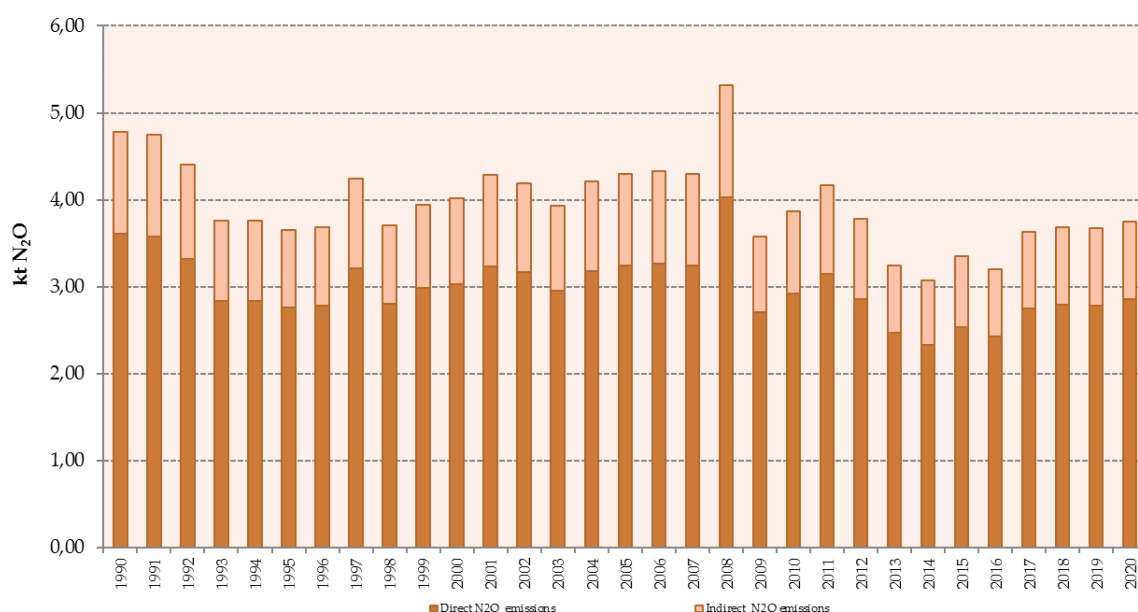
5.5.1. Direct N₂O Emission from Managed Soils (CRF 3.D.1.)

5.5.1.1. Category description

Direct N₂O 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 N₂O from Managed Soils for the period from 1990 to 2018 are shown in Figure 5.5-2.

Figure 5.5-2: Direct N₂O emissions from Agricultural soils
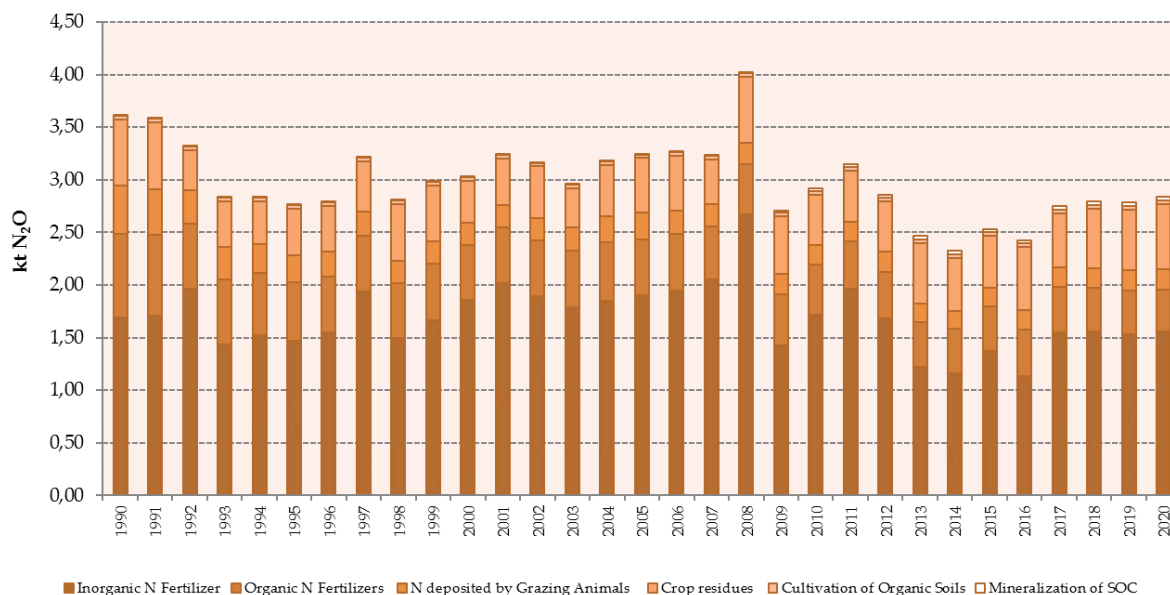
5.5.1.2.   Methodological issues

In order to calculate emission from Agricultural Soils, the IPCC methodology (Tier 1) has been used. Emission factors were taken from the 2006 IPCC Guidance.

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.

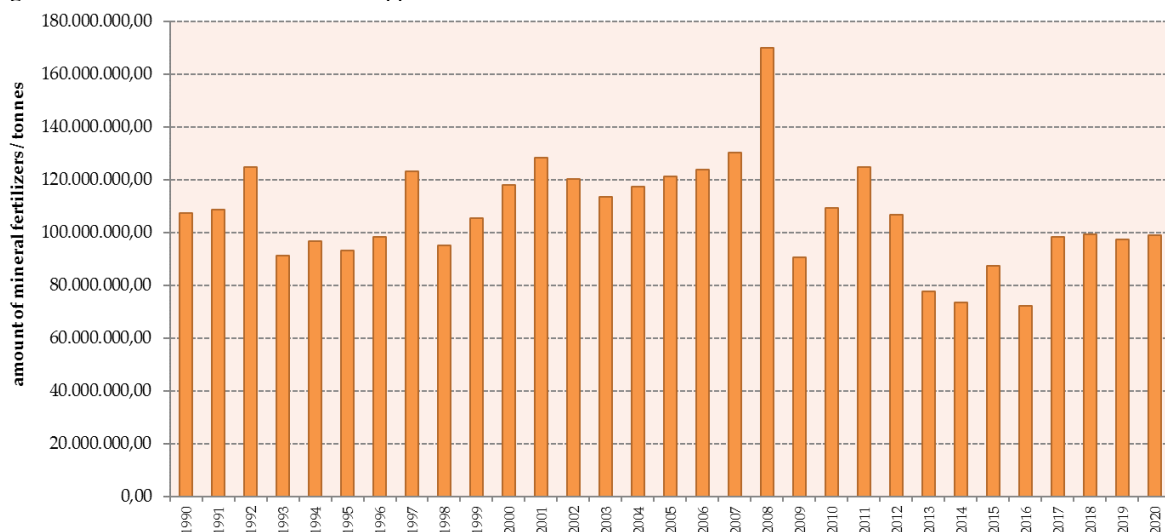Figure 5.5-3: N from mineral fertilizers applied to soils

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 2000-2020

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

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.

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 2005-2020, 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 MEE. Data source is the yearly publication "Wastewater purification sludge management for the sludge used in agriculture", MEE 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%

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
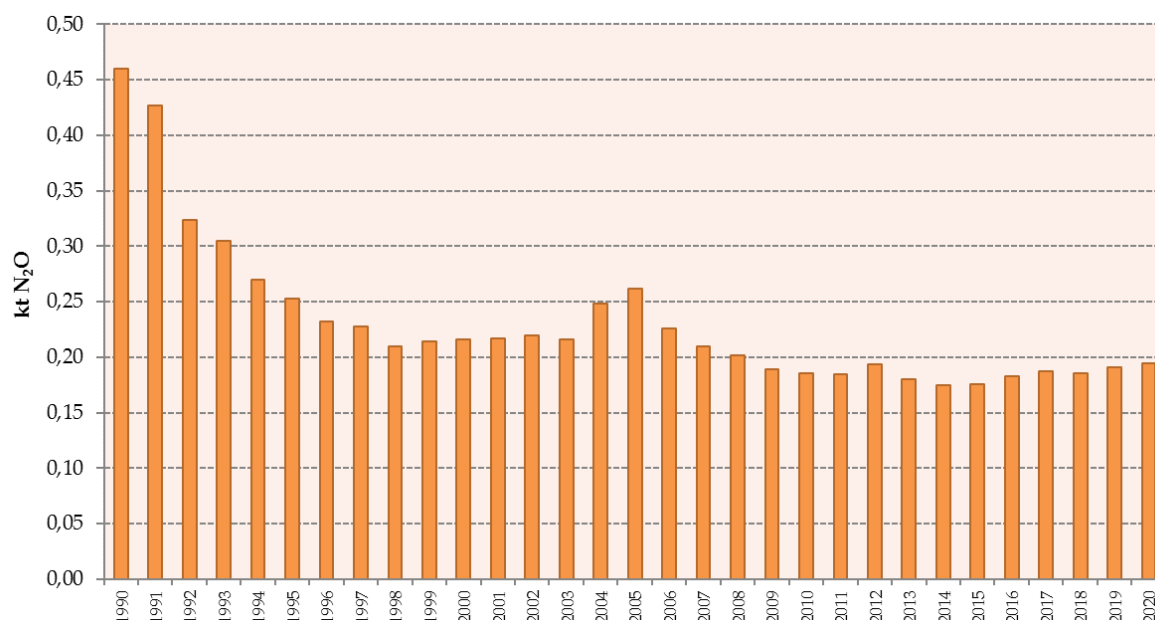
Crop Residues (3.D.1.4)

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	Crop yield			Crop area		
	CBS	FAO	Extrapolation*	CBS	FAO	Extrapolation*
Soyabeans	1990-2020			1990-2020		
Beans, dry	1990-2020			1990-2020		
Cow peas, dry	2008-2020	1992-2007	1990-1991	1998-1999 2008-2020	1992-1997 2000-2007	1990-1991
Lentils	1990-1991, 2020	1992-2019		1990-1998, 2020	1999-2019	
Peas, dry	1990-2020			1990-2020		
Vetches	1990-1997, 2020	1998-2019		1990-1997, 2020	1998-2019	
Clover	1990-2020			1990-2020		
Alfalfa	1990-2020			1990-2020		
Wheat	1990-2020			1990-2020		
Maize	1990-2020			1990-2020		
Potatoes	1990-2020			1990-2020		
Sugar beets	1990-2020			1990-2020		
Tobacco	1990-2020			1990-2020		
Sunflowers	1990-2020			1990-2020		
Rapeseed	1990-2020			1990-2020		
Tomatoes	1990-2020			1990-2020		
Barley	1990-2020			1990-2020		
Oats	1990-2020			1990-2020		
Cabbages and other brassicas	1990-2020			1990-2020		
Garlic**	1990-2020			1990-2020		
Onions**	1990-2020			1990-2020		
Rye	2014-2020	1992-2013	1990-1991	2014-2020	1992-2013	1990-1991
Sorghum***	1990-1997, 2020	1998-2019		1990-1997, 2020	1998-2019	
Watermelons	1990-2020			1990-2020		

*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 – 2020

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

Table 5.5-5: Production and harvest data for crops in the period from 1990 – 2020 (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	NO	NO	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

Table 5.5-5: Production and harvest data for crops in the period from 1990 – 2020 (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	NO	NO	83.817	20.270	124.055	24.803
2013	111.316	47.156	1.480	1.097	1.378	721	80	44	189	154	NO	NO	82.844	16.783	177.857	25.694
2014	131.424	47.104	1.329	1.483	1.413	678	83	29	579	219	NO	NO	70.873	10.497	128.702	22.116
2015	196.431	88.867	1.156	1.475	1.346	600	60	27	194	94	NO	NO	82.992	9.549	112.876	18.386
2016	244.075	78.614	1.461	1.574	3.985	1543	50	25	246	71	NO	NO	67.853	9.920	191.540	23.559
2017	207.765	85.133	1.340	1.539	2.347	938	46	22	142	71	NO	NO	24.861	5.326	187.917	26.057
2018	245.188	77.087	1.737	1.403	2.223	915	52	25	314	147	NO	NO	67.946	10.223	186.490	24.248
2019	244.279	78.334	1.381	1.113	2.870	1181	52	25	499	143	NO	NO	50.833	8.437	193.318	29.006
2020	266.014	86.185	1.325	984	1.629	602	0	0	170	130	NO	NO	60.049	9.332	201.460	26.337

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

Legend:
- 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 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
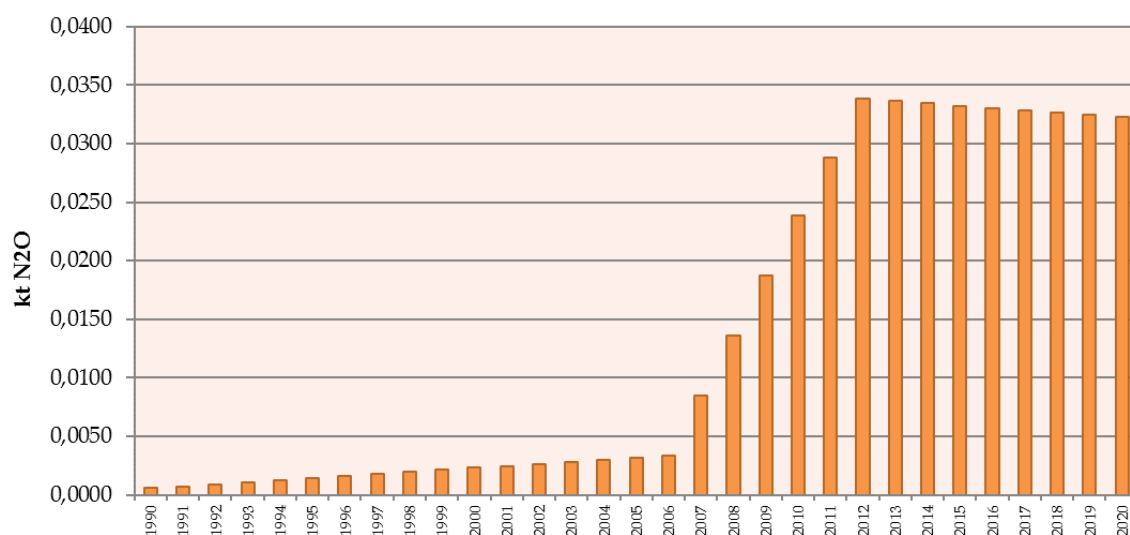
Cultivation of Organic Soils (3.D.1.6)

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 N2O 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 1992-2020 and compared with the available 2000-2020 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 2010-2019 period 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 compared to the last submission is negligible (> ±0.1) and 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)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt CO_2 eq.	-0.2681	-0.318	-0.350	0.016	0.000173	0.000173	0.001034	0.000173	0.000347	0.0084
%	-0.000309	-0.0003	-0.00041	0.000022	0.0000002	0.0000002	0.000001	0.0000002	0.0000004	0.0000101

5.5.1.6. Category-specific planned improvement

Planned improvements assumed to be short-term (1 year):

- 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).

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, compost) with the purpose of a more detailed explanation of the activity data trends and further verification of source data.

5.5.2. Indirect N$_2$O Emissions from Managed Soils (CRF 3.D.2.)

5.5.2.1. Category description

Calculations of indirect N$_2$O 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$_2$O from managed soils for the period from 1990 to 2020 are shown in Figure 5.6-6.

Figure 5.5-6: Indirect N$_2$O emissions from Managed Soils
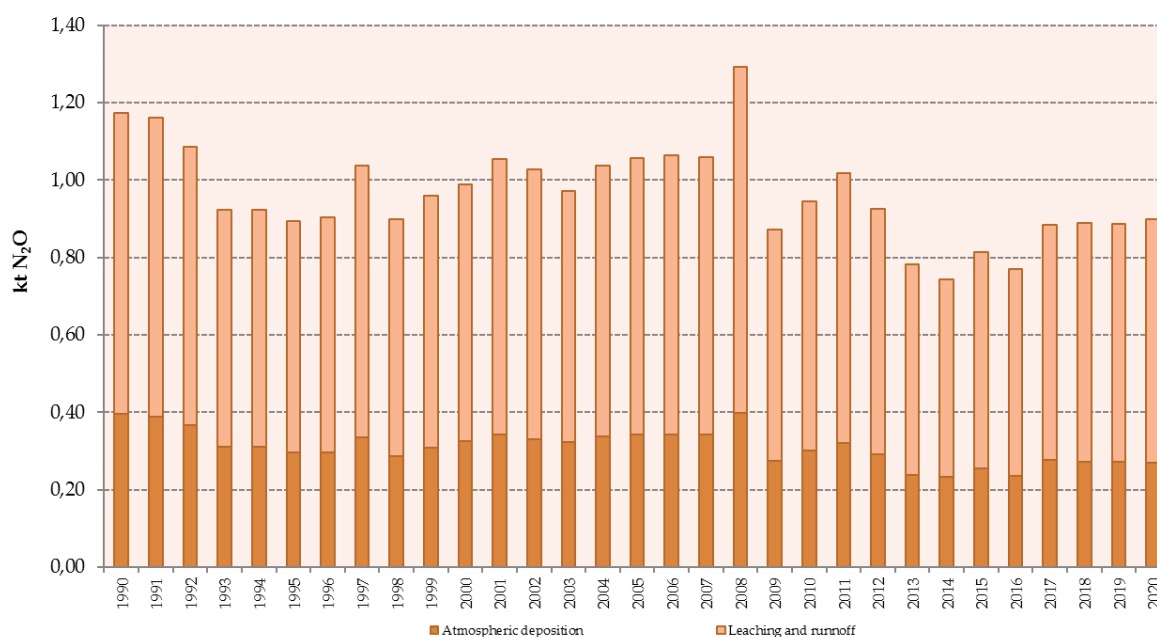
5.5.2.2. Methodological issues

Atmospheric deposition due to volatilization

N$_2$O 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.

Nitrogen leaching and run-off

N$_2$O 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 N2O 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 2010-2019 period 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 negligible (> ±0.1) and 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)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt CO$_2$ eq.	-0.1140	-0.1351	-0.1486	0.0068	0.0000736	0.0000736	0.000442	0.0000736	0.0001473	0.00357
%	-0.0004	-0.0004	-0.0005	0.00003	0.0000003	0.0000003	0.000002	0.0000003	0.0000006	0.00001

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); 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 2020 are presented in Figure 5.8-1.

Figure 5.8-1: Direct CO_2 emissions from Liming
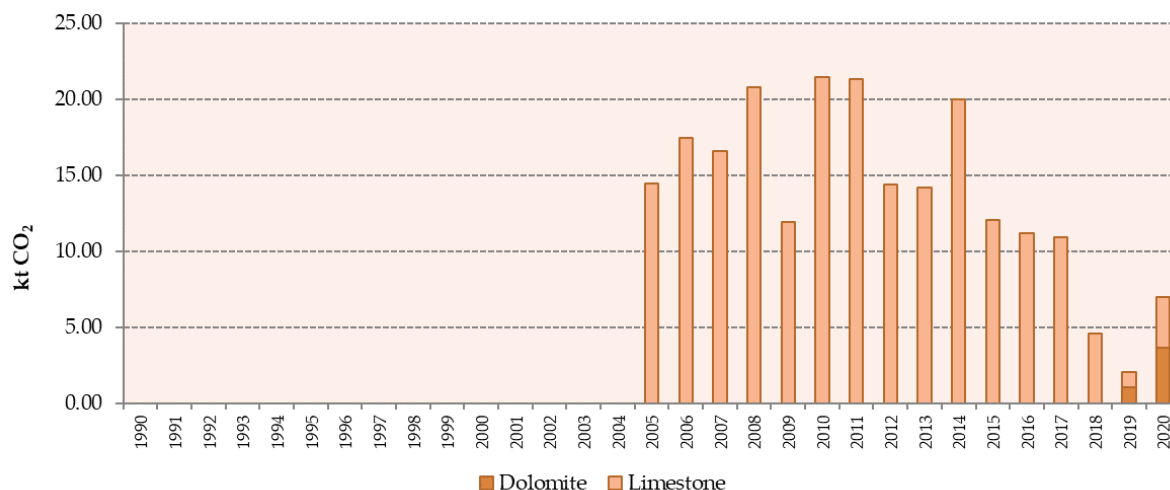
5.8.2. Methodological issues

Estimation due to liming was performed using the 2006 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

Due to a correction of AD for year 2019, emission estimate was recalulcated for year 2019. Impact of the recalculation is a 1.4kt CO_2 eq. decrease of emissions (-69%).

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 2018 is shown in Figure 5.9-1.

Figure 5.9-1: Direct CO_2 emissions from Urea Application
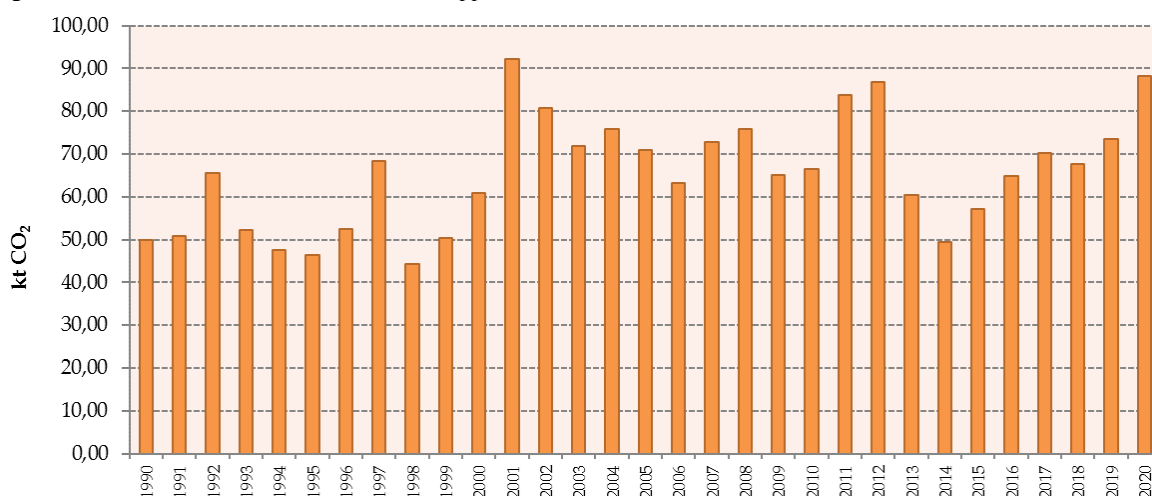
5.9.2. Methodological issues

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	2006	86,167
1991	69,472	2007	99,165
1992	89,334	2008	103,398
1993	71,099	2009	88,691
1994	64,868	2010	90,789
1995	63,128	2011	114,348
1996	71,509	2012	118,436
1997	93,256	2013	82,348

Year	Urea applied / tonnes	Year	Urea applied / tonnes
1998	60,339	2014	67,463
1999	68,846	2015	78,065
2000	82,999	2016	88,588
2001	125,584	2017	95,742
2002	110,121	2018	92,212
2003	97,899	2019	100,352
2004	103,555	2020	120,395
2005	96,782		

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

No recalculations were performed.

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,
- Cropland,
- Grassland,
- Wetlands,
- Settlements and
- Other land.

According to the IPCC 2006 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 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, Settlement remaining Settlement and Other land remaining Other land are not estimated.

In LULUCF sector Forest land remaining Forest land, Cropland remaining Cropland and Land converted to Settlement 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 2020

Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, 2022)					
IPCC Source Categories	GHG	Key	If Column C is Yes, Criteria for Identification		Com.
4(III).Direct N2O emissions from N mineralization/immobilization	N_2O	Yes		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		
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	T1i, T2i	
4.B.2 Land Converted to Cropland	CO_2	Yes	L2i	T1i, 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 CO₂ emissions/removals	CH₄	N₂O
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: Emission/removal trend for LULUCF
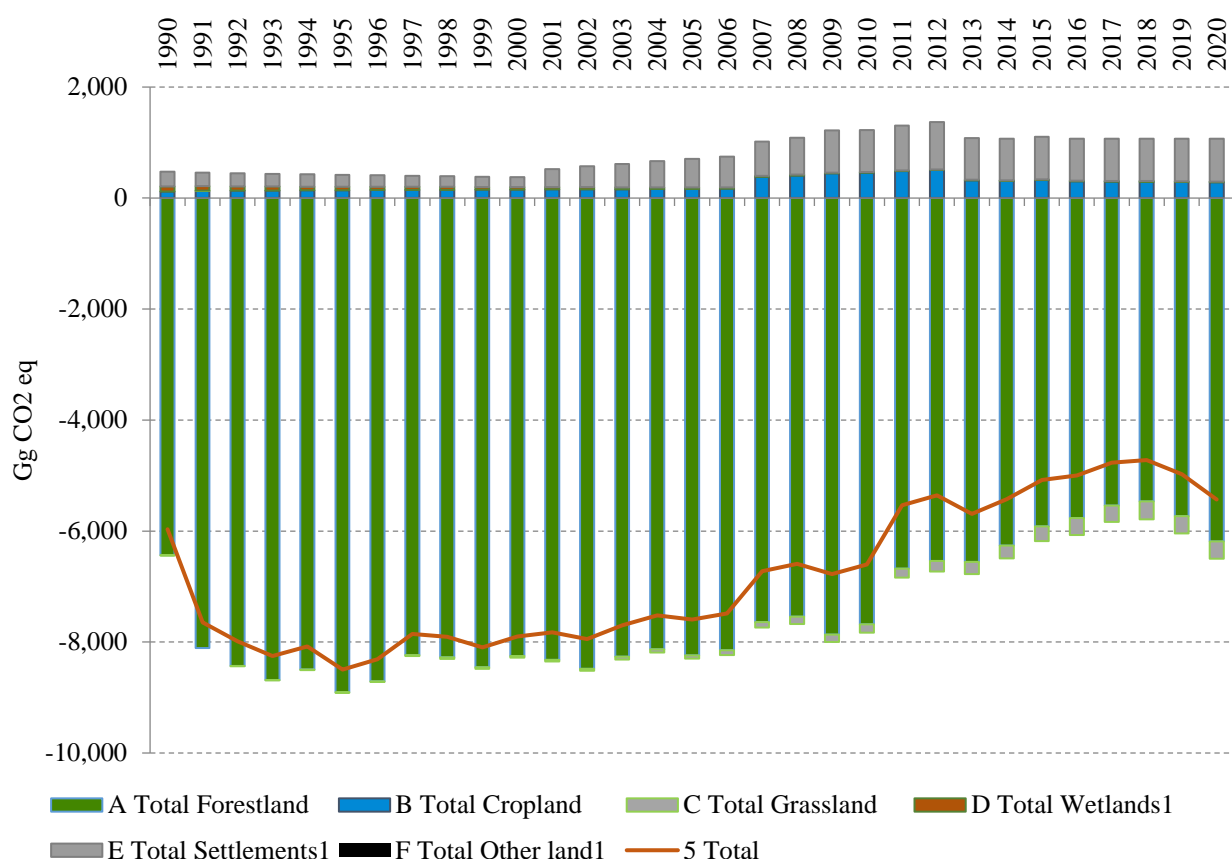
6.1.2. Methodology

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[25] 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.

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

---

[25] Forest Act (Official Gazette No. 68/18, 115/18)

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.

IPCC 2006 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.

The 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 for Croatia for the years 1990-2020

Area in kha	1990	2020	2020 - 1990
4.A Forest land - Total	2,326.19	2,387.28	61.08
4.A1. Forest land remaining forest land	2,326.19	2,386.93	60.74
4.A1a Forest land remaining forest land -coniferous	214.72	223.09	8.37
4.A1b Forest land remaining forest land -deciduous	1,609.95	1,625.26	15.31
4.A1c Forest land remaining forest land -out of yield	501.52	538.58	37.06
4.A2 LUC in Forest land	0.00	0.34	0.34
4.A2.1a Annual cropland in forest land	0.00	0.00	0.00
4.A2.1b Perennial cropland in forest land	0.00	0.00	0.00
4.A2.2 Grassland in forest land	0.00	0.34	0.34
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	1,623.77	1,525.98	-97.78
Cropland annual	1,479.23	1,404.20	-75.03

Area in kha	1990	2020	2020 - 1990
Cropland perennial	144.54	121.79	-22.75
4.B1. Cropland remaining cropland	1,625.03	1,525.82	-99.21
4.B1a Annual cropland remaining annual cropland	1,480.35	1,404.12	-76.23
4.B1b Perennial cropland remaining perennial cropland	144.61	121.61	-23.01
4.B1c LUC perennial cropland in annual cropland	0.02	0.01	-0.01
4.B1d LUC annual cropland in perennial cropland	0.04	0.07	0.03
4.B2 LUC in cropland	0.35	0.17	-0.18
4.B2.1a Forest land in annual cropland	0.00	0.00	0.00
4.B2.1b Forest land in perennial cropland	0.00	0.00	0.00
4.B2.2a Grassland in annual cropland	0.33	0.07	-0.26
4.B2.2b Grassland in perennial cropland	0.02	0.10	0.08
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	1,561.83	1,153.22	-408.60
4.C1. Grassland remaining grassland	1,201.06	1,152.39	-48.66
4.C2. LUC in grassland	0.00	0.83	0.83
4.C2.1 Forest land in grassland	0.00	0.00	0.00
4.C2.2a Annual cropland in grassland	0.00	0.75	0.75
4.C2.2b Perennial cropland in grassland	0.00	0.07	0.07
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	73.86	75.28	1.42
4.D1. Wetlands remaining wetlands	73.51	75.21	1.70
4.D2. LUC in wetlands	0.35	0.07	-0.28
4.D2.1 Forest land in wetlands	0.00	0.00	0.00
4.D2.2a Annual cropland in wetlands	0.32	0.07	-0.25
4.D2.2b Perennial cropland in wetlands	0.03	0.01	-0.02
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	200.65	287.03	86.38

Area in kha	1990	2020	2020 - 1990
4.E1 Settlements remaining Settlements	199.33	286.11	86.78
4.E2 LUC in Settlements	1.32	0.92	-0.39
4.E2.1 Forest land in Settlements	0.00	0.02	0.02
4.E2.2a Annual cropland in Settlements	0.78	0.53	-0.25
4.E2.2b Perennial cropland in Settlements	0.08	0.05	-0.02
4.E2.3 Grassland in Settlements	0.46	0.32	-0.15
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	71.13	76.29	5.16
4.F1 Other land remaining other land	71.13	76.29	5.16
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.F2.3 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	5,659.40	5,659.40	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 Guidelines and KP reporting requirements for both UNFCCC and KP reporting frame to be completely harmonized, transparent and comparable. Therefore, Forest land remaining forest land is represented in KP reporting within Article 3.4 (Forest Management) and Land converted to forest land refers to afforestation activities under the Article 3.3 activities while Forest land converted to Settlements and Cropland refers to deforestation activities under the Article 3.3. Reforestation activity does not occur in Croatia. All definitions applied for KP are the same as applied for the UNFCCC reporting (as presented in Croatian NIR 2022, KP Chapters 11.1.1 *Definition of forest and any other criteria* and 11.1.3, *Description of how the definitions of each activity under article 3.3 and each elected activity under article 3.4 have been implemented and applied consistently over time*).

The Forest land is composed of the Forest land remaining forest land and Land converted to forest land. 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[26] 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.

6.2.2. Cropland (4.B)

Based on the IPCC 2006 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:

---

[26] Ordinance on forest management (OG 97/18)

- 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[27] 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),
- 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'

---

[27] Forest Act (Official Gazette No. 68/18, 115/18)

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)
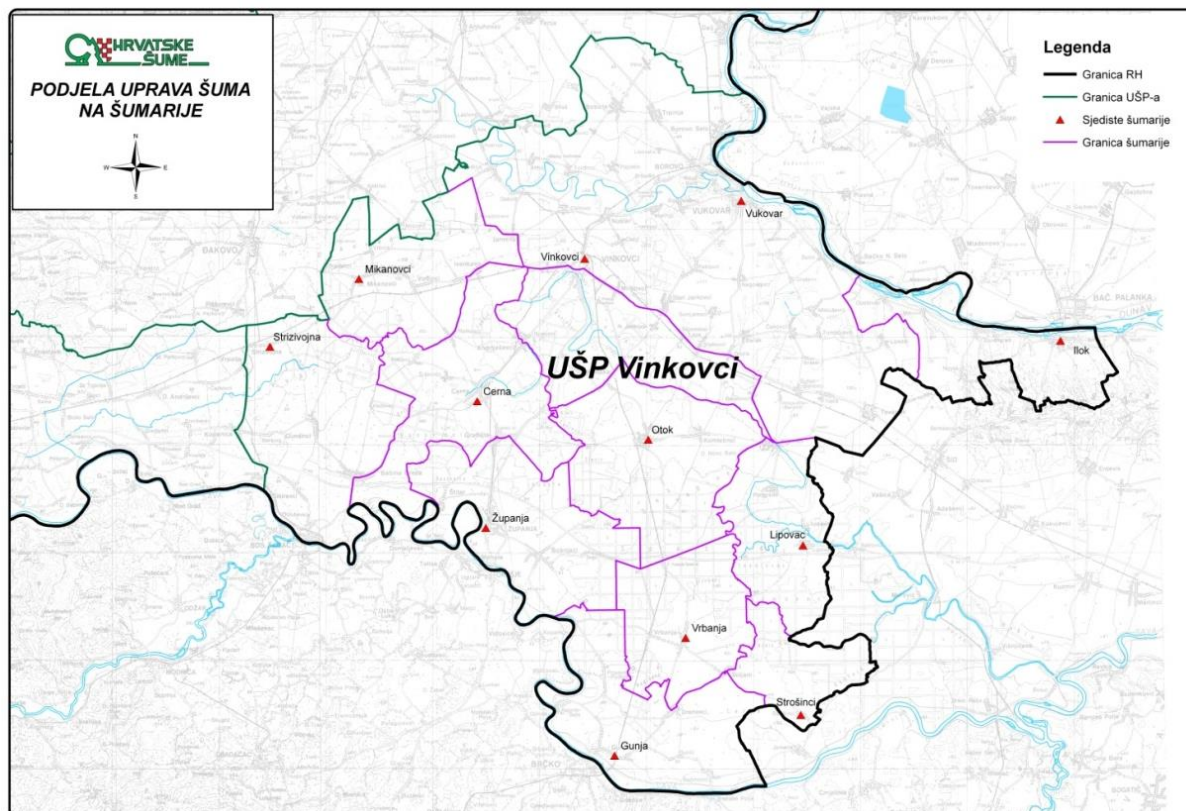
Figure 6.3-3: Area of a forest office "Cerna" with the spatial division on related management units (example)
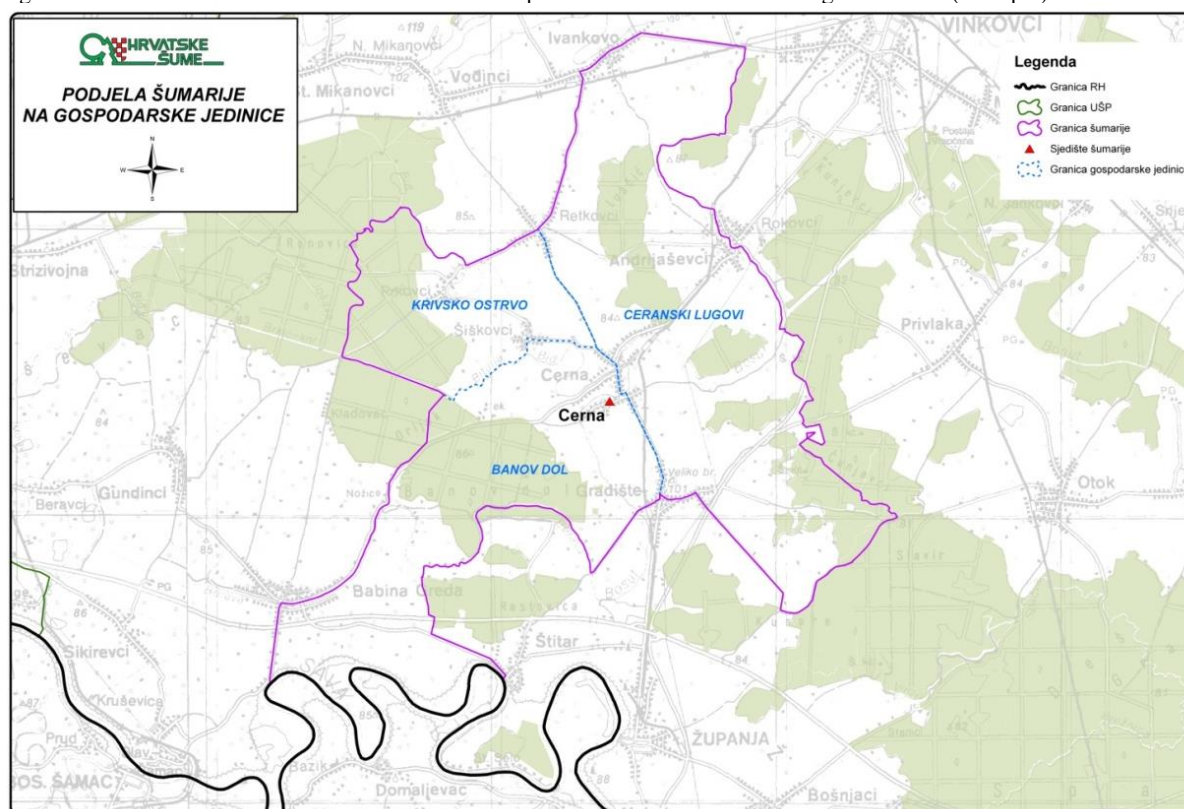
Figure 6.3-4: Area of a management unit "Krivsko ostrvo" divided into compartments (example)
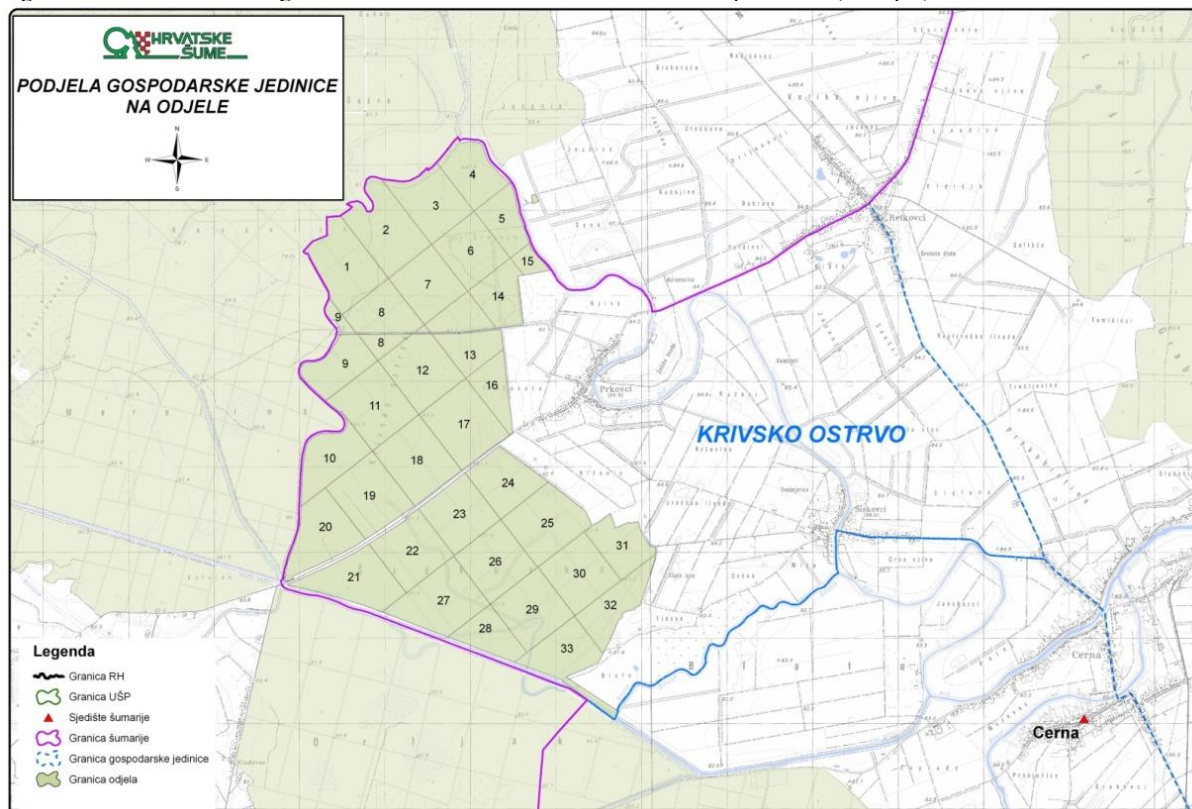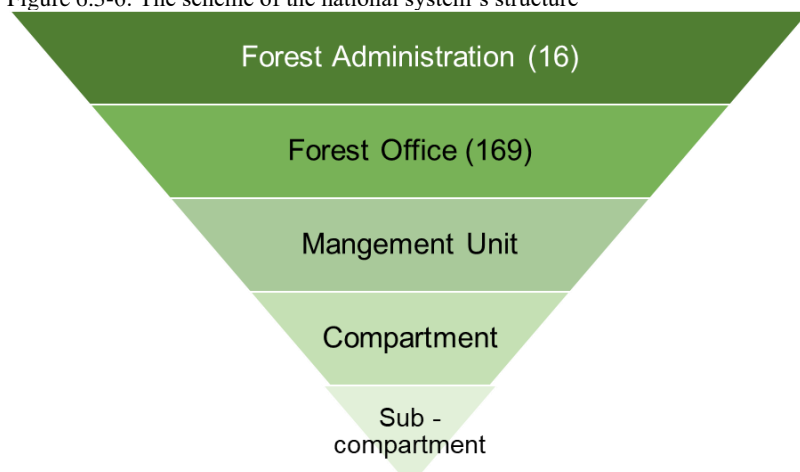

Figure 6.3-5: Compartment area divided into sub-compartments (example)
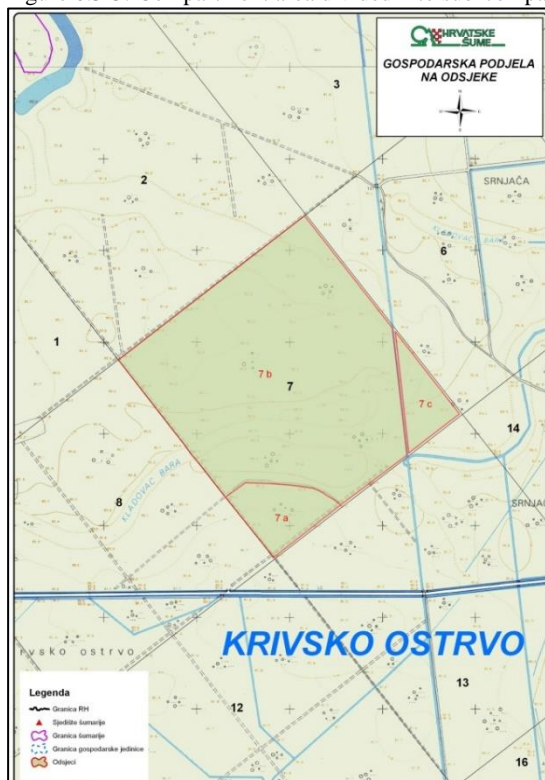
Short scheme of the system's structure is presented in Figure 6.3-6.

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

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
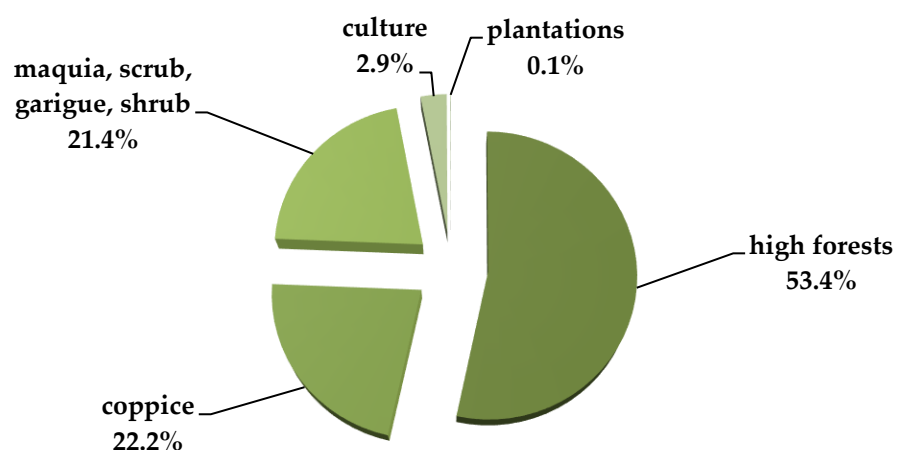
According to the Forest Act forests are classified in three categories:

- 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
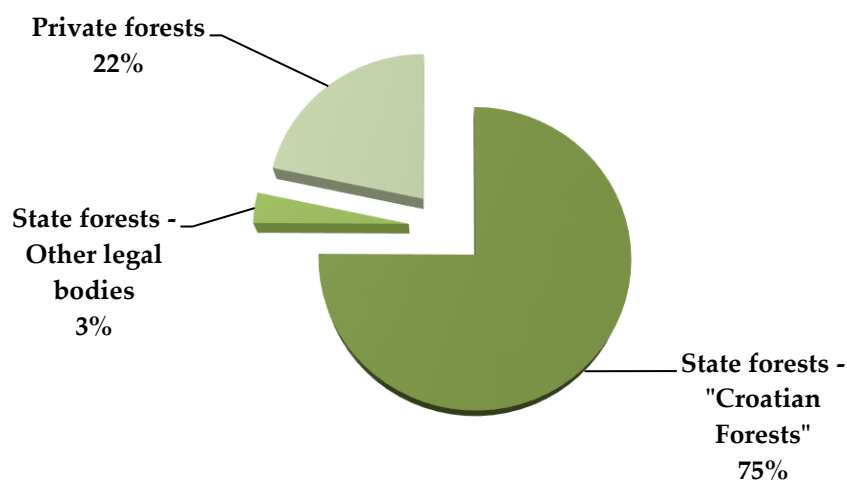
The area of forests is determined based on all available cadastral maps in various scales. However, while preparing the FMAP 2016-2025, it was noticed that cadastral data on forest area did not match real conditions – private forests were larger than those presented in the cadastre. Since private forests 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 Figure 6.3-9 and 6.3-10) by calculation based on the following measured data:

- diameters at breast height
- 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
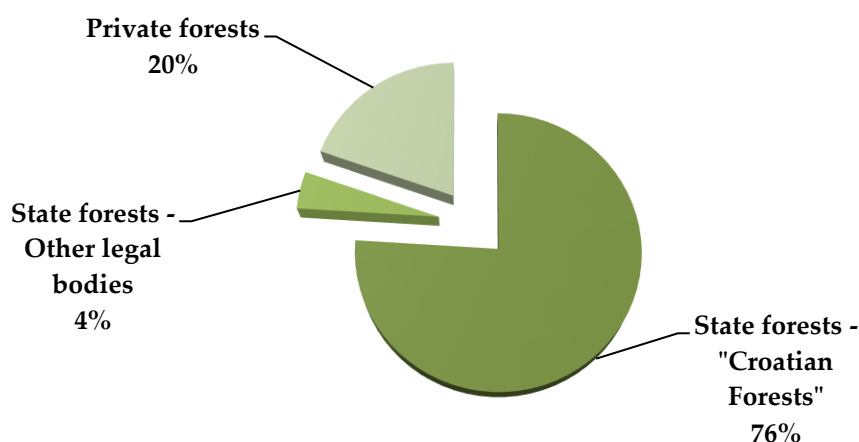
Figure 6.3-10: Share of main species in total growing stock, General FMAP 2016-2025
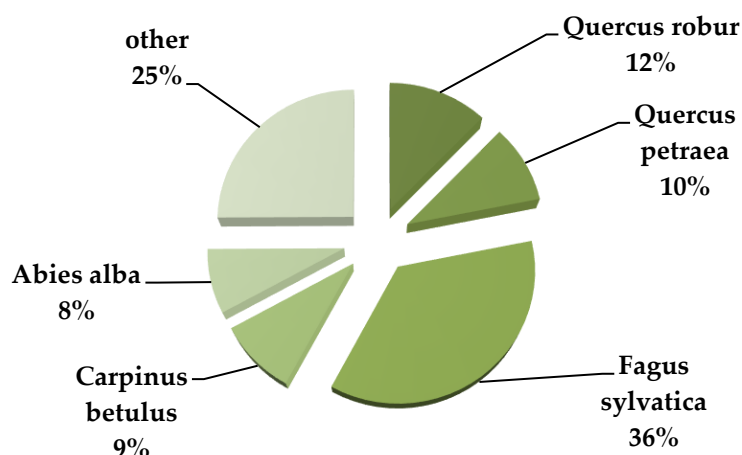
At least 2% in even-aged stands of the second age class regarding the high forests in area that is subject of FMAP, forests with limited management, coppices, protection forests and private forests.

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"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[28], 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.

---

[28] Ordinance on Forest Management

Figure 6.3-11: The share of increment in state and private forests, General FMAP 2016-2025
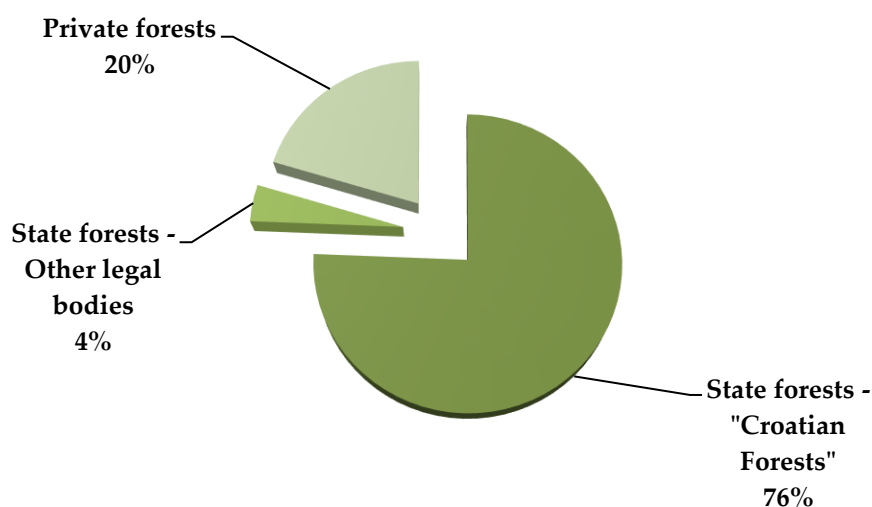
Representation of the Forest land in this report is based on the definitions provided in the following chapter (Chapter 6.4). The related data have been obtained from the FMAPs. The forests in Croatia are presented by forest type as broadleaved and coniferous forests and out of yield forests (maquies and shrub forests).

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[29]. 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.

---

[29] Croatian Agency for Environment and Nature, Corine Land Cover database. See list of References

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 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''[30].

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 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.

[30] Statistical Yearbook of the Republic of Croatia 2012. See list of References

Figure 6.3-13: Total Cropland Area Corrected, kha
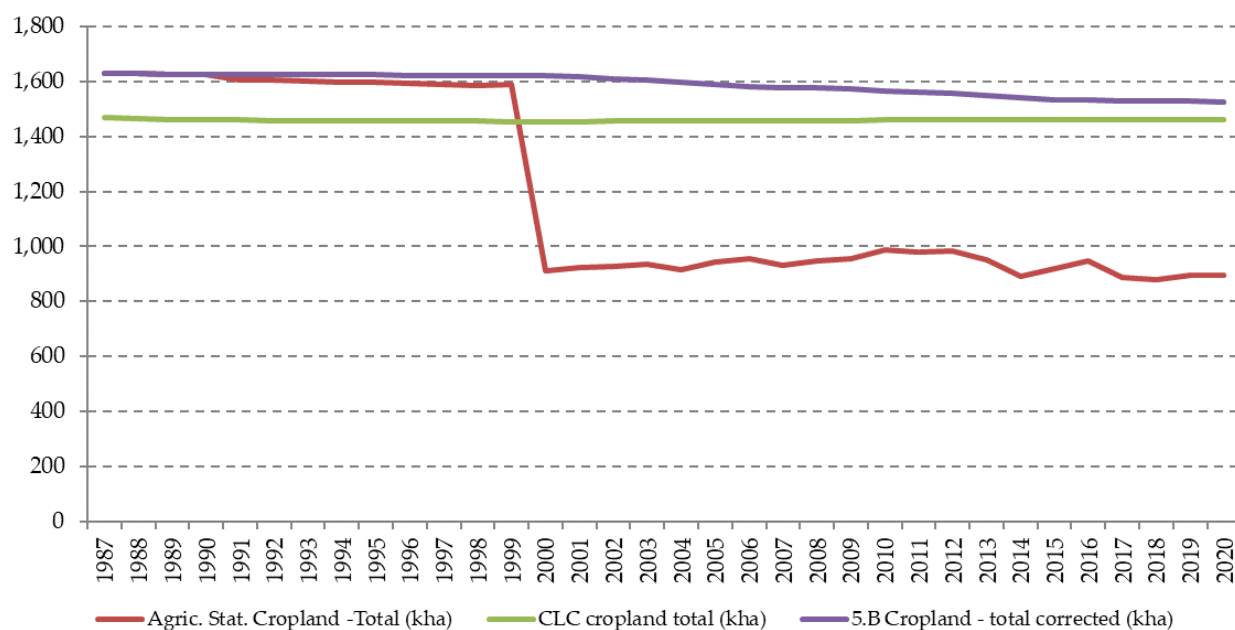
The share of perennial cropland in the adjusted total cropland area since 2000 has been estimated based on the relative shares of perennial cropland according to CBS data from the 2000ies. For the years before 2000 the CBS data on annual and perennial cropland area were used. The relative shares of perennial and annual cropland are rather consistent across the whole time series (0.1 vs. 0.9).

The area of annual CL and perennial CL used for LULUCF reporting depends on official CBS data on pCL and 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.

Figure 6.3-14: Area of annual and perennial cropland in Croatia after adjustments of CBS data, kha
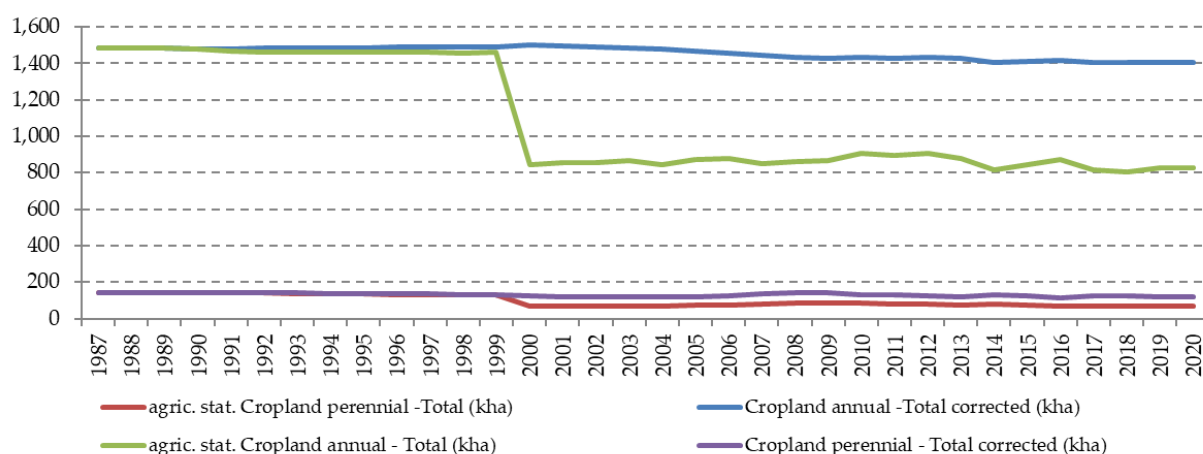
For the comparison in this figure the CLC results are based on linear interpolation between the single CLC assessment years (1980–1990, 1990-2006, 2006-2012, 2012-2018). For the years after 2018 extrapolation of the CLC trend was applied.

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 6.3-15).

Figure 6.3-15: Total grassland area in Croatia according to the CBS data and CLC database, kha
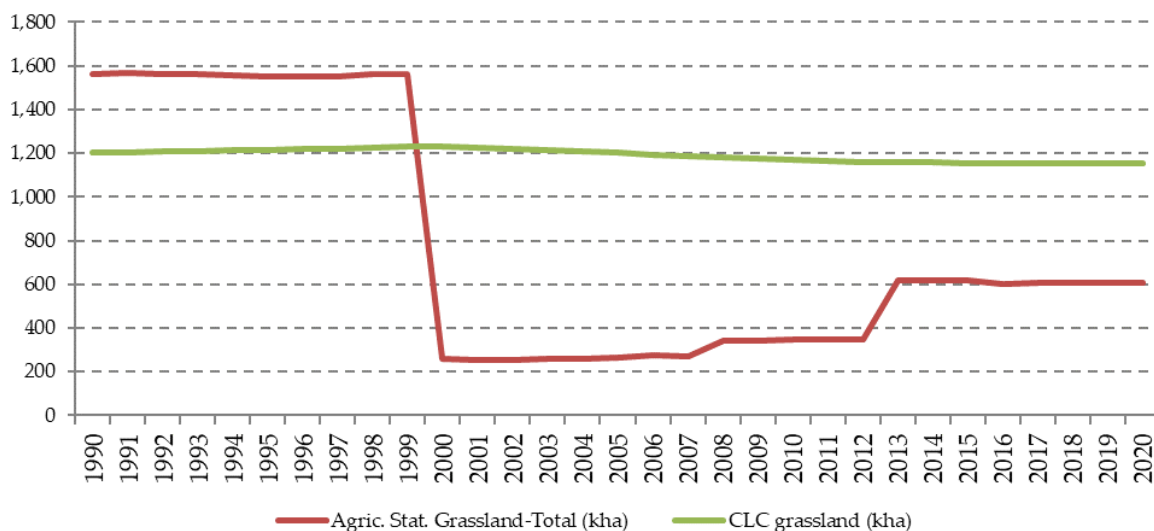
In this report CLC data were used to present grassland area in Croatia in the years 1980, 1990, 2000, 2006, 2012 and 2018. Linear interpolation of the CLC trend between these CLC assessment years was carried out. Extrapolation of the CLC trend was applied for the years after 2018.

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.

Based on the CLC data on LUC areas and the information from Croatian Forests Ltd, 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.

For the years before 1990 the mean LUC areas of the years 1990-1994 were used as LUCs into settlements.

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 and 2012) 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 53.77 and 76.43 kha in the period 1990-2020, 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 IPCC 2006 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[31] , 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 C stock changes in dead organic matter 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

---

[31] Below ground biomass is combined with the above ground and thus the notation key IE is used for below ground biomass.

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) 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.

Figure 6.4.-1: Trend of forest land and LUC to forest land in period 1990-2020 (kha) *
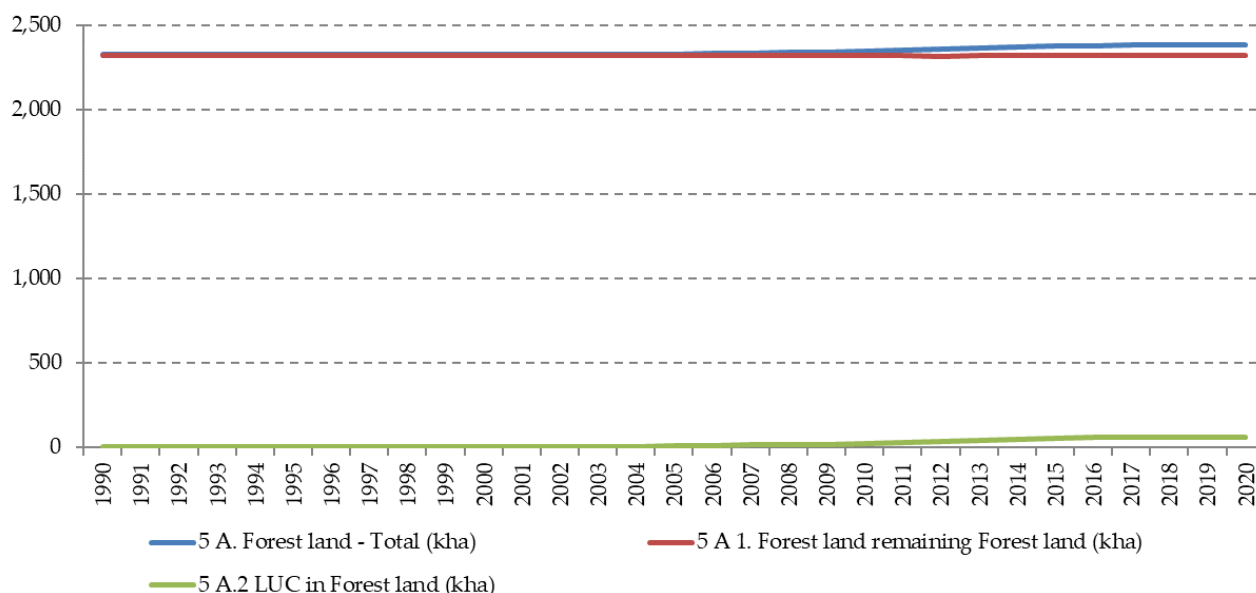
* Forest land area including forests Out of yield

CO_2 removals from Forest land remaining Forest land in 2019 are -5,553.75 kt CO_2 and from Land converted to Forest land -268.82 kt CO_2. Therefore, the share of removals from land conversion in total Forest land removals makes only 4.84 %. 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 Forest land - Total	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	-6,433	-6,404	-28.89	NO	-28.89	NO	NO	NE
1991	-8,108	-8,082	-25.79	NO	-25.79	NO	NO	NE
1992	-8,432	-8,405	-26.36	NO	-26.36	NO	NO	NE
1993	-8,687	-8,662	-25.15	NO	-25.15	NO	NO	NE
1994	-8,498	-8,471	-26.34	NO	-26.34	NO	NO	NE
1995	-8,904	-8,877	-27.12	NO	-27.12	NO	NO	NE
1996	-8,705	-8,678	-27.07	NO	-27.07	NO	NO	NE

Year	4.A Forest land - Total	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
1997	-8,235	-8,206	-28.64	NO	-28.64	NO	NO	NE
1998	-8,277	-8,249	-28.26	NO	-28.26	NO	NO	NE
1999	-8,454	-8,426	-28.23	NO	-28.23	NO	NO	NE
2000	-8,250	-8,220	-30.17	NO	-30.17	NO	NO	NE
2001	-8,323	-8,292	-30.57	NO	-30.57	NO	NO	NE
2002	-8,482	-8,451	-30.87	NO	-30.87	NO	NO	NE
2003	-8,266	-8,234	-31.95	0.01	-31.96	NO	NO	NE
2004	-8,129	-8,097	-31.19	0.27	-31.46	NO	NO	NE
2005	-8,241	-8,241	0.15	0.37	-0.21	NO	NO	NE
2006	-8,151	-8,142	-8.64	-0.02	-8.61	NO	NO	NE
2007	-7,640	-7,640	0.31	-0.16	0.47	NO	NO	NE
2008	-7,544	-7,499	-44.40	-1.19	-43.21	NO	NO	NE
2009	-7,868	-7,849	-19.30	-1.53	-17.77	NO	NO	NE
2010	-7,683	-7,645	-38.56	-2.51	-36.05	NO	NO	NE
2011	-6,677	-6,642	-35.17	-4.17	-31.00	NO	NO	NE
2012	-6,538	-6,451	-86.44	-4.91	-81.53	NO	NO	NE
2013	-6,557	-6,471	-85.43	-7.08	-78.35	NO	NO	NE
2014	-6,261	-6,166	-95.12	-7.17	-87.95	NO	NO	NE
2015	-5,914	-5,773	-140.66	-6.11	-134.55	NO	NO	NE
2016	-5,764	-5,530	-233.91	-19.32	-214.59	NO	NO	NE
2017	-5,543	-5,336	-206.69	-19.32	-187.37	NO	NO	NE
2018	-5,468	-5,223	-244.12	-19.32	-224.80	NO	NO	NE
2019	-5,730	-5,467	-262.29	-19.32	-242.78	NO	-0.19	NE
2020	-6,189	-5,922	-266.97	-19.32	-246.82	-0.21	-0.40	-0.21

Table 6.4.-2: CO$_2$ eq. emissions from wildfires

Year	Area burnt (ha)	CO$_2$ emissions (kt)	CH$_4$ emissions (CO$_2$ eq (kt))	N$_2$O emissions (CO$_2$ eq (kt))
1990	482.15	14.98	1.12	0.74
1991	1,291.45	40.12	3.00	1.98
1992	5,863.79	182.17	13.64	9.00
1993	14,101.90	438.09	32.81	21.63
1994	4,591.34	142.64	10.68	7.04
1995	3,010.79	93.53	7.00	4.62
1996	6,493.73	201.74	15.11	9.96
1997	6,884.57	213.88	16.02	10.56
1998	17,092.83	531.01	39.77	26.22
1999	1,829.71	56.84	4.26	2.81
2000	37,363.79	1160.75	86.93	57.32
2001	6,879.85	213.73	16.01	10.55
2002	2,413.60	74.98	5.62	3.70
2003	15,395.45	478.28	35.82	23.62
2004	839.00	26.06	1.95	1.29
2005	912.50	28.35	2.12	1.40
2006	2,322.00	72.14	5.40	3.56
2007	12,574.66	390.65	29.25	19.29
2008	3,642.58	113.16	8.47	5.59
2009	2,043.60	63.49	4.75	3.14
2010	687.67	21.36	1.60	1.05
2011	6,478.26	201.25	15.07	9.94
2012	15,270.09	474.38	35.53	23.43
2013	614.97	19.10	1.43	0.94
2014	78.83	2.45	0.18	0.12
2015	4,067.94	126.38	9.46	6.24
2016	2,829.01	87.89	6.58	4.34
2017	25,273.87	785.16	58.80	38.77
2018	291.71	9.06	0.68	0.45
2019	733.42	22.78	1.71	1.13
2020	12,261.23	380.91	28.53	18.81

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 1990-2020 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:

ΔC_{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 feelings. Methodological issues are explained in detail below. 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[32] 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.

The carbon loss due to felling is calculated using Tier 2 and equation 2.12 from IPCC 2006 Guidelines.

---

[32] Draft strategy for management and disposal of property of the Republic of Croatia 2013-2017. See list of References

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$_{d.m.}$m^{-3}	dimensionless	dimensionless	dimensionless	(tonnesd$_{m.}$)$^{-1}$
Deciduous	0.56	1.20	0.23	1.20	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

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[33] and share of species in total growing stock in Croatia[34], 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$_o$/VWET) 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% [35].

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 limestone[36]. 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[37] were used and corrected by the shrinkage factor of 19.7% in order to calculate wood density of absolute dry wood per fresh volume.

---

[33] Scientific papers of Badjun, Horvat,Sinković, Govorčin, Štajduhar. See list of References

[34] Forest Management Area Plan of the Republic of Croatia 2006-2015. See list of References

[35] Scientific paper of Sinković, Govorčin and Sedlar. See list of References

[36] Scientific paper of Horvat. See list of References

[37] Scientific paper of Govorčin, Sinković, Trajković, Šefc. See list of References

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[38].

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 IPCC 2006 Guidelines. The detailed overview of the approach is shown below:

ΔC_B = $\Delta C_G - \Delta C_L$

ΔC_G = $\Sigma_{i,j} (A_{i,j} \times I_V \times BEF_1 \times D_1 \times (1+R) \times CF)$

where:

ΔC_B	=	annual change in carbon stocks in biomass, tonnes C yr^{-1}
ΔC_G	=	annual increase in carbon stocks due to biomass growth, C yr^{-1}
ΔC_L	=	annual decrease in carbon stocks due to biomass losses, C yr^{-1}
ΔC_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)$^{-1}$

ΔC_L = $L_{wood-removals} + L_{fuelwood} + L_{disturbance}$

$L_{wood-removals}$ = $\Sigma H \times BEF_2 \times D_R \times (1+R) \times CF$

where:

ΔC_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

---

[38] Mali šumarsko-tehnički priručnik. See list of References

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 DW pools for the entire period from 1990-2020.

The related definition of Land Converted to Forest land is provided in Chapter 6.2.1. As stated before, Land Converted to Forest land refers to Afforestation within the KP reporting but takes the different time frames for both reporting obligations into account (since 1st January 1990 and permanence of AR lands for KP vs. transition period of 20 years for UNFCCC).

The basic input data for the estimation of emissions/removals was the area afforested. 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[39] as one of outcomes of the project. Detailed description of conducted work is presented in KP Chapter.

---

[39] Janes *et al.* (2014), Separation of areas under the Article 3.3 and 3.4 of the Kyoto protocol. See list of References

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[40] 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*[41], 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).

---

[40] 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.

[41] Ordinance on amendments to the Ordinance on the Register of forest owners (OG 84/2008). See list of References.

Figure 6.4.-2: 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
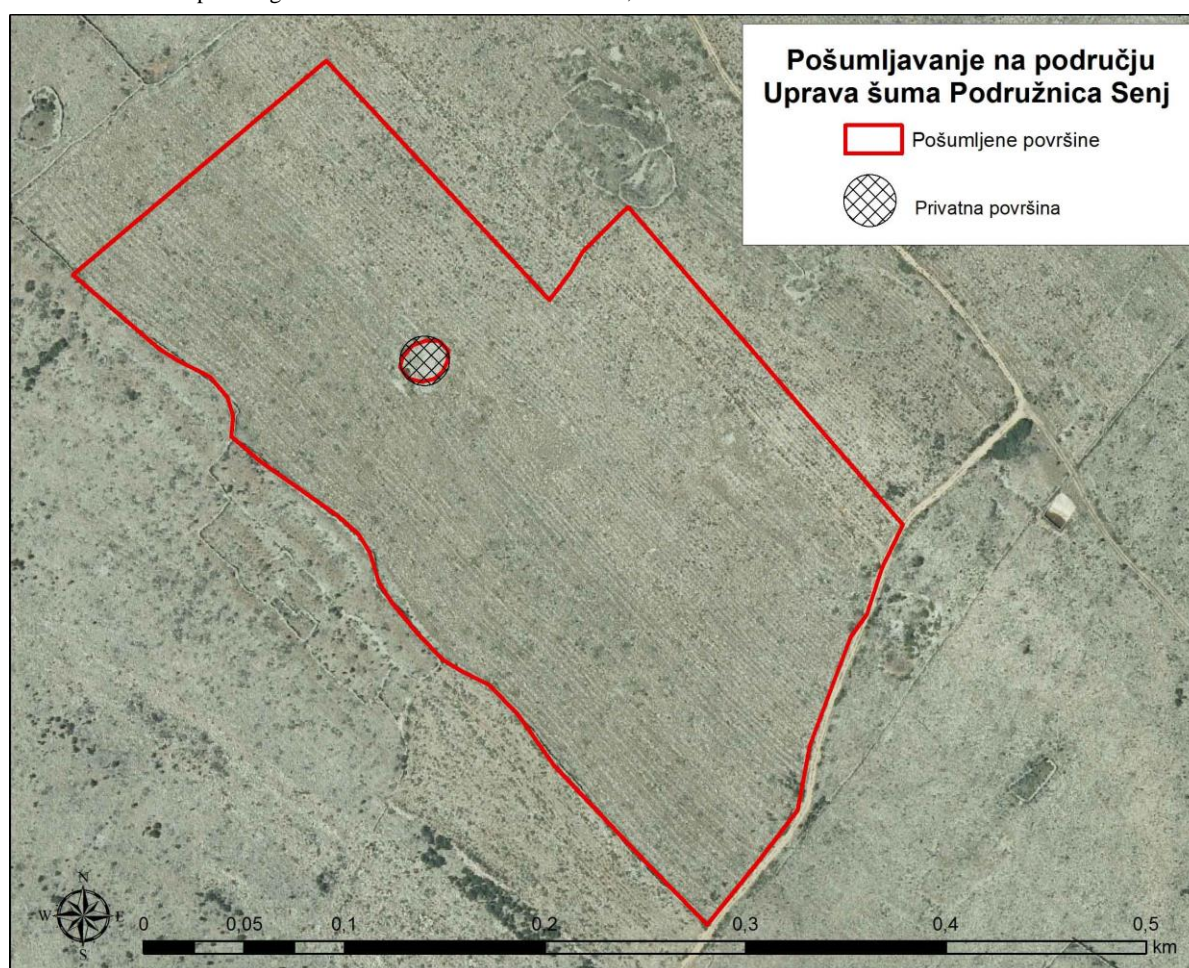
Total area of grassland, annual Cropland and perennial Cropland converted to Forest land in period 1990-2012 for state and private owned forests through afforestation measures (seeding and planting and human induced promotion of natural seed sources) on yearly bases as it is determined through conducted 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 (kha)

Year	LUCs		
	aCL – FL	pCL - FL	GL - FL
1990	NO	NO	NO
1991	NO	NO	0.213
1992	NO	NO	0.163
1993	NO	NO	0.298
1994	NO	NO	0.259

Year	LUCs		
	aCL – FL	pCL - FL	GL - FL
1995	NO	NO	0.232
1996	NO	NO	0.287
1997	NO	NO	0.196
1998	NO	NO	0.260
1999	NO	NO	0.332
2000	NO	NO	0.244
2001	NO	NO	0.254
2002	NO	NO	0.299
2003	NO	NO	0.283
2004	NO	NO	0.613
2005	NO	NO	2.985
2006	NO	NO	2.809
2007	NO	NO	3.880
2008	NO	NO	1.750
2009	NO	NO	4.328
2010	NO	NO	4.644
2011	NO	NO	5.904
2012	NO	NO	4.760
2013	0.30	0.03	6.814
2014	0.38	0.04	7.929
2015	0.551	0.054	5.775
2016	NO	NO	1.427
2017	NO	NO	3.931
2018	NO	NO	1.733
2019	NO	NO	0.537
2020	NO	NO	3.342

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. Detailed description of work performed is presented in Croatian NIR 2020, Chapter 11.1.3.

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 IPCC 2006 Guideline 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 IPCC 2006 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 from IPCC 2006 Guidelines were used (0.4 (for coniferous in age class ≤ 20 years), 0.29 (for coniferous in age class ≥ 20 years), 0.46 (for deciduous) in both age classes). Regarding the maquies and shrub forests the expert judgement was applied when deciding to use the value of 0.46 from IPCC 2006 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 analyzed 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 Forestland.

The estimates of the soil carbon stock changes at land converted to forest land (afforestation) follow the equation below:

$\Delta C_{LFMineral} = [(SOC_{ref} - SOC_{Non Forest Land}) \times A_{Aff}]/T_{Aff}$

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 and from forests are calculated using the Equation 2.23 form the IPCC 2006 GL as follows:

$$\Delta C_{LT} = A * (C_n - C_o)/T$$

ΔC_{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	Biomass net carbon stock change	Net soil carbon stock change	Net carbon sock change in litter	Net carbon sock change in deadwood	Total
	Gg C						
1990	8.07	0.00	8.07	-1.040	0.81	0.04	7.88
1991	8.15	-0.92	7.23	-1.050	0.82	0.04	7.04
1992	8.08	-0.70	7.38	-1.040	0.81	0.04	7.19
1993	8.34	-1.28	7.06	-1.080	0.84	0.04	6.86
1994	8.50	-1.11	7.39	-1.100	0.85	0.04	7.18
1995	8.60	-0.99	7.60	-1.110	0.86	0.04	7.40
1996	8.83	-1.23	7.60	-1.140	0.89	0.04	7.39
1997	8.87	-0.84	8.02	-1.140	0.89	0.04	7.82
1998	9.04	-1.12	7.92	-1.170	0.9	0.05	7.70
1999	9.35	-1.42	7.92	-1.210	0.94	0.05	7.70
2000	9.50	-1.05	8.45	-1.230	0.95	0.05	8.22
2001	9.66	-1.09	8.57	-1.250	0.97	0.05	8.34
2002	9.94	-1.29	8.65	-1.280	0.99	0.05	8.42
2003	10.17	-1.22	8.95	-1.310	1.01	0.05	8.71
2004	11.45	-2.63	8.82	-1.430	1.11	0.09	8.58
2005	13.28	-12.82	0.46	-2.260	1.75	0.11	0.06
2006	14.97	-12.06	2.90	-3.030	2.35	0.13	2.35
2007	17.30	-16.66	0.64	-4.120	3.19	0.16	-0.13
2008	20.13	-7.52	12.61	-4.580	3.55	0.21	11.79

Year	Biomass carbon stocks gains	Biomass carbon stocks losses	Biomass net carbon stock change	Net soil carbon stock change	Net carbon sock change in litter	Net carbon sock change in deadwood	Total
2009	24.47	-18.59	5.88	-5.800	4.5	0.28	4.86
2010	31.02	-19.94	11.07	-7.160	5.56	0.38	9.85
2011	35.38	-25.36	10.02	-8.840	6.86	0.44	8.48
2012	44.40	-20.44	23.96	-10.190	7.91	0.60	22.27
2013	52.67	-29.26	23.40	-12.110	9.4	0.72	21.42
2014	60.45	-34.05	26.40	-14.370	11.15	0.85	24.03
2015	64.22	-24.80	39.42	-16.000	12.42	0.91	36.75
2016	67.40	-6.13	61.27	-16.340	12.68	0.97	58.57
2017	70.92	-16.88	54.04	-17.440	13.53	1.02	51.15
2018	71.77	-7.44	64.33	-17.870	13.87	1.04	61.36
2019	71.55	-2.31	69.24	-17.930	13.92	1.09	66.32
2020	71.81	-1.47	70.35	-17.960	13.94	1.27	67.59

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

Inputs	Uncertainty	Source of information
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
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

Inputs	Uncertainty	Source of information
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
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 General FMAP 2016-2025 is developed using the data from increased number of forest plans/programs for private forests comparing to the General FMAP 2006-2015, the recalculation of forest areas according to the forest types has been performed. In addition, small correction in wood densities for Coniferous and Deciduous type of forests has been needed because of the General FMAP 2016-2025 data application. Also, nationally determined value in biomass CS in perennial Cropland was applied for this year reporting. The improvements introduced resulted with the decrease of removals in total Forest land category for 3.4% comparing the NIR 2021 and NIR 2022 data.

The detailed description of the performed work has been given in KP Chapter of this report (11.3.1.7)

The result of the performed recalculation can be seen in Figure 6.4-3.

Figure 6.4-3: Current and previously reported emissions for category 4.A (kt CO_2)
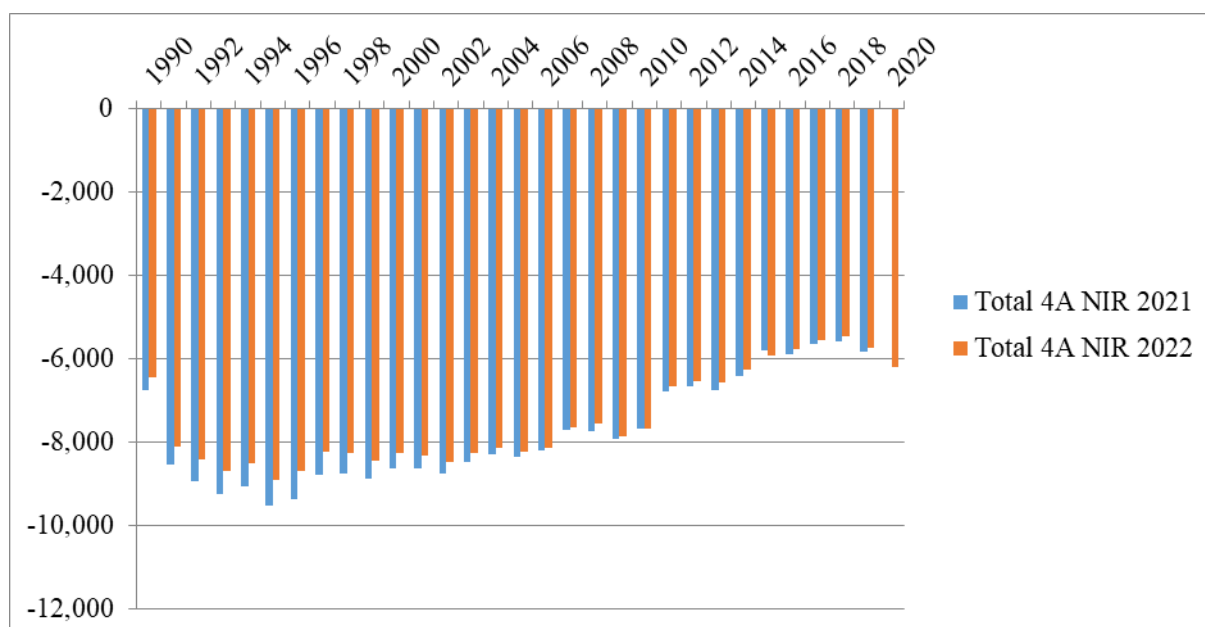
6.4.6. Category-specific planned improvements

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 nw.

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.

Cropland area ranged from 1,527.29 to 1,625.38 in the period 1990-2020. Total emissions from cropland category ranged from 13.75 kt CO_{2eq} to 524.73 ktCO_{2eq} 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 to cropland in the period 1990-2020.

Table 6.5-1: Activity Data of Cropland from 1990 to 2020 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 Fores land converted to perrenial cropland	4.B.2.2.a Grassland converted to annual	4.B.2.2.b Grassland converted to perennial cropland
1990	1,625.38	1,625.029	1,480.352	144.611	0.021	0.045	0.348	NO	0.3252	0.0223
1991	1,625.00	1,623.78	1,479.976	143.421	0.155	0.224	1.234	NO	0.94	0.29
1992	1,624.69	1,623	1,481	142	0.155	0.224	1.234	NO	0.94	0.29
1993	1,624	1,623	1,483	140	0.155	0.224	1.234	NO	0.94	0.29
1994	1,624	1,623	1,484	138	0.155	0.224	1.234	NO	0.94	0.29
1995	1,624	1,622	1,485	137	0.155	0.224	1.234	NO	0.94	0.29
1996	1,623	1,622	1,486	135	0.155	0.224	1.234	NO	0.94	0.29
1997	1,623	1,622	1,488	133	0.155	0.224	1.234	NO	0.94	0.29
1998	1,622	1,621	1,489	132	0.155	0.224	1.234	NO	0.94	0.29
1999	1,622	1,621	1,489	131	0.155	0.224	1.234	NO	0.94	0.29
2000	1,622	1,621	1,621	122	0.155	0.224	1.234	NO	0.94	0.29
2001	1,616	1,615	1,615	120	0.155	0.224	1.234	NO	0.94	0.29
2002	1,610	1,609	1,609	120	0.155	0.224	1.234	NO	0.94	0.29
2003	1,604	1,603	1,603	120	0.155	0.224	1.234	NO	0.94	0.29
2004	1,598	1,597	1,597	122	0.155	0.224	1.276	0.04	0.94	0.29
2005	1,590	1,588	1,588	121	0.155	0.224	1.264	0.03	0.94	0.29

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 Fores land converted to perennial cropland	4.B.2.2.a Grassland converted to annual	4.B.2.2.b Grassland converted to perennial cropland
2006	1,581	1,580	1,580	125	0.155	0.224	1.261	0.03	0.94	0.29
2007	1,577	1,572	1,569	133	3.951	0.917	5.458	0.15	4.31	1.00
2008	1,576	1,570	1,567	139	3.951	0.917	5.443	0.13	4.31	1.00
2009	1,572	1,566	1,563	141	3.951	0.917	5.798	0.49	4.31	1.00
2010	1,567	1,562	1,559	130	3.951	0.917	5.482	0.17	4.31	1.00
2011	1,561	1,556	1,553	130	3.951	0.917	5.479	0.17	4.31	1.00
2012	1,556	1,551	1,548	122	3.951	0.917	5.416	NO	4.31	1.00
2013	1,549	1,549	1,549	119	0.013	0.075	0.245	NO	0.07	0.10
2014	1,541	1,540	1,541	134	0.013	0.075	0.191	NO	0.07	0.10
2015	1,534	1,534	1,534	125	0.013	0.075	0.341	NO	0.07	0.10
2016	1,532.969	1,533	1,533	115	0.013	0.075	0.184	NO	0.07	0.10
2017	1,528.957	1,529	1,529	123	0.013	0.075	0.170	NO	0.07	0.10
2018	1,528.341	1,528	1,528	124	0.013	0.075	0.170	NO	0.07	0.10
2019	1,527.301	1,527	1,527	122	0.013	0.075	0.170	NO	0.07	0.10
2020	1,525.985	1,526	1,526	122	0.013	0.075	0.170	NO	0.07	0.10

Table 6.5-2: Emissions (+) / removals (-) of CO2 in Cropland from 1990 to 2020 (kt CO2 equivalent)

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	N_2O in CO_2 eq
1990	118.86	89.06	29.80	0.00	25.85	NO	NO	NO	3.95
1991	132.06	98.28	33.78	0.00	29.43	NO	NO	NO	4.36
1992	134.39	97.83	36.57	0.00	31.81	NO	NO	NO	4.76
1993	136.73	97.38	39.35	0.00	34.19	NO	NO	NO	5.16
1994	139.06	96.93	42.14	0.00	36.58	NO	NO	NO	5.56
1995	141.40	96.48	44.92	0.00	38.96	NO	NO	NO	5.96
1996	143.73	96.02	47.71	0.00	41.34	NO	NO	NO	6.36
1997	146.06	95.57	50.49	0.00	43.73	NO	NO	NO	6.76
1998	148.40	95.12	53.27	0.00	46.11	NO	NO	NO	7.16
1999	150.73	94.67	56.06	0.00	48.49	NO	NO	NO	7.57

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	N_2O in CO_2 eq
2000	153.07	94.22	58.84	0.00	50.88	NO	NO	NO	7.97
2001	155.40	93.77	61.63	0.00	53.26	NO	NO	NO	8.37
2002	157.73	93.32	64.41	0.00	55.64	NO	NO	NO	8.77
2003	160.07	92.87	67.20	0.00	58.03	NO	NO	NO	9.17
2004	164.24	92.42	71.82	1.84	60.41	NO	NO	NO	9.57
2005	165.97	91.97	74.00	1.23	62.79	NO	NO	NO	9.97
2006	168.15	91.52	76.63	1.08	65.18	NO	NO	NO	10.38
2007	381.70	283.83	97.87	9.60	75.39	NO	NO	NO	12.89
2008	404.79	292.66	112.13	5.27	91.48	NO	NO	NO	15.39
2009	447.44	301.49	145.94	20.50	107.56	NO	NO	NO	17.90
2010	460.20	310.33	149.87	5.84	123.64	NO	NO	NO	20.41
2011	487.33	319.61	167.72	7.89	137.34	NO	NO	NO	22.52
2012	507.48	328.89	178.59	2.95	151.04	NO	NO	NO	24.63
2013	318.96	136.24	182.71	3.90	154.77	NO	NO	NO	24.08
2014	309.64	136.51	173.13	-1.60	151.22	NO	NO	NO	23.54
2015	325.64	136.78	188.85	18.22	147.68	NO	NO	NO	22.99
2016	304.22	137.05	167.17	0.63	144.14	NO	NO	NO	22.44
2017	296.84	137.32	159.52	-2.93	140.59	NO	NO	NO	21.89
2018	293.02	137.59	155.43	-2.93	137.05	NO	NO	NO	21.35
2019	289.20	137.86	151.34	-2.93	133.51	NO	NO	NO	20.80
2020	285.38	138.13	147.25	-2.93	129.97	NO	NO	NO	20.25

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 remaining annual and perennial remaining perennial cropland

2. annual cropland converted to perennial cropland

3. perennial cropland converted to annual cropland.

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[42]) 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

The IPCC default value of 2.1 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 ΔC_{Growth} + annual area of currently converted land x $L_{Conversion}$

where:

$$L_{Conversion} = C_{After} - C_{Before}$$

ΔC_{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

---

[42] 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[43]), as well as expansion factors from the Austrian Expert Panel for Soil Fertility[44]. 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:

$$L_{Conversion} = C_{After} - C_{Before}$$

ΔC_{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[45]. 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

---

[43] Bulgaria's National Inventory Report for 2012; Austria's National Inventory Report 2012; Luxembourg's National Inventory Report 2012. See list of References

[44] Bulgaria's National Inventory Report for 2012; Austria's National Inventory Report 2012; Luxembourg's National Inventory Report 2012. See list of References

[45] Work performed by Croatian Geological Institute. See list of References

LULUCF categories of land[46]. 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) approach, 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

ΔSOC = $(SOC_0 - SOC_{0-T})/20$ = 0.95 tC/ha annually

where:

ΔSOC = 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

ΔSOC = $(SOC_0 - SOC_{0-T})/20$ = -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 2019 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 $GgCO_2$ 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 x EF

[46] Work performed by Croatian Geological Institute, Croatian forest Institut Jastrebarsko and Agency for Agricultural land .
   See list of References ("SOC stock changes, total nitrogen and total organic carbon trends, C:N ratio")

where:

$\Delta C_{CC\ Organic}$ = CO_2 emissions from cultivated organic soils (tC/year)

A= land area of organic soils (ha)

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)

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 1990-2019. 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:

-    2.10 tC/ha – for biomass growth in perennial cropland (default, IPCC)

-    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:

-    56.1 tC/ha when calculating losses due to conversion of deciduous forests to perennial Cropland (including below-ground biomass),

-    7.6 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:

ΔC_{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 (m³/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 deadwood stock

	Forest type	Standing deadwood	Lying deadwood
Deadwood stock (m³/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, BEF2 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	BEF2	R/S	Carbon fraction	Deadwood carbon
	(t d.m./m³)			(CF) (t C/ 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: Deadwood 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 (ha)	Deadwood carbon stock change (GgC)
1990	0.00	0.00
1991	0.00	0.00
1992	0.00	0.00
1993	0.00	0.00
1994	0.00	0.00
1995	0.00	0.00
1996	0.00	0.00
1997	0.00	0.00

Year	Area of deforestated land (ha)	Deadwood carbon stock change (GgC)
1998	0.00	0.00
1999	0.00	0.00
2000	0.00	0.00
2001	0.00	0.00
2002	0.00	0.00
2003	0.00	0.00
2004	0.04	-0.02
2005	0.03	-0.01
2006	0.03	-0.01
2007	0.15	-0.14
2008	0.13	-0.06
2009	0.49	-0.22
2010	0.17	-0.08
2011	0.17	-0.13
2012	0.10	-0.06
2013	0.08	-0.10
2014	0.02	-0.01
2015	0.17	-0.35
2016	0.01	-0.07
2017	0.00	0.00
2018	0.00	0.00
2019	0.00	0.00
2020	0.00	0.00

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.

6.5.2.3.   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, 0.17 kha of grassland area were converted to cropland in 2020. 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 2020 in emissions of 129.97 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 ($L_{Conversion}$ + ΔC_{Growth})

where:

$L_{Conversion}$ = C_{After} - C_{Before}

ΔC_{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 IPCC 2006 Guidelines, Tier 1 equation was applied, as follows:

$$\Delta SOC = (SOC_0 - SOC_{0-T})/20$$

ΔSOC = 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 -2.04 Gg C for grassland converted to perennial cropland for the period 1990-2020. In case of grassland converted to annual cropland, removals were from -7.49 to -36.88 Gg C.

6.5.2.4. 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:

$N_2O_{net-min}$ - N = EF_1 x $\Delta C_{LCmineral}$ x 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 2022 reporting Croatia used nationally determined value for biomass CS in perennial cropland (17.8 tC/ha) as well as value for pCL biomass growth of 0.45 tC/ha*y, as a result of conducted LULUCF 3 project. Basic information on the tasks of this project are provided in Annex 3.2. The introduced improvements in Croatian reporting resulted in decrease of the total emissions for CL category for 0.33% comparing the total emissions in NIR 2021 and NIR 2022.

Figure 6.5-1: Current and previously reported emissions for category 4.B (kt CO_2 eq.)
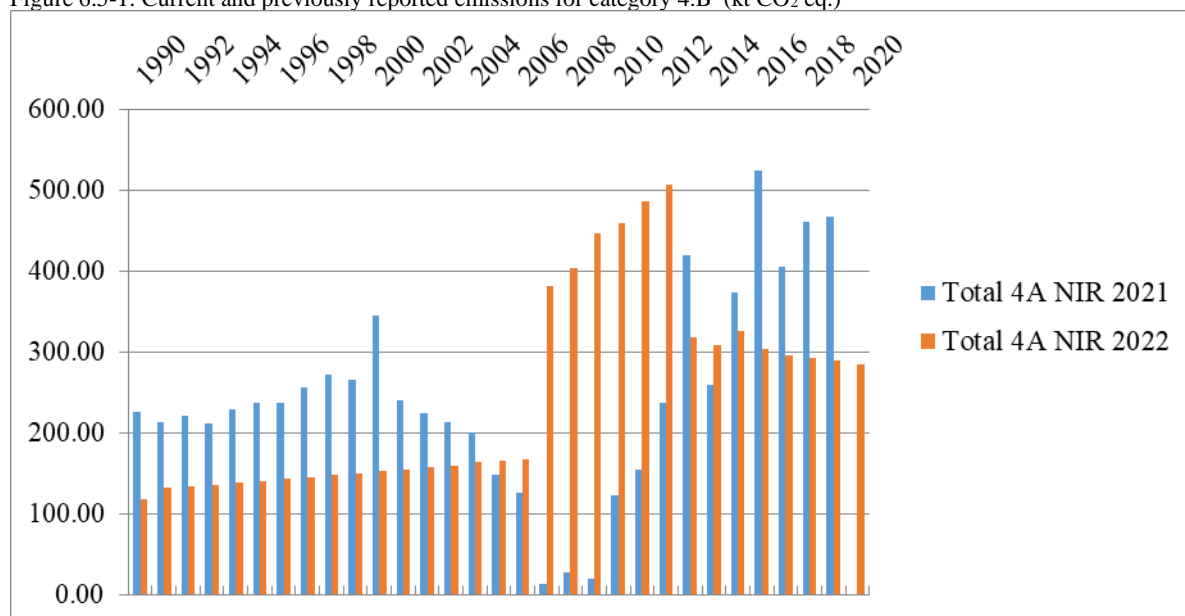
6.5.6. Category-specific planned improvements

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 1990-2020. The change in carbon stock in biomass and soil ranges from removals –7.88 $ktCO_2$ to -311.36 $ktCO_2$ in period 1990-2020.

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 do not exist in the grassland category, so they are not subject to this report.

Tables 6.6-1 and 6.6-2 show the land use change and removals/emissions from LUC to grassland in the period from 1990 to 2020.

Table 6.6-1: Activity Data of Grassland in the period 1990-2020 in kha

Year	4.C Grassland - Total	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	1,201.06	1,201.06	0.00	NO	NO	0.00	0.00	NO	NO
1991	1,200.67	1,199.44	1.23	NO	NO	1.02	0.22	NO	NO
1992	1,200.28	1,199.10	1.18	NO	NO	0.97	0.21	NO	NO
1993	1,199.90	1,198.58	1.32	NO	NO	1.10	0.22	NO	NO
1994	1,199.51	1,198.25	1.26	NO	NO	1.04	0.22	NO	NO
1995	1,199.12	1,197.87	1.25	NO	NO	1.03	0.22	NO	NO
1996	1,198.73	1,197.43	1.31	NO	NO	1.09	0.22	NO	NO
1997	1,198.35	1,197.16	1.19	NO	NO	0.98	0.21	NO	NO
1998	1,197.96	1,196.71	1.24	NO	NO	1.03	0.22	NO	NO
1999	1,197.57	1,196.23	1.34	NO	NO	1.12	0.22	NO	NO
2000	1,197.18	1,195.98	1.21	NO	NO	0.99	0.21	NO	NO
2001	1,196.80	1,193.66	3.14	NO	NO	2.75	0.39	NO	NO
2002	1,196.41	1,193.18	3.23	NO	NO	2.83	0.40	NO	NO
2003	1,196.02	1,192.76	3.26	NO	NO	2.86	0.40	NO	NO
2004	1,195.63	1,192.11	3.52	NO	NO	3.10	0.42	NO	NO
2005	1,195.24	1,189.37	5.88	NO	NO	5.24	0.63	NO	NO
2006	1,194.86	1,189.15	5.71	NO	NO	5.09	0.62	NO	NO
2007	1,188.82	1,183.54	5.29	NO	NO	4.58	0.71	NO	NO
2008	1,182.79	1,179.71	3.09	NO	NO	2.58	0.51	NO	NO
2009	1,176.76	1,171.04	5.72	NO	NO	4.97	0.75	NO	NO
2010	1,170.73	1,164.71	6.01	NO	NO	5.24	0.77	NO	NO
2011	1,164.69	1,157.37	7.33	NO	NO	6.44	0.89	NO	NO
2012	1,158.66	1,152.52	6.14	NO	NO	5.36	0.79	NO	NO
2013	1,157.75	1,151.39	6.37	NO	NO	5.80	0.57	NO	NO
2014	1,156.85	1,149.35	7.50	NO	NO	6.83	0.67	NO	NO
2015	1,155.94	1,150.61	5.33	NO	NO	4.85	0.48	NO	NO
2016	1,155.04	1,154.03	1.01	NO	NO	0.92	0.09	NO	NO
2017	1,154.13	1,150.61	3.51	NO	NO	3.20	0.31	NO	NO
2018	1,153.22	1,153.10	0.12	NO	NO	0.11	0.01	NO	NO
2019	1,153.22	1,152.66	0.56	NO	NO	0.51	0.05	NO	NO
2020	1,153.22	1,152.39	0.83	NO	NO	0.75	0.07	NO	NO

Table 6.6-2: Emissions (+) / removals (-) of CO_2 in Grassland 1990-2020 (kt CO_2)

Year	4.C Grassland - Total	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
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	-219.28	2.07	-221.35	NO	-221.35	NO	NO	NO
2014	-233.89	2.07	-235.96	NO	-235.96	NO	NO	NO
2015	-269.89	2.07	-271.96	NO	-271.96	NO	NO	NO
2016	-308.16	2.07	-310.23	NO	-310.23	NO	NO	NO
2017	-294.94	2.07	-297.01	NO	-297.01	NO	NO	NO
2018	-321.61	2.07	-323.68	NO	-323.68	NO	NO	NO
2019	-314.92	2.07	-316.99	NO	-316.99	NO	NO	NO
2020	-311.36	2.07	-313.43	NO	-313.43	NO	NO	NO

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 (IPCC 2006 Guidelines).

The area of grassland remaining grassland in 2020 amounts to 1,070 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 t C/ ha annually). Increase in the carbon stock change from organic soils were determined in the value of 0.56 Gg C annually for the period 1990-2020.

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, 83.5 kha of Cropland area were converted into Grassland in year 2020. The changes of carbon stocks during the conversion from one category to another vary between years. In year 1990 LUCs in this category resulted in removals of -9.95 Gg CO_2 and -313.43 GgCO_2 in year 2020.

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 ($L_{Conversion}$ + ΔC_{Growth})

where:

$$L_{Conversion} = C_{After} - C_{Before}$$

ΔC_{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:

ΔSOC = 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 2020 was 85.25GgC and for perennial cropland converted to grassland was 2.29 Gg 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 DW 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 2022 reporting Croatia used nationally defined CS in biomass pool for perennial Cropland (17.8 tC/ha) instead of previously used value of 63 tC/ha from 2006 GL. This contributed to the significant increase in removals in total category of Grassland as presented in Figure 6.6-1.

Figure 6.6-1: Current and previously reported emissions for category 4.C (kt CO_2)
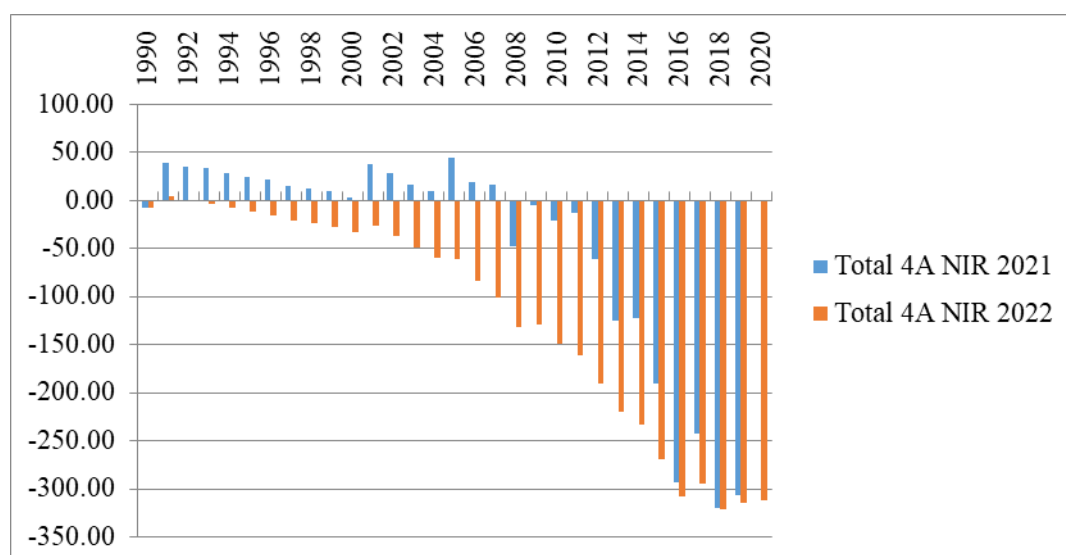
6.6.6. Category-specific planned improvements

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 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 wetland area ranged from 73.86 kha in 1990 to 75.21 kha in 2020.

The land use change and removals/emissions from the IPCC land use categories to Wetland in the period 1990-2020 are presented in Tables 6.7-1 and 6.7-2.

Table 6.7-1: Activity data of wetland in the period 1990-2020 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 Pereremnial 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	73.51	0.35	NO	0.32	0.03	NO	NO	NO
1991	73.90	73.86	0.04	NO	0.04	0.00	NO	NO	NO
1992	73.95	73.90	0.04	NO	0.04	0.00	NO	NO	NO
1993	73.99	73.95	0.04	NO	0.04	0.00	NO	NO	NO
1994	74.03	73.99	0.04	NO	0.04	0.00	NO	NO	NO
1995	74.08	74.03	0.04	NO	0.04	0.00	NO	NO	NO
1996	74.12	74.08	0.04	NO	0.04	0.00	NO	NO	NO
1997	74.17	74.12	0.04	NO	0.04	0.00	NO	NO	NO
1998	74.21	74.17	0.04	NO	0.04	0.00	NO	NO	NO
1999	74.25	74.21	0.04	NO	0.04	0.00	NO	NO	NO
2000	74.30	74.25	0.04	NO	0.04	0.00	NO	NO	NO
2001	74.32	74.30	0.02	NO	0.02	0.00	NO	NO	NO
2002	74.34	74.32	0.02	NO	0.02	0.00	NO	NO	NO
2003	74.36	74.34	0.02	NO	0.02	0.00	NO	NO	NO
2004	74.38	74.36	0.02	NO	0.02	0.00	NO	NO	NO
2005	74.40	74.38	0.02	NO	0.02	0.00	NO	NO	NO
2006	74.42	74.40	0.02	NO	0.02	0.00	NO	NO	NO
2007	74.47	74.42	0.05	NO	0.04	0.00	NO	NO	NO
2008	74.52	74.47	0.05	NO	0.04	0.00	NO	NO	NO
2009	74.56	74.52	0.05	NO	0.04	0.00	NO	NO	NO
2010	74.61	74.56	0.05	NO	0.04	0.00	NO	NO	NO
2011	74.66	74.61	0.05	NO	0.04	0.00	NO	NO	NO
2012	74.70	74.66	0.05	NO	0.04	0.00	NO	NO	NO
2013	74.77	74.70	0.07	NO	0.07	0.01	NO	NO	NO
2014	74.85	74.77	0.07	NO	0.07	0.01	NO	NO	NO
2015	74.92	74.85	0.07	NO	0.07	0.01	NO	NO	NO
2016	74.99	74.92	0.07	NO	0.07	0.01	NO	NO	NO

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
2017	75.07	74.99	0.07	NO	0.07	0.01	NO	NO	NO
2018	75.14	75.07	0.07	NO	0.07	0.01	NO	NO	NO
2019	75.21	75.14	0.07	NO	0.07	0.01	NO	NO	NO
2020	75.28	75.21	0.07	NO	0.07	0.01	NO	NO	NO

Table 6.7-2: Emissions of wetland in the period 1990-2020 in ktCO$_2$

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$_2$O in CO$_2$eq)
1990	88.34	NE	88.34	0.00	77.23	NO	NO	NO	88.34
1991	78.14	NE	78.14	0.00	67.51	NO	NO	NO	78.14
1992	74.61	NE	74.61	0.00	64.47	NO	NO	NO	74.61
1993	71.08	NE	71.08	0.00	61.43	NO	NO	NO	71.08
1994	67.55	NE	67.55	0.00	58.39	NO	NO	NO	67.55
1995	64.02	NE	64.02	0.00	55.34	NO	NO	NO	64.02
1996	60.50	NE	60.50	0.00	52.30	NO	NO	NO	60.50
1997	56.97	NE	56.97	0.00	49.26	NO	NO	NO	56.97
1998	53.44	NE	53.44	0.00	46.21	NO	NO	NO	53.44
1999	49.91	NE	49.91	0.00	43.17	NO	NO	NO	49.91
2000	46.38	NE	46.38	0.00	40.13	NO	NO	NO	46.38
2001	42.09	NE	42.09	0.00	36.36	NO	NO	NO	42.09
2002	38.30	NE	38.30	0.00	33.09	NO	NO	NO	38.30
2003	34.50	NE	34.50	0.00	29.82	NO	NO	NO	34.50
2004	30.71	NE	30.71	0.00	26.55	NO	NO	NO	30.71
2005	26.92	NE	26.92	0.00	23.28	NO	NO	NO	26.92
2006	23.13	NE	23.13	0.00	20.01	NO	NO	NO	23.13
2007	20.18	NE	20.18	0.00	17.54	NO	NO	NO	20.18
2008	16.68	NE	16.68	0.00	14.53	NO	NO	NO	16.68
2009	13.19	NE	13.19	0.00	11.51	NO	NO	NO	13.19
2010	9.69	NE	9.69	0.00	8.49	NO	NO	NO	9.69
2011	9.72	NE	9.72	0.00	8.52	NO	NO	NO	9.72

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_2eq)
2012	9.75	NE	9.75	0.00	8.55	NO	NO	NO	9.75
2013	10.65	NE	10.65	0.00	9.41	NO	NO	NO	10.65
2014	10.99	NE	10.99	0.00	9.69	NO	NO	NO	10.99
2015	11.32	NE	11.32	0.00	9.98	NO	NO	NO	11.32
2016	11.65	NE	11.65	0.00	10.27	NO	NO	NO	11.65
2017	11.99	NE	11.99	0.00	10.56	NO	NO	NO	11.99
2018	12.32	NE	12.32	0.00	10.84	NO	NO	NO	12.32
2019	12.65	NE	12.65	0.00	11.13	NO	NO	NO	12.65
2020	12.99	NE	12.99	0.00	11.42	NO	NO	NO	12.99

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.

6.7.2.2. Cropland Converted to Wetland (4.D.2.2)

Changes in Carbon stocks in Biomass of Cropland and Grassland Converted to Wetland

For the calculation of the annual change in carbon stocks of living biomass in cropland converted to wetland the IPCC 2006 Guidelines equation 7.10 was applied.

The annual change in carbon stocks of living biomass in Cropland converted to Wetland (t C/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:

$$\Delta C_{LW\ flood} = \sum A_i \times (B_{after} - B_{before})_i /20$$

where:

A_i = area of land converted to flooded land for a transition period of 20 years, ha

B_{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_{After} = carbon stock in soil immediately after conversion to wetland (default = 0 t C/ha)

N$_2$O Emissions in Soils of Land Converted to Wetland

The annual release of N$_2$O due to the conversion of Cropland to Wetland were calculated using the IPCC default value (Tier 1) and equation 11.8 as follows:

N$_2$O net-min-N = EF1 x ΔCLCmineral x 1/ (C/N ratio)

where:

EF1 = the emission factor for calculating emissions of N$_2$O from N in the soil = 0.01 kg N2O-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 used nationally defined value for CS in biomass pool (17.8 tC/ha). In the estimation under the WL category a half of the stock has been used because the new land use will require the land immediately after the decision of land use change independent of the age of the stocks and half stocks would be the likely average. The application of this value decreased emissions in total Wetland category for 2.8% in NIR 2022 comparing the reported in NIR 2021.

Figure 6.7-1: Current and previously reported emissions for category 4.D (kt CO$_2$ eq.)
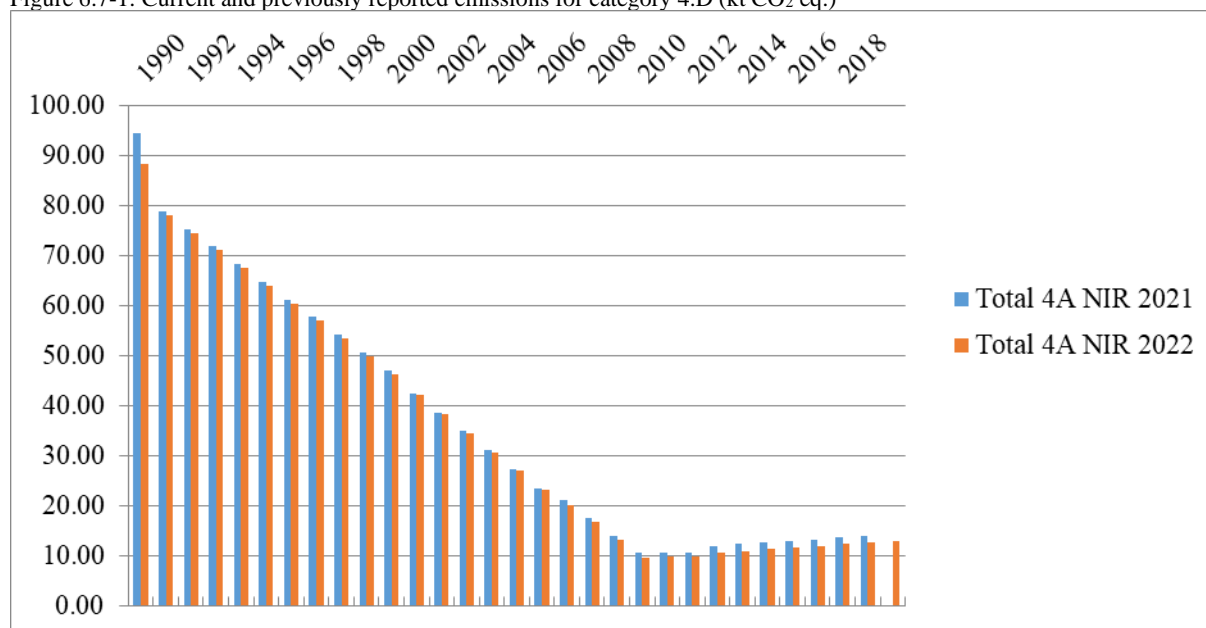
6.7.6. Category-specific planned improvements

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 do not occur in the settlements area.

The settlements area ranges from 200.65 kha in 1990 to 286.11 kha in 2020. Emissions from the change in the carbon stock ranges from -184.23 kt CO$_2$ to 921.76 ktCO$_2$.

Annual LUCs to Settlements occur from the subcategories Forest Land, Cropland (annual and perennial) and Grassland.

Tables 6.8-1 and 6.8-2 show the land use change and removals/emissions from LUC to Settlements in the period 1990 to 2020.

Table 6.8-1: Activity data of Settlements for 1990-2020 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	199.33	1.32	0.00	0.78	0.08	0.46	0.00	0.00
1991	201.15	200.65	0.50	0.00	0.29	0.03	0.17	0.00	0.00
1992	201.64	201.15	0.50	0.00	0.29	0.03	0.17	0.00	0.00
1993	202.14	201.64	0.50	0.00	0.29	0.03	0.17	0.00	0.00

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
1994	202.64	202.14	0.50	0.06	0.26	0.03	0.15	0.00	0.00
1995	203.14	202.64	0.50	0.00	0.29	0.03	0.17	0.00	0.00
1996	203.64	203.14	0.50	0.00	0.29	0.03	0.17	0.00	0.00
1997	204.14	203.64	0.50	0.08	0.25	0.02	0.15	0.00	0.00
1998	204.63	204.14	0.50	0.10	0.23	0.02	0.14	0.00	0.00
1999	205.13	204.63	0.50	0.03	0.28	0.03	0.16	0.00	0.00
2000	205.63	205.13	0.50	0.17	0.20	0.02	0.12	0.00	0.00
2001	211.81	205.63	6.18	0.35	3.45	0.34	2.04	0.00	0.00
2002	218.00	211.81	6.18	0.23	3.52	0.35	2.08	0.00	0.00
2003	224.18	218.00	6.18	0.10	3.60	0.36	2.13	0.00	0.00
2004	230.36	224.18	6.18	0.31	3.48	0.34	2.06	0.00	0.00
2005	236.54	230.36	6.18	0.33	3.46	0.34	2.05	0.00	0.00
2006	242.73	236.54	6.18	0.32	3.47	0.34	2.05	0.00	0.00
2007	248.88	242.73	6.15	0.08	3.59	0.36	2.13	0.00	0.00
2008	255.04	248.88	6.15	0.28	3.48	0.34	2.06	0.00	0.00
2009	261.19	255.04	6.15	0.12	3.57	0.35	2.11	0.00	0.00
2010	267.34	261.19	6.15	0.18	3.53	0.35	2.09	0.00	0.00
2011	273.50	267.34	6.15	0.02	3.63	0.36	2.15	0.00	0.00
2012	279.65	273.50	6.15	0.14	3.56	0.35	2.10	0.00	0.00
2013	280.57	279.65	0.92	0.09	0.49	0.05	0.29	0.00	0.00
2014	281.50	280.57	0.92	0.02	0.53	0.05	0.32	0.00	0.00
2015	282.42	281.50	0.92	0.07	0.50	0.05	0.30	0.00	0.00
2016	283.34	282.42	0.92	0.02	0.53	0.05	0.32	0.00	0.00
2017	284.27	283.34	0.92	0.01	0.54	0.05	0.32	0.00	0.00
2018	285.19	284.27	0.92	0.01	0.54	0.05	0.32	0.00	0.00
2019	286.11	285.19	0.92	0.03	0.53	0.05	0.31	0.00	0.00
2020	287.03	286.11	0.92	0.02	0.53	0.05	0.32	0.00	0.00

Table 6.8-2: Emissions of Settlements 1990-2019 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_2eq)
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
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

6.8.2. Methodological issues

6.8.2.1. Land Use Change to Settlements (5.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 46.4 t C/ha. The GPG default value of 63 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 70.6 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 0.2 kha to 2.74 kha in 1990-2020.

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 -0.58.1 to -180.32 Gg C in the period 1990-2020.

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 -0.5 to -7.9 Gg C in the period 1990 to 2020.

Previously, the average annual carbon stock change in dead wood 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:

ΔC_{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 deadwood stock

	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, BEF2 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	BEF2	R/S	Carbon fraction	Deadwood carbon
	(t d.m./m³)			(CF) (t C/ 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: Deadwood carbon stock change (kt C) on the deforested areas due to land use change from Forest land to SL

Year	Area of deforestated land (ha)	Deadwood carbon stock change (GgC)
1990	0.00	0.00
1991	0.00	0.00
1992	0.00	0.00
1993	0.00	0.00
1994	0.02	-0.01
1995	0.00	0.00
1996	0.00	0.00
1997	0.00	-0.00
1998	0.06	-0.03
1999	0.03	-0.01
2000	0.14	-0.07
2001	0.05	-0.02
2002	0.09	-0.04
2003	0.05	-0.02
2004	0.18	-0.21
2005	0.14	-0.15
2006	0.08	-0.12

Year	Area of deforestated land (ha)	Deadwood carbon stock change (GgC)
2007	0.17	-0.46
2008	0.25	-0.51
2009	0.58	-1.71
2010	0.24	-0.62
2011	0.16	-0.53
2012	0.15	-0.37
2013	0.12	-0.23
2014	0.04	-0.08
2015	0.16	-0.38
2016	0.01	-0.003
2017	0.01	-0.003
2018	0.01	-0.003
2019	0.03	-0.014
2020	0.02	-0.009

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 FL to SL 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 51.13 kha in the years 1990 and 2020.

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 -26.9 to -81.2 Gg C in annual cropland and -4.1 to -12.2 Gg C in perennial cropland converted to settlements in the years 1990 and 2020.

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 -18.2 to -80.6 Gg C in annual cropland converted to settlements and from -2.7 to -12.2 Gg C in perennial cropland converted to settlements in years 1990 and 2020.

Regarding this conversion type, Croatia uses Tier 1 for dead wood and litter pools. According to the IPCC 2006 GL litter and DW pools are not present on non-forest categories of land. Consequently, notation key NO is used for these pools in case of CL converted to SL 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 0.12 to 2.15 kha.

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 0.32 to -8.46 Gg C during the period 1990-2020.

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 -40.2 to -180.3 Gg C in the period 1990-2020.

Regarding this conversion type, Croatia uses Tier 1 for dead wood and litter pools. According to the IPCC 2006 GL litter and DW pools are not present on non-forest categories of land. Consequently, notation key NO is used for these pools in case of CL converted to SL 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 forestland, grassland and cropland to Settlement were calculated using the IPCC default value (Tier 1) and equation 11.8 as follows:

$N_2Onet\text{- }min\text{ - }N = EF1 \times \Delta CLCmineral \times 1/(C/N \text{ ratio})$

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)

$\Delta CLCmineral$ = 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 Croatia used nationally defined value for CS in biomass pool (17.8 tC/ha). Half of the stock (8.9 tC/ha) has been used because in the estimation of biomass loss and pCL change to SL since the new land use will require the land immediately after the decision of land use change independent of the age of the stocks and half stocks would be the likely average.

An error when using CLC database to define unsealed settlement area in Croatia has been corrected. This changed a value used in previous reports for CS in biomass (from 0,19 tC/ha to 0.88 tC/ha). As the result of conducted improvements the emissions in total Settlement category in NIR 2022 decreased for 6.1% comparing to the emissions reported in NIR 2021.

The result of the performed recalculation can be seen in Figure 6.8-1.

Figure 6.8-1: Current and previously reported emissions for category 4.E (kt CO_2 eq.)
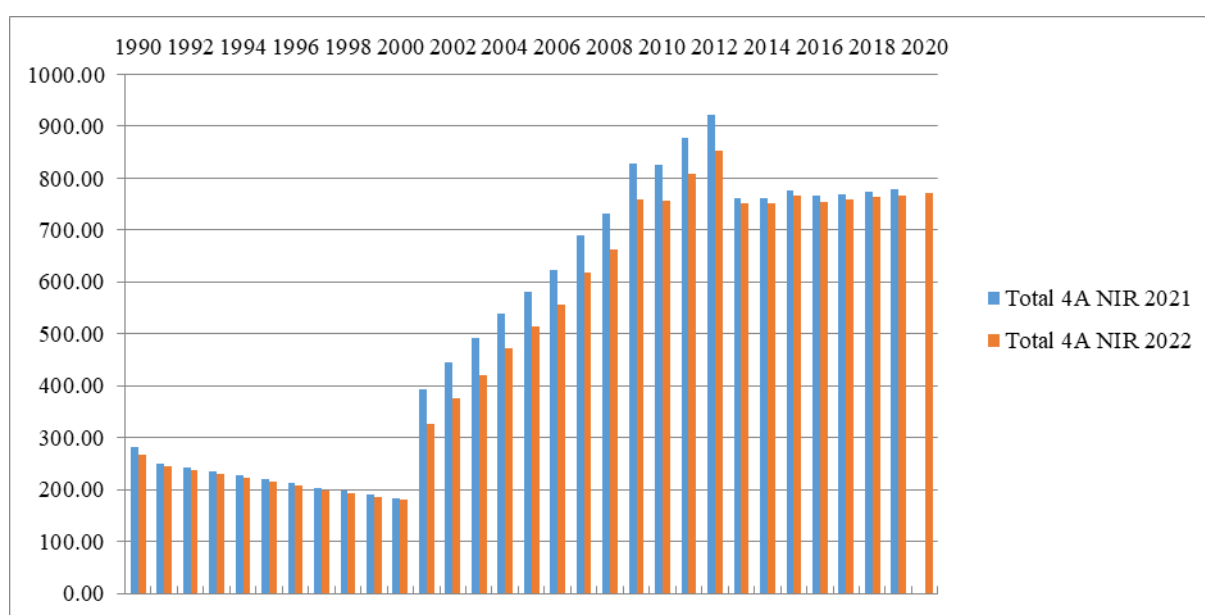
6.8.6. Category-specific planned improvements

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, 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 Forest and 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	71.13	71.13	0.00	NO	NO	NO	NO	NO	NO
1991	71.66	71.66	0.00	NO	NO	NO	NO	NO	NO
1992	72.19	72.19	0.00	NO	NO	NO	NO	NO	NO
1993	72.72	72.72	0.00	NO	NO	NO	NO	NO	NO
1994	73.25	73.25	0.00	NO	NO	NO	NO	NO	NO
1995	73.78	73.78	0.00	NO	NO	NO	NO	NO	NO
1996	74.31	74.31	0.00	NO	NO	NO	NO	NO	NO
1997	74.84	74.84	0.00	NO	NO	NO	NO	NO	NO
1998	75.37	75.37	0.00	NO	NO	NO	NO	NO	NO
1999	75.90	75.90	0.00	NO	NO	NO	NO	NO	NO
2000	76.43	76.43	0.00	NO	NO	NO	NO	NO	NO
2001	72.66	72.66	0.00	NO	NO	NO	NO	NO	NO
2002	68.88	68.88	0.00	NO	NO	NO	NO	NO	NO
2003	65.10	65.10	0.00	NO	NO	NO	NO	NO	NO
2004	61.32	61.32	0.00	NO	NO	NO	NO	NO	NO
2005	57.55	57.55	0.00	NO	NO	NO	NO	NO	NO
2006	53.77	53.77	0.00	NO	NO	NO	NO	NO	NO
2007	54.88	54.88	0.00	NO	NO	NO	NO	NO	NO
2008	55.98	55.98	0.00	NO	NO	NO	NO	NO	NO
2009	57.09	57.09	0.00	NO	NO	NO	NO	NO	NO
2010	58.20	58.20	0.00	NO	NO	NO	NO	NO	NO
2011	59.31	59.31	0.00	NO	NO	NO	NO	NO	NO
2012	60.42	60.42	0.00	NO	NO	NO	NO	NO	NO
2013	62.40	62.40	0.00	NO	NO	NO	NO	NO	NO
2014	64.38	64.38	0.00	NO	NO	NO	NO	NO	NO
2015	66.37	66.37	0.00	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 Forest land 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
2016	68.35	68.35	0.00	NO	NO	NO	NO	NO	NO
2017	70.34	70.34	0.00	NO	NO	NO	NO	NO	NO
2018	72.32	72.32	0.00	NO	NO	NO	NO	NO	NO
2019	74.31	74.31	0.00	NO	NO	NO	NO	NO	NO
2020	76.29	76.29	0.00	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

NA

6.9.6. Category-specific planned improvements

NA

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 1990-2020. The estimation has been based on of HWP production data for Croatia presented in Table 6.10-2.

Table 6.10-1: Emissions/removals from HWPs in the period between 1990-2020 [kt CO_2]

Year	HWP total	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
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

Year	HWP total	Sawn wood	Wood panels	Paper and paper board
2015	-764.15	-859.11	-88.27	183.23
2016	-780.07	-786.78	-21.76	28.47
2017	-1,029.35	-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

Table 6.10-2: HWP produced in Croatia

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
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

Year	Sawn wood (m³)	Wood panels (m³)	Paper and paper board (t)
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
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

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.[47]

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[48], that are and stored / available to the Central Bureau of Statistics (CBS).

For the period before 1961, equation 12.6 from 2006 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]

---

[47] 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")

[48] 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. Statistical Bulletins for period 1971-1989; Important products in the export and import of SR Croatia for period 1976 -1990. See References

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 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):

$$f_{IRW}(i) = \frac{IRWp(i) - IRWex(i)}{IRWp(i) + IRWim(i) - IRWex(i)}$$

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)

The correlation coefficient r = 0.99202183 and the coefficient of determination R2 = 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.

For this year reporting 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 (IPCC 2006 Guidelines, Chapter 12):

$$C(i+1) = e^{-k} * C(i) + \left[\frac{(1-e^{-k})}{k}\right] * Infow(i+1)$$

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 2022 Submission Croatia applied equation 2.8.2 form the KP Supplement and corrected domestically produced wood pulp. The improvement contributed to the increase of total removal in HWP pool in reporting period for 2.9% comparing this year values with reported in NIR 2021.

Figure 6.10-1: Current and previously reported emissions/removals in HWP (kt CO_2)
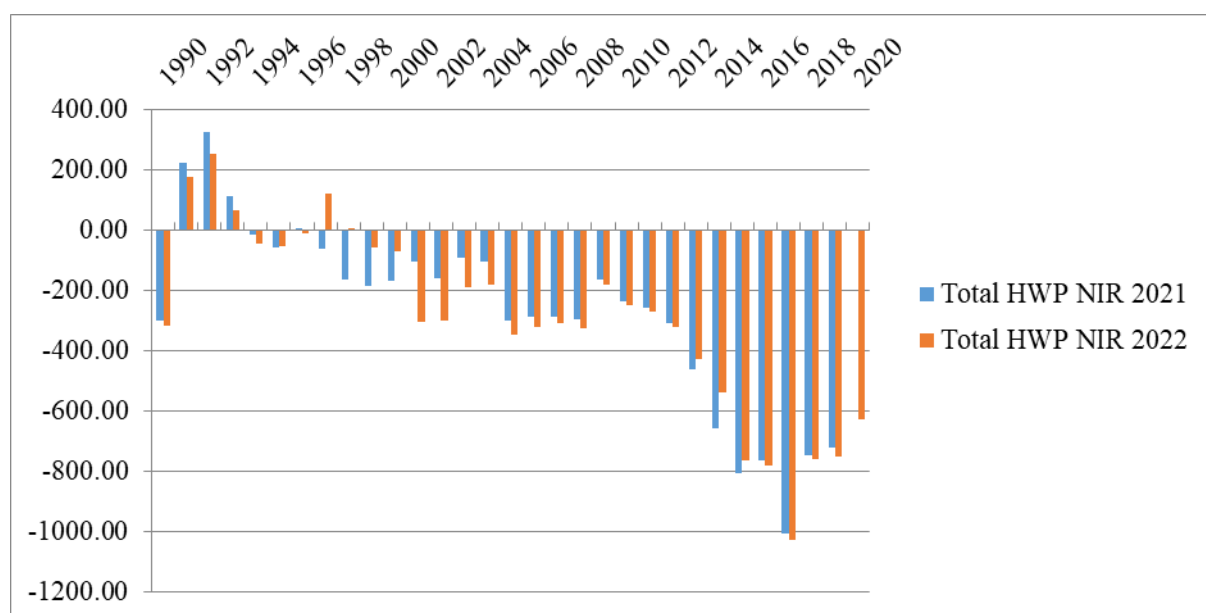
6.10.5. Planned Improvements

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 2023 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 1990-2017 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 IPCC 2006 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:

$N_2O_{net-min} - N = EF_1 \times \Delta C_{LCmineral} \times 1/(C/N\ ratio)$

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 N2O 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)

Under land use change according to latest expert judgement, there are indirect N2O 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*[49] and at that time relevant Ordinance[50]. 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.

---

[49] Forest Act (OG 140/05), Article 40

[50] *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[51] 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[52].

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[53]. 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* [54]and *Ordinance[55]* 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 4.15-2).

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

---

[51] *Ordinance on the method of data collection, conducting the Register and requirements for using data on forest fires* (OG 175/13)

[52] 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

[53] Ibid

[54] Ibid

[55] Ibid

in Croatia (Figure 6.15-3). This work enabled development of the map with detailed spatial information on forest fires (Figure 6.15-4).

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))
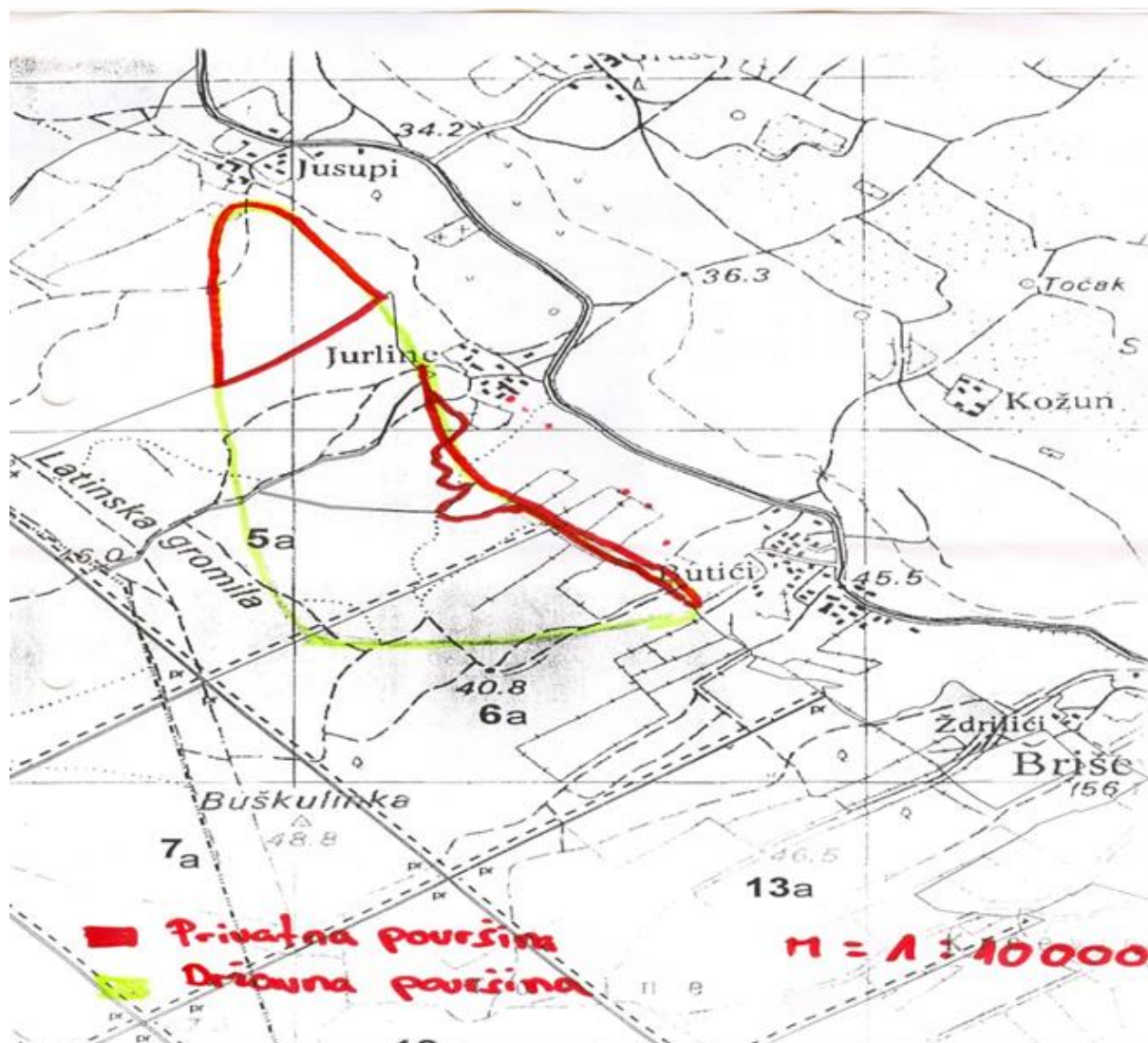
Figure 6.15-2: Map of state-owned forests affected by fires in 2007 defined using GPS (Forest district Split, Forest Office Metković, Management unit Šibovnica; total affected area 77.10 ha)

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)
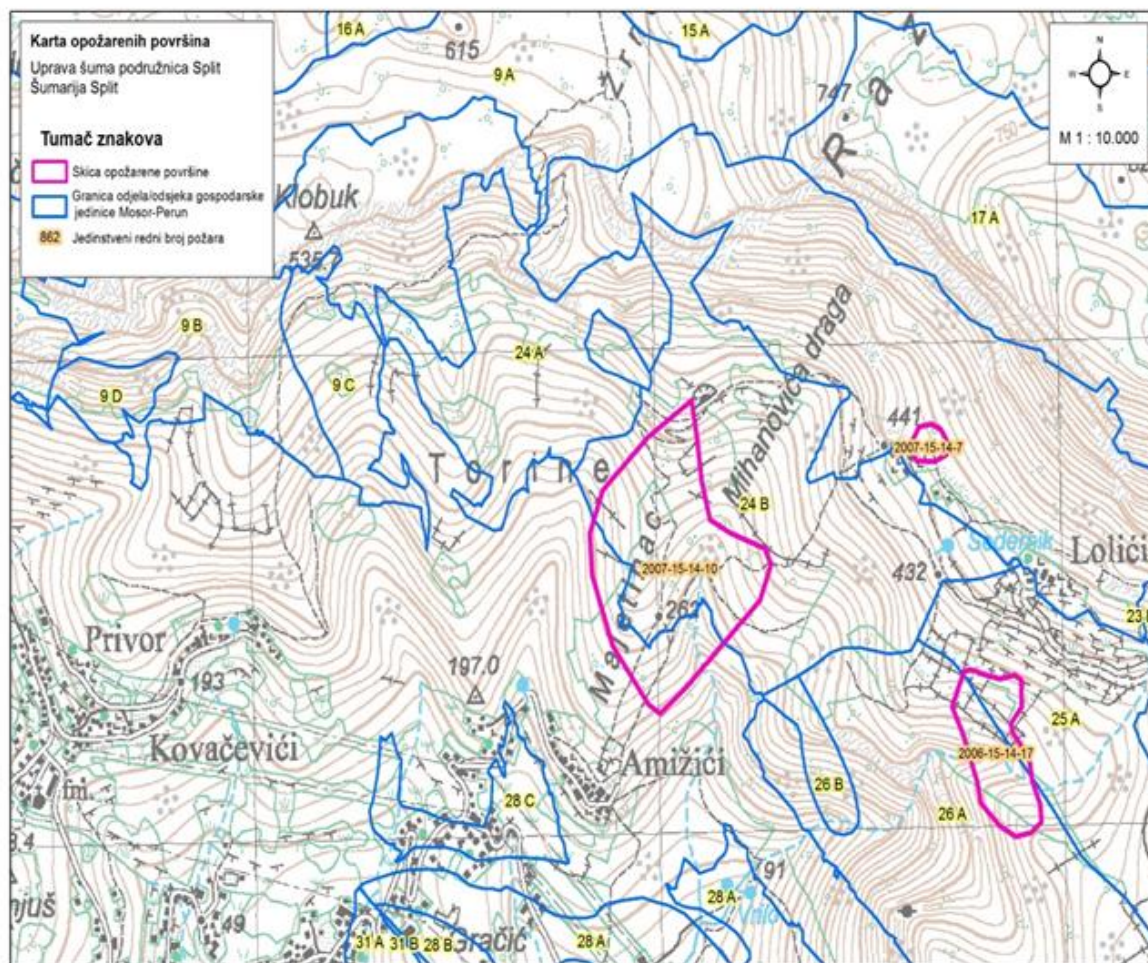
Figure 6.15-4: Spatial distribution of forest fires in Croatia 2013-2019
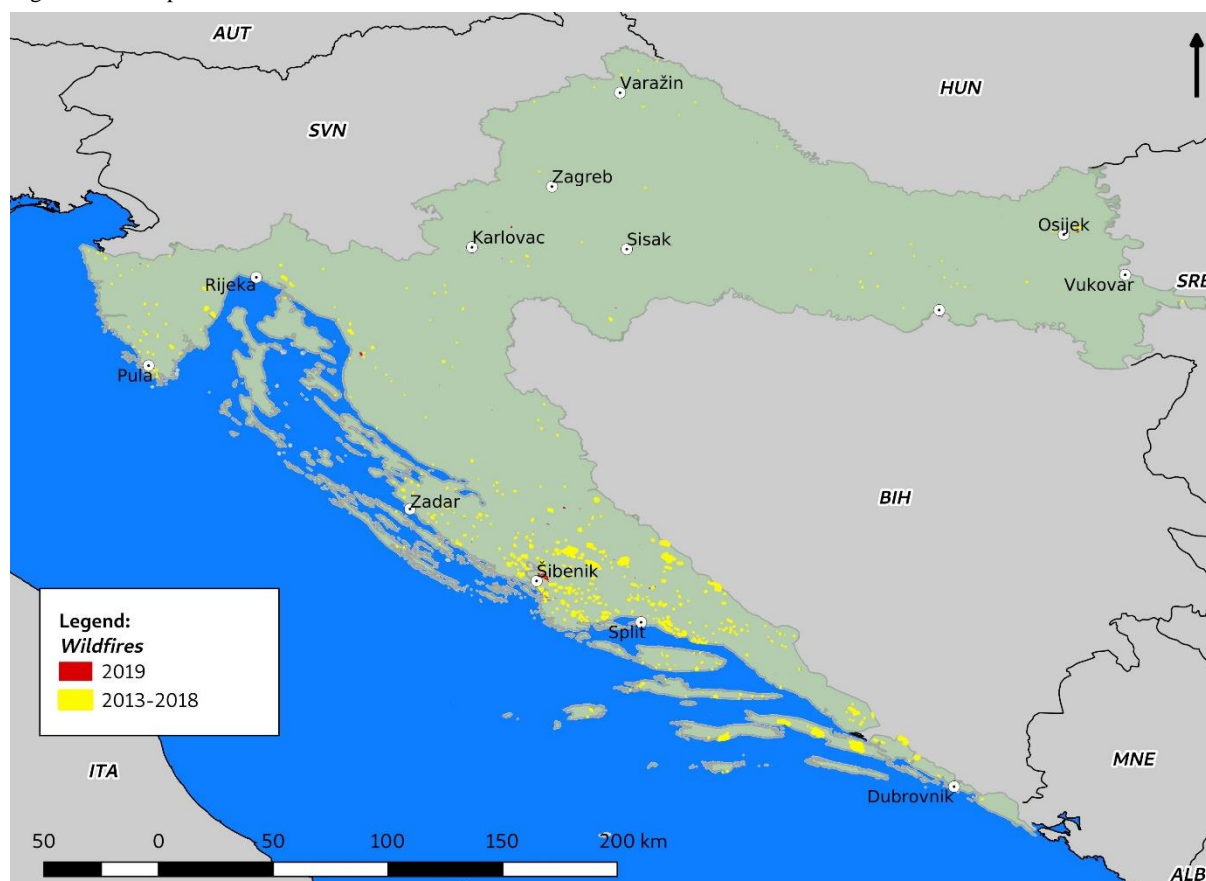
In order to secure reporting on emissions due to forest fires separately for categories Forest land remaining Forest land and land converted to/from Forest land, each record on each single forest fire in Register in period 1990-2013 were checked. All data and information in Register were then compared 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 Settlement 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 Forestland using equation 2.27, Tier 1 method and default values prescribed in IPCC 2006 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 aCL (except for residues). In this case CH_4 and N_2O emissions are reported in CRF tables while CO2 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 pCL 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.

Lfire (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 $ktCO_2$ equivalents, CH_4 emissions ranged between 0.18 and 86.93 while N_2O emissions ranged from 0.12 to 57.32 $ktCO_2$ equivalent in the reporting period 1990-2017. 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 1990-2020 following the ERT's request in 2020.

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 CO2 (D)	75%	Default, IPCC 2006
Emission factor for CH4 (D)	75%	Default, IPCC 2006
Emission factor for N2O (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

CO_2 emissions are estimated for the whole area (100% of area) that was subject of forest fires in period 1990-2017 instead of performing the estimation of CO_2 emissions on 60% of the burnt forest area in previous reports. This increased CO_{2eq} emissions in average of 35% in the period 1990-2016 when comparing this year report with NIR 2018.

6.15.6. Category-specific planned improvements

A separate project has been envisaged in order to switching to Tier 2 methodology in future LULUCF and KP reporting in case of emissions due to 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. The fact that waste management activities in Croatia were not organized and implemented in line with legislation in the past, results in the lack and inconsistency of data. Research should be started in order to collect all the necessary data for the emission calculation, which is included in the improvement plan. However, the improvements in quality and quantity of data are visible in the last couple of years. Effort was done in order to evaluate and compile data coming from different sources and adjust them to recommended IPCC methodology which is used for GHG emissions estimation.

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[56] and Waste Management Plan[57]. 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[58] 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[59] 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 disposed at landfills in the framework

---

[56] Waste Management Act (OG 84/2021)

[57] Decision on the adoption of theWaste Management Plan of the Republic of Croatia for the period 2017 - 2022 (OG 3/2017, 1/2022)

[58] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

[59] Ordinance on construction waste and asbestos-containing waste (OG 69/2016) (suceeding Ordinance on construction waste management from 2008)

of industrial waste, pursuant to the Act and Ordinance should be disposed of according to procedures and practices as well as municipal waste. General conditions for landfilling are prescribed in Ordinance on the methods and conditions for the landfill of waste, categories and operational requirements for waste landfills[60] and Directive on the landfill of waste[61]. 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.

Regulation on the Greenhouse Gases Emissions Monitoring, Policy and Measures for Climate Change Mitigation in the Republic of Croatia[62] 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.

7.1.1. Emission trends

The total annual emissions of GHG from Sector 5 Waste (with related IPCC categories), expressed in kt CO_2-eq, in the period 1990 - 2020 are presented in the Figure 7.1-1.

Figure 7.1-1: Emissions of GHGs from Waste sector (1990 - 2020)
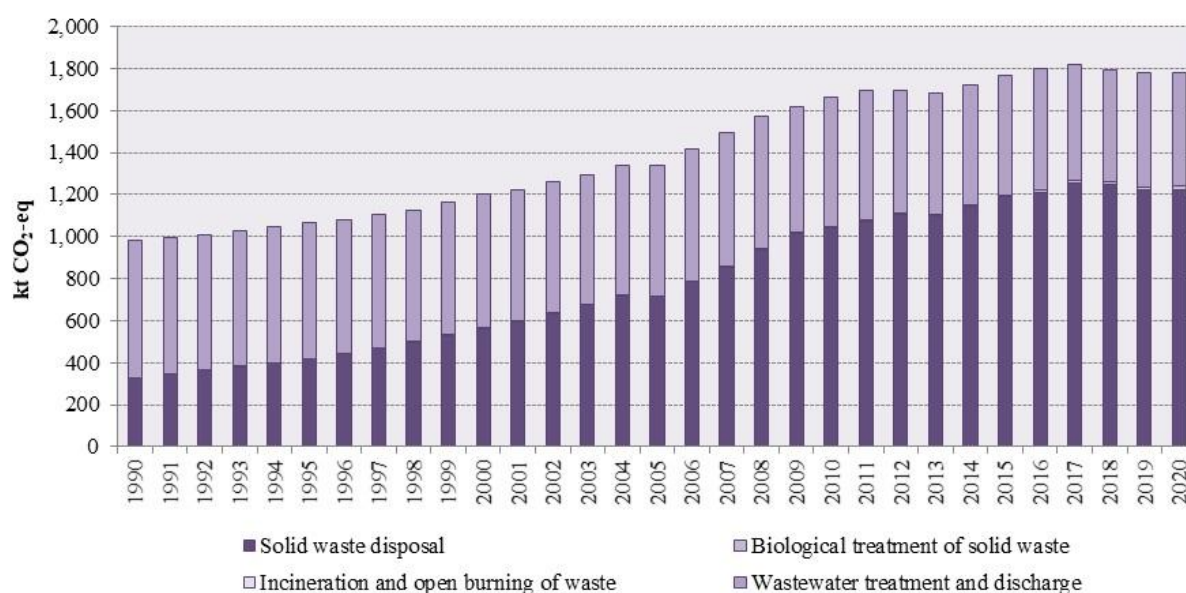
In 2020, GHG emissions from Sector 5 Waste amounted to 1,779.26 kt CO_2 equivalent, compared to 984.27 kt in 1990. These emissions constituted 7.6% of Croatia's total GHG emissions (without LULUCF) in 2020 and 3.1% of total emissions in 1990. GHG emissions from this sector increased during the reporting period. In recent years, the increasing trend is slower compared to the previous period and starts to decrease:

---

[60] Ordinance on the methods and conditions for the landfill of waste, categories and operational requirements for waste landfills (OG 114/2015, 103/2018, 56/2019)
[61] Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste
[62] Regulation on the Greenhouse Gases Emissions Monitoring, Policy and Measures for Climate Change Mitigation in the Republic of Croatia (OG 5/2017)

- 68.6% of sectoral emissions refer to the emission from solid waste disposal in 2020, compared to 33.3% in 1990. An increase in generated and disposed 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;

- 30.2% of sectoral emissions refer to the emission from wastewater treatment and discharge in 2020, compared to 66.6% 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 category regardless of LULUCF (detailed in Table 7.1-1):

Table 7.1-1: Key categories in Waste sector based on the level and trend assessment in 2020[63]

Table								
Tier 1 and Tier 2 Analysis - Source Analysis Summary (Croatian Inventory, 2022)								
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		L1i, L2i			
5.D Wastewater Treatment and Discharge	N$_2$O	Yes	L2e	T2e				

L1e - Level excluding LULUCF Tier1   L2e - Level excluding LULUCF Tier 2
L1i - Level including LULUCF Tier1   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

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 disposed of in an environmentally friendly way.

Data on generated and disposed of quantities of MSW and disposed quantities of industrial waste (IW) and sludge from wastewater treatment were provided by the Ministry of Economy and Sustainable development (MESD) for the period 2010 - 2020. In 2020, there was 65% of MSW, 33% of IW and 2% of sludge in total waste that was disposed at official landfills. From total MSW disposed in 2020, 63% were biodegradable. From total IW disposed of in 2020, 6% were biodegradable waste and 3% were sludge from wastewater treatment.

---

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

Before 2010, data reported for landfilling were based on reports from municipal waste collectors/landfill operators. There were no data of sufficient quality on the share of IW in total waste landfilled, but most of the quantities sent to landfills were mixed MSW. Detailed explanation on data sources on MSW, IW and sludge are provided in the section 7.2.2.1.

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, 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 disposed 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 2020, 41% (694,160 tonnes) was separately collected fractions. The largest separately collected fractions were paper and cardboard waste (29%), bulky waste (19%) and biowaste (17%), followed by plastic (10%), glass (6%), metal waste (6%), electrical and electronic waste (5%), wood (3%), textile (1%), and other waste (4%). The recovery rate of MSW in 2019 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 2020 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). This report contains data on the estimated composition of mixed municipal waste for 2015 (see Table 7.2-7, section 7.2.2.2.).

Apart from a certain amount of waste being separately collected, still, plenty of waste are disposed 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 methods and conditions for the landfill of waste, categories and operational requirements for waste landfills and Ordinance on the waste management[64], 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

---

[64] Ordinance on the Waste Management (OG 81/2020)

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 Environment Protection and Energy Efficiency Fund (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 disposed of by the end of 2020 are presented in the Table 7.2-1, Table 7.2-2 (MSW landfills) and Table 7.2-3 (IW landfills - active).

Table 7.2-1: The total number of active and closed landfills (total landfilled waste) by the end of 2020

Number of landfills	Active	Closed	Closed (waste was removed)	Total
Managed SWDS	81	81	84	246
Unmanaged deep	11	18	2	31
Unmanaged shallow	1	39	0	40
Total	**93**	**138**	**86**	**317**

Table 7.2-2: The total number of active and closed MSW landfills by the end of 2020

Number of landfills	Active	Closed	Closed (waste was removed)	Total
Managed SWDS	76	80	84	240
Unmanaged deep	8	18	1	27
Unmanaged shallow	0	38	0	38
Total	**84**	**136**	**85**	**305**

Table 7.2-3: The total number of active IW landfills by the end of 2020

Number of landfills	Active (IW)	Active (biodegradable IW)	Active (sludge)
Managed SWDS	52	17	13
Unmanaged deep	6	1	2
Unmanaged shallow	1	0	1
Total	**59**	**18**	**16**

Tables do not include data for unofficial sites in which the waste is improperly discarded into environment since the data for such sites are not provided. In 2020, the electronic application for registering the locations of discarded waste was put into operation, requesting regular input of data, covering whole state territory. Municipal services monitoring officer is responsible for data entry for the respective administrative area (municipality/city) which he covers. Therefore, database should contain results – data on locations, estimated quantities and types of waste discarded into environment. For now, 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 Environmental Protection and Energy Efficiency Fund.

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. It is planned to build 11 centres. This activities combined with planned increase of primary separation will further lead to the considerable reduction of biodegradable MSW and IW on landfills.

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. Obviously, Croatia doesn't have good historical data available, so the answer to the question on the first box is 'no'. However, 5. A is key category and therefore Croatia is estimating historical data using the guidance in section 3.2.2. Croatia doesn't apply a CS-model or use CS-key parameters and therefore after the final question we end up in Box 2: Tier 2.

Using the guidance in the 2006 IPCC Guidelines, section 3.2.1.1, the IPCC FOD model provides two options for the estimation of CH_4 emissions that can be chosen depending on the level of data available. Croatia uses the second option, which is single-phase model based on bulk waste.

According to the requirements of the 2006 IPCC Guidelines, Croatia included the CH_4 emissions for category 5. A Solid waste disposal from MSW, IW and sludge disposed at SWDS for the complete time series. The quantity of disposed MSW, IW and sludge from wastewater treatment is taken into account from 1955 onwards.

Description of data sources, AD, parameters, SWDS, and method for estimating CH_4 emissions from the 5. A Solid waste disposal are presented in the Figure 7.2-1.

Figure 7.2-1: Description of data sources, AD, parameters, SWDS, and method for estimating CH$_4$ emissions from the 5.A Solid waste disposal
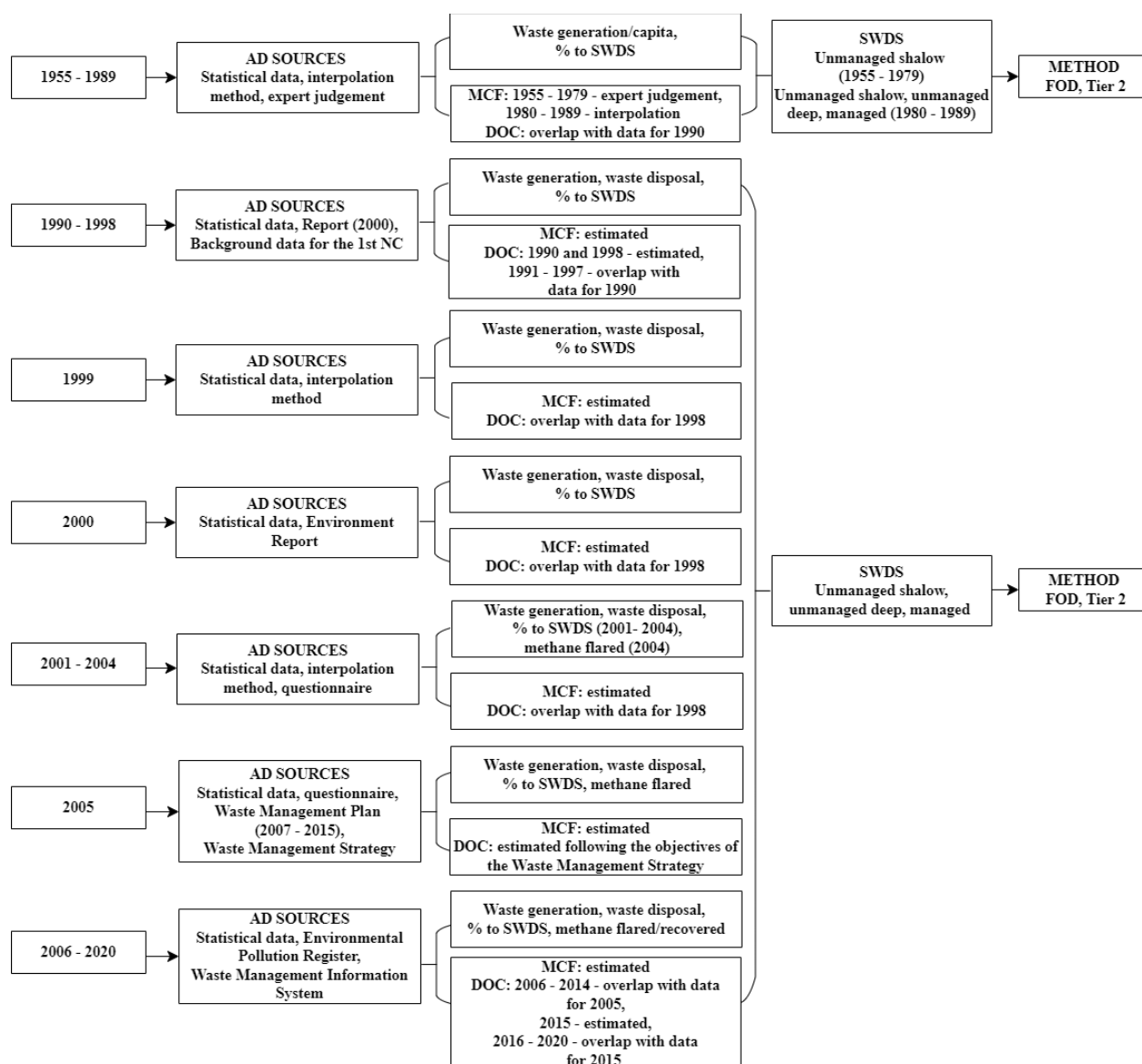
7.2.2.1. Activity data and data sources description

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 Environmental Pollution Register, Register of permits and certificates for waste management and Waste Management Information System.

By the Ordinance on the Environmental Pollution Register[65] adopted according to the Environment Protection Act[66], the MESD is collecting data on the quantities and types of waste produced, collected, recovered or disposed 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

---

[65] Ordinance on the Environmental Pollution Register (OG 3/2022)
[66] Environment Protection Act (OG 80/2013, 78/2015, 12/2018, 118/2018)

on the mass of biodegradable municipal waste disposed 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 disposed 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, but still, a certain amount of waste is not being weighted, which usually lead to overestimation of collected and disposed quantities. For example, the share of non-weighted quantity of the total disposed MSW in 2020 is 8%, which is an improvement compared to 2015 when the share of non-weighted waste was 33%.

Activity data included in the IPCC FOD model

MSW activity data

Population

For historical data, the total population is included, due to lack of data on urban population (for which waste collection is organised).

The data for 1955, 1961, 1971, 1981, and 1990 - 2020 were taken from Statistical Yearbooks and Statistical First Releases (https://www.dzs.hr/).

The data between 1955 and 1961, 1961 and 1971, 1971 and 1981 were calculated by linear interpolation method, using technique given in 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.3).

1955, 1961, 1971, 1981

https://www.dzs.hr/Hrv_Eng/ljetopis/2017/sljh2017.pdf

Statistical Yearbook of the Republic of Croatia, December 2017, 5. Population, 5-1. Population and number of settlements, according to censuses, page 107.

Data is available for 1953, not for 1955. Therefore, data for 1955 were estimated according to data for 1953.

1956 - 1960

Linear interpolation - data for the period 1956 - 1960 were estimated by assuming a constant annual increase of population from 1955 to 1961.

1962 - 1970

Linear interpolation - data for the period 1962 - 1970 were estimated by assuming a constant annual increase of population from 1961 to 1971.

1972 - 1980

Linear interpolation - data for the period 1972 - 1980 were estimated by assuming a constant annual increase of population from 1971 to 1981.

1982 - 1989

Linear interpolation - data for the period 1982 - 1989 were estimated by assuming a constant annual increase of population from 1981 to 1990.

1990 - 2000

https://www.dzs.hr/Hrv_Eng/ljetopis/2017/sljh2017.pdf

Statistical Yearbook of the Republic of Croatia, December 2017, 5. Population, 5-8. Population - mid-year estimate and natural change, page 113.

<u>2001 - 2010</u>

https://www.dzs.hr/Hrv_Eng/publication/2013/07-01-05_01_2013.htm

First Release, 9 December 2013, Number: 7.1.5. Revision of population estimates of the Republic of Croatia, 2001-2010, 2. Comparison of population estimates of the Republic of Croatia based on 2001 census with population estimates of the Republic of Croatia based on 2011 census, 2001 - 2010.

<u>2011 - 2013</u>

https://www.dzs.hr/

First Release/14 September 2016/Number: 7.1.4/Population estimate of the Republic of Croatia, 2015/1. Mid-year total population estimate of the Republic of Croatia, by counties, 2011 - 2015.

<u>2014 - 2018</u>

https://www.dzs.hr/

First Release/13 September 2019/Number: 7.1.3/Population estimate of the Republic of Croatia, 2018/1. Mid-year total population estimate of the Republic of Croatia, by counties, 2014 - 2018.

<u>2019 - 2020</u>

https://www.dzs.hr/

First Release/10 September 2021/Number: 7.1.3/Population estimate of the Republic of Croatia, 2020/1. Mid-year total population estimate of the Republic of Croatia, by counties, 2016 - 2020.

Waste per capita

Waste generation rate in kg/cap/yr for 1955, 1960, 1970, and 1980 were assessed as follows: 1955 (125 kg/cap/yr), 1960 (144 kg/cap/yr), 1970 (168 kg/cap/yr), 1980 (201 kg/cap/yr). Expert judgement was used.

The data between 1955 and 1960, 1960 and 1970, 1970 and 1980, 1980 and 1990 were calculated by linear interpolation method, using technique given in 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.3).

<u>1956 - 1959</u>

Linear interpolation - data for the period 1956 - 1959 were estimated by assuming a constant annual increase of waste per capita from 1955 to 1960.

<u>1961 - 1969</u>

Linear interpolation - data for the period 1961 - 1969 were estimated by assuming a constant annual increase of waste per capita from 1960 to 1970.

<u>1971 - 1979</u>

Linear interpolation - data for the period 1971 - 1979 were estimated by assuming a constant annual increase of waste per capita from 1970 to 1980.

<u>1981 - 1989</u>

Linear interpolation - data for the period 1981 - 1989 were estimated by assuming a constant annual increase of waste per capita from 1980 to 1990.

<u>1990 - 2020</u>

Waste per capita in kg/cap/yr for the period 1990 - 2020 were calculated from the ratio of the total amount of generated MSW and population. Data on generated MSW for the period 1990 - 2020 were taken from different sources (presented in the Figure 7.2-1).

Total MSW

For the period 1955 - 1989, data on total generated MSW were calculated by multiplying population and waste per capita. For the period 1990 - 2020, data on total generated MSW were taken from different sources (presented in the Figure 7.2-1).

% to SWDS

The data for the percentage of waste disposed at SWDS for 1955, 1960, 1970, 1980 were calculated by linear extrapolation method.

Linear extrapolation method was used for the period backward from 1990, using the technique given in the 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.4). Data for 1955, 1960, 1970 and 1980 were extrapolated based on data for 1990 and 2000 that were estimated according to information provided in data sources (Background data for the 1st NC of Croatia) - expert judgement was used.

The data between 1955 and 1960, 1960 and 1970, 1970 and 1980, 1980 and 1990 were calculated by linear interpolation method, using technique given in 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.3).

1956 - 1959

Linear interpolation - data for the period 1956 - 1959 were estimated by assuming a constant annual increase of percentage of waste disposed at SWDS from 1955 to 1960.

1961 - 1969

Linear interpolation - data for the period 1961 - 1969 were estimated by assuming a constant annual increase of percentage of waste disposed at SWDS from 1960 to 1970.

1971 - 1979

Linear interpolation - data for the period 1971 - 1979 were estimated by assuming a constant annual increase of percentage of waste disposed at SWDS from 1970 to 1980.

1981 - 1989

Linear interpolation - data for the period 1981 - 1989 were estimated by assuming a constant annual increase of percentage of waste disposed at SWDS from 1980 to 1990.

1990 - 2020

Data on generated and disposed MSW were taken from different sources (presented in the Figure 7.2-1). The percentage of waste disposed at SWDS for the period 1990 - 2020 were calculated from the ratio of disposed and generated MSW.

Population, waste generation rate, generated MSW and percentage of MSW disposed at SWDS in the period 1955 - 1989 are reported in the Table 7.2-4.

Table 7.2-4: Population, waste generation rate, generated MSW and percentage of MSW disposed at SWDS in the period 1955 - 1989

Year	Population (millions)	Waste generation rate (kg/cap/yr)	Generated MSW (kt)	% to SWDS
1955	3.936	125	492.003	27
1956	3.973	129	511.761	28
1957	4.011	133	531.803	29
1958	4.048	136	552.128	30
1959	4.085	140	572.736	31
1960	4.122	144	593.628	32
1961	4.160	146	608.979	33
1962	4.186	149	622.929	34
1963	4.213	151	637.006	35
1964	4.240	154	651.211	36
1965	4.266	156	665.544	36
1966	4.293	158	680.005	37
1967	4.320	161	694.593	38
1968	4.346	163	709.310	39
1969	4.373	166	724.155	40
1970	4.400	168	739.128	41
1971	4.426	171	758.212	42
1972	4.444	175	775.878	43
1973	4.461	178	793.660	44
1974	4.479	181	811.558	45
1975	4.496	185	829.571	46
1976	4.514	188	847.700	46
1977	4.531	191	865.945	47
1978	4.549	194	884.305	48
1979	4.566	198	902.781	49
1980	4.584	201	921.373	50
1981	4.601	202	928.711	51
1982	4.621	203	936.502	52
1983	4.641	203	944.325	53
1984	4.660	204	952.181	54
1985	4.680	205	960.070	55
1986	4.700	206	967.991	55
1987	4.719	207	975.944	56
1988	4.739	208	983.930	57
1989	4.758	208	991.949	58

As presented in the Figure 7.2-1, total annual MSW disposed at SWDS for the period 1990 - 1998 has been evaluated from available relevant data compiled into Report (2000); Fundurulja, D., Mužinić, M. *Estimation of the Quantities of Municipal Solid Waste in the Republic of Croatia in the period 1990 – 1998*, Zagreb, which is a part of the Background data for the 1st NC of Croatia. Insufficient data for the quantity of disposed MSW in 1999 were evaluated by interpolation method. Data for the quantity of disposed MSW in 2000 were obtained from the *Environment Report of the Republic of Croatia (2012)*, Croatian Environment Agency (today: MESD). Data for the quantity of disposed MSW in 2005 were obtained from the *Waste Management Plan in the Republic of Croatia for 2007 - 2015* (OG 85/2007, 126/2010, 31/2011, 46/2015). Taking into account the pattern over 2000 and 2005, the quantity of disposed MSW for the period 2001 to 2004 were assessed by the interpolation method. Data for the

quantity of disposed MSW for the period 2006 - 2020 were obtained from the Environmental Pollution Register and Waste Management Information System. Due to the low quality of data for the period 2006 – 2009 provided by operators of landfills, the data were taken from the reports of companies collecting the MSW (reporting destination of MSW). Data on the quantity of generated and disposed MSW for the period 2010 - 2020 were obtained from the Environmental Pollution Register - reports delivered by the operators of active landfills. Data on the quantity of disposed biodegradable MSW for the period 2010 - 2020 were obtained from the Waste Management Information System - reports on landfills and waste disposal.

Population, waste generation rate, generated MSW and percentage of MSW disposed at SWDS in the period 1990 - 2020 are reported in the Table 7.2-5.

Table 7.2-5: Population, waste generation rate, generated MSW and percentage of MSW disposed at SWDS in the period 1990 - 2020

Year	Population (millions)	Waste generation rate (kg/cap/yr)	Generated MSW (kt)	% to SWDS
1990	4.778	209	1,000.000	59
1991	4.513	217	980.000	61
1992	4.470	217	970.000	63
1993	4.641	212	985.000	65
1994	4.649	216	1,005.000	67
1995	4.669	227	1,060.000	70
1996	4.494	245	1,100.000	72
1997	4.572	252	1,150.000	74
1998	4.501	268	1,205.000	76
1999	4.554	275	1,253.000	78
2000	4.381	268	1,173.000	80
2001	4.305	292	1,258.750	80
2002	4.305	313	1,346.250	80
2003	4.306	333	1,433.750	80
2004	4.311	334	1,439.053	85
2005	4.312	336	1,449.381	89
2006	4.314	377	1,626.948	89
2007	4.312	390	1,683.132	96
2008	4.310	415	1,788.311	97
2009	4.303	405	1,742.803	102*
2010	4.290	380	1,629.915	97
2011	4.281	384	1,645.295	95
2012	4.268	391	1,670.005	83
2013	4.256	405	1,723.460	82
2014	4.238	386	1,637.371	80
2015	4.204	393	1,653.918	80
2016	4.174	402	1,679.765	76
2017	4.125	416	1,716.441	72
2018	4.088	433	1,768.411	66
2019	4.065	446**	1,811.617	59
2020	4.048	418	1,692.966	56

* quantity of waste removed from remediated landfills is added

** in the 2019 Municipal Waste Report the value is 444 kg/cap/yr – a list used by Eurostat was taken

IW activity data

Historical data on the quantity of disposed IW for the period 1955 - 2009 are not available and were calculated by linear extrapolation using technique given in 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.4). Historical data were extrapolated based on appropriate data: average for the period 2010 - 2016 was taken into account for conducting calculation forward. Because of the long period, there is potential inconsistencies in the time series. For that reason, trend extrapolation back in time was done in combination with other splicing technique. Respectively, data for 1955 (the first year in the time series) was calculated using the ratio of the total amount of disposed MSW in 1955 and the average of disposed MSW for the period 2010 - 2016.

Data on the quantity of disposed IW for the period 2010 - 2020 are taken from Waste Management Information System (presented in Figure 7.2-1).

Sludge

Historical data on the quantity of disposed sludge for the period 1955 – 2009 are not available. Data on the disposed quantity of sludge was calculated using the average for the period 2010 - 2016 to overlap data for 1955 - 2012. Because of the high discrepancy of the data for the period 2010 - 2016, average value 2010 - 2016 was used to construct the time series - back in time was done by overlapping data for 1955 - 2012. Linear extrapolation was not used due to the high discrepancy of the data for the period 2010 - 2016.

Data on the quantity of disposed sludge for the period 2010 - 2020 are taken from Waste Management Information System (presented in Figure 7.2-1).

Total annual disposed MSW, IW and sludge at SWDS in the period 1955 - 2020 are reported in the Table 7.2-6.

Table 7.2-6: Total annual disposed MSW, IW and sludge at SWDS in the period 1955 - 2020

Year	Disposed MSW (kt)	Disposed IW (kt)	Disposed sludge (kt)	TOTAL DISPOSED WASTE (kt)
1955	135.301	348.493	16.317	**500.111**
1956	145.340	351.225	16.317	**512.882**
1957	155.818	353.957	16.317	**526.093**
1958	166.743	356.689	16.317	**539.749**
1959	178.121	359.421	16.317	**553.860**
1960	189.961	362.154	16.317	**568.432**
1961	200.354	364.886	16.317	**581.557**
1962	210.550	367.618	16.317	**594.485**
1963	221.041	370.350	16.317	**607.708**
1964	231.831	373.082	16.317	**621.231**
1965	242.923	375.814	16.317	**635.055**
1966	254.322	378.547	16.317	**649.186**
1967	266.029	381.279	16.317	**663.625**
1968	278.050	384.011	16.317	**678.378**
1969	290.386	386.743	16.317	**693.447**
1970	303.042	389.475	16.317	**708.835**
1971	317.691	392.207	16.317	**726.216**
1972	332.076	394.940	16.317	**743.333**
1973	346.829	397.672	16.317	**760.819**

Year	Disposed MSW (kt)	Disposed IW (kt)	Disposed sludge (kt)	TOTAL DISPOSED WASTE (kt)
1974	361.955	400.404	16.317	**778.676**
1975	377.455	403.136	16.317	**796.908**
1976	393.333	405.868	16.317	**815.519**
1977	409.592	408.601	16.317	**834.510**
1978	426.235	411.333	16.317	**853.885**
1979	443.266	414.065	16.317	**873.648**
1980	460.686	416.797	16.317	**893.801**
1981	472.714	419.529	16.317	**908.560**
1982	485.108	422.261	16.317	**923.687**
1983	497.659	424.994	16.317	**938.970**
1984	510.369	427.726	16.317	**954.412**
1985	523.238	430.458	16.317	**970.013**
1986	536.267	433.190	16.317	**985.774**
1987	549.457	435.922	16.317	**1,001.696**
1988	562.808	438.654	16.317	**1,017.780**
1989	576.322	441.387	16.317	**1,034.026**
1990	590.000	444.119	16.317	**1,050.436**
1991	598.780	446.851	16.317	**1,061.948**
1992	613.040	449.583	16.317	**1,078.940**
1993	643.205	452.315	16.317	**1,111.838**
1994	677.370	455.047	16.317	**1,148.735**
1995	736.700	457.780	16.317	**1,210.797**
1996	787.600	460.512	16.317	**1,264.429**
1997	847.550	463.244	16.317	**1,327.111**
1998	913.390	465.976	16.317	**1,395.683**
1999	976.087	468.708	16.317	**1,461.113**
2000	938.400	471.440	16.317	**1,426.158**
2001	1,007.000	474.173	16.317	**1,497.490**
2002	1,077.000	476.905	16.317	**1,570.222**
2003	1,147.000	479.637	16.317	**1,642.954**
2004	1,216.000	482.369	16.317	**1,714.686**
2005	1,286.078	485.101	16.317	**1,787.497**
2006	1,447.984	487.833	16.317	**1,952.135**
2007	1,609.890	490.566	16.317	**2,116.773**
2008	1,730.671	493.298	16.317	**2,240.286**
2009	1,778.143	496.030	16.317	**2,290.490**
2010	1,587.291	395.389	16.317	**1,998.998**
2011	1,563.321	453.953	16.317	**2,033.592**
2012	1,382.283	552.401	16.317	**1,951.002**
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**

A fluctuating trend for solid waste disposal by type at SWDS during reporting time series was due to multiple factors, such as the fact that AD for waste were acquired from several sources (presented in the Figure 7.2-1) as well the influence of the economic crisis and measures undertaken to avoid or reduce solid waste disposal. In addition, the calculation of historical data for IW and sludge affects the trend. 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.

1.1.2.1. Parameters description

Methane correction factor (MCF)

In the process of adjustment the country-specific to IPCC SWDS classification, some assumptions have been made. The same distribution was assumed for MSW and IW for the period 1955 - 2020.

For the period 1955 - 1979, default MCF for unmanaged shallow SDWS, which is 0.4, was used – expert judgement according to a large proportion of unmanaged shallow SWDS.

Linear interpolation method was used for the period 1980 - 1989, using the technique given in the 2006 IPCC Guidelines (Volume 1, Chapter 5, Section 5.3.3.3) for:

- unmanaged shallow SWDS - data for the period 1980 - 1989 were estimated by assuming a constant annual decrease of quantity of disposed waste from 1979 - 1990,

- unmanaged deep SWDS - data for the period 1980 - 1989 were estimated by assuming a constant annual increase of quantity of disposed waste from 1979 - 1990,

- managed SWDS - the share of disposed waste was calculated from the difference between 100 % and the share of waste disposed at unmanaged shallow and unmanaged deep SWDS.

For the period 1990 - 2020, weighted average MCF calculated by the national data (mass fractions) were used for unmanaged shallow, unmanaged deep and managed SWDS.

Proportion of waste (by weight) in each type of site (unmanaged shallow, unmanaged deep and managed) have been assessed for the period 1990 - 1998 from available relevant data compiled into Report (2000); Fundurulja, D., Mužinić, M. *Estimation of the Quantities of Municipal Solid Waste in the Republic of Croatia in the period 1990 – 1998,* Zagreb, which is a part of the Background data for the 1st NC of Croatia. Due to the fact that data for 1999 are not available, the proportion of waste in each type of site has been assessed by the interpolation method. Information on the proportion of disposed waste (by weight) in 2000 was obtained from *Environment Report of the Republic of Croatia (2012)*, Croatian Environment Agency (today: MESD). Distribution of quantity of waste disposed at all three IPCC categories has been made by applying a factor of increasing disposed waste at managed and unmanaged deep SWDS in the amount of 25% compared to 1998 (according to expert judgement). Distribution of quantity of waste disposed at unmanaged shallow, unmanaged deep and managed SWDS for 2005 and 2006 has been made by information provided in *Waste Management Plan in the Republic of Croatia for 2007 - 2015*. Taking into account the pattern over 2000 - 2005, quantity of disposed waste at unmanaged shallow, unmanaged deep and managed SWDS for the period 2001 - 2004 has been assessed by the interpolation method.

In the process of adjustment, the country-specific to IPCC SWDS classification for the period 2010 - 2012, the set of criteria was defined by working group, using the data for 2009 available in Waste Management Information System and Environmental Emission Register. Landfills on which remediation activities were reported as finished have been selected as managed. Landfills which reported having fully surrounding landfill fences and implemented at least one operation among aligning, compacting or covering, have been selected as managed. Other landfills have been selected as

unmanaged and classified as unmanaged deep or unmanaged shallow. Taking into account the pattern over 2005/2006 and 2010/2011, quantities of disposed waste at unmanaged shallow, unmanaged deep and managed SWDS for the period 2007 to 2009 have been assessed by the interpolation method.

In the process of adjustment the country-specific to IPCC SWDS classification for the period 2013 - 2020 the set of criteria was defined by working group using the data for the period 2013 - 2020 available at Waste Management Information System (according the information on remediation activities, landfill depth, fences, aligning, compacting or covering …). Data from Waste Management Information System used for SWDS classification for the period 2013 - 2020 were collected using the reports on landfills and waste disposal and vary significantly in quality and quantity than partial information from 2009 that have been used for the classification of SWDS in the previous period (2010 - 2012).

Distribution of waste by waste management type at SWDS in the period 1955 - 2020 are reported in the Table 7.2-7.

Table 7.2-7: Distribution of waste by waste management type at SWDS in the period 1955 - 2020

Year	Unmanaged shallow (%)	Unmanaged deep (%)	Managed (%)
1955	100.00	0.00	0.00
1956	100.00	0.00	0.00
1957	100.00	0.00	0.00
1958	100.00	0.00	0.00
1959	100.00	0.00	0.00
1960	100.00	0.00	0.00
1961	100.00	0.00	0.00
1962	100.00	0.00	0.00
1963	100.00	0.00	0.00
1964	100.00	0.00	0.00
1965	100.00	0.00	0.00
1966	100.00	0.00	0.00
1967	100.00	0.00	0.00
1968	100.00	0.00	0.00
1969	100.00	0.00	0.00
1970	100.00	0.00	0.00
1971	100.00	0.00	0.00
1972	100.00	0.00	0.00
1973	100.00	0.00	0.00
1974	100.00	0.00	0.00
1975	100.00	0.00	0.00
1976	100.00	0.00	0.00
1977	100.00	0.00	0.00
1978	100.00	0.00	0.00
1979	100.00	0.00	0.00
1980	95.45	4.27	0.27
1981	90.91	8.55	0.55
1982	86.36	12.82	0.82
1983	81.82	17.09	1.09
1984	77.27	21.36	1.36
1985	72.73	25.64	1.64
1986	68.18	29.91	1.91
1987	63.64	34.18	2.18

Year	Unmanaged shallow (%)	Unmanaged deep (%)	Managed (%)
1988	59.09	38.45	2.45
1989	54.55	42.73	2.73
1990	50.00	47.00	3.00
1991	50.06	46.77	3.17
1992	50.36	46.32	3.32
1993	50.34	46.17	3.50
1994	48.61	47.59	3.80
1995	46.39	49.46	4.15
1996	45.83	49.79	4.39
1997	44.25	51.03	4.72
1998	43.57	51.45	4.98
1999	39.27	55.15	5.58
2000	27.70	65.91	6.39
2001	24.82	62.18	13.00
2002	22.29	58.96	18.75
2003	20.07	56.13	23.81
2004	18.10	53.62	28.29
2005	16.33	51.40	32.27
2006	13.82	49.71	36.46
2007	10.89	38.02	51.09
2008	9.01	32.59	58.40
2009	7.67	29.02	63.31
2010	6.84	28.73	64.44
2011	6.52	26.93	66.55
2012	8.37	28.71	62.92
2013	4.19	27.69	68.12
2014	4.48	23.21	72.31
2015	1.72	18.54	79.74
2016	0.96	11.59	87.45
2017	0.26	10.81	88.93
2018	0.22	9.08	90.70
2019	0.09	7.69	92.22
2020	0.13	5.79	94.08

Proportion of waste (by weight) for each type of SDWS are multiplied by corresponding default MCF proposed by the 2006 IPCC Guidelines. The mass fraction of the waste disposed of on each type of SWDS (unmanaged shallow, unmanaged deep and managed) in the total mass of disposed waste has been calculated by dividing the mass of disposed waste at each type of SWDS (unmanaged shallow, unmanaged deep and managed) by the total mass of disposed waste. These calculated mass fractions have been multiplied by corresponding default MCF proposed by the 2006 IPCC Guidelines, Volume 5, Table 3.1. (i.e. mass fraction for unmanaged shallow * 0.4; mass fraction for unmanaged deep SWDS * 0.8; mass fraction for managed SWDS * 1.0). So, 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 the period 1955 - 2020 are reported in the Table 7.2-8.

Table 7.2-8: The total weighted average MCF (1955 - 2020)

Year	MCF (fraction)
1955	0.400
1956	0.400
1957	0.400
1958	0.400
1959	0.400
1960	0.400
1961	0.400
1962	0.400
1963	0.400
1964	0.400
1965	0.400
1966	0.400
1967	0.400
1968	0.400
1969	0.400
1970	0.400
1971	0.400
1972	0.400
1973	0.400
1974	0.400
1975	0.400
1976	0.400
1977	0.400
1978	0.400
1979	0.400
1980	0.419
1981	0.437
1982	0.456
1983	0.475
1984	0.494
1985	0.512
1986	0.531
1987	0.550
1988	0.569
1989	0.587
1990	0.606
1991	0.606
1992	0.605
1993	0.606
1994	0.613
1995	0.623
1996	0.625
1997	0.632
1998	0.636
1999	0.654
2000	0.702
2001	0.727

Year	MCF (fraction)
2002	0.748
2003	0.767
2004	0.784
2005	0.799
2006	0.818
2007	0.859
2008	0.881
2009	0.896
2010	0.902
2011	0.907
2012	0.892
2013	0.919
2014	0.927
2015	0.953
2016	0.971
2017	0.977
2018	0.981
2019	0.984
2020	0.988

Degradable organic carbon (DOC)

The DOC is defined as the organic carbon in waste that is accessible to biochemical decomposition. The DOC in bulk waste 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 bulk 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

Only small numbers of municipalities/cities implement the analysis of the composition of mixed municipal waste sent to landfills. There is no obligation to send the result of analysis to the competent body but is available on request only.

For the period up to 2004, DOC was estimated by using country-specific data on waste composition and quantities based on compiled data from Potočnik, V. (2000), *Report: The basis for methane emissions estimation in Croatia 1990 - 1998, B. Data on Municipal Solid Waste in Croatia 1990 - 1998,* which is a part of the Background data for the 1st NC of Croatia.

For the period 2005 - 2014, objectives defined by Waste Management Strategy[67] and Waste Management Plan[68] include the assumed time-lags with respect to relevant EU legislation.

---

[67] Waste Management Strategy of the Republic of Croatia (OG 130/2005)
[68] Waste Management Plan of the Republic of Croatia for 2007 - 2015 (OG 85/2007, 126/2010, 31/2011, 46/2015)

Default values for DOC content (in % of wet waste) for MSW component is taken from the 2006 IPCC Guidelines, Volume 5, Table 2.4.

Reference value for paper and textiles are used according to proposed default values, as well as expert judgement - using drivers from the above-mentioned Report.

Composition of MSW and DOC for the period 1955 - 2014 are presented in the Table 7.2-9.

Table 7.2-9: Composition of MSW and DOC for the period 1955 - 2014

Waste stream	% in the MSW (1955 - 1997)	% in the MSW (1998 - 2004)	2005 - 2014
Paper and textiles	22	22	
Garden and park waste	17	19	
Food waste	22	24	
Wood and straw waste	4	3	
DOC	16.99	16.53	15.70*

* objectives defined by Waste Management Strategy and Waste Management Plan of the Republic of Croatia for 2007 - 2015 include the assumed time-lags with respect to relevant EU legislation

In 2015 the project was implemented for determination of average composition of MSW (see information in section 7.2-1). Results are available for mixed municipal waste (European list of waste, waste code: 20 03 01), as well as for total municipal waste (mixed municipal waste+separately collected fractions from municipal waste). The biodegradable fraction of mixed municipal waste was determined as 65%. This project contains data on estimated composition of mixed municipal waste for 2015 which is presented in the Table 7.2-10. This data are more detailed than the data for the previous period and therefore are shown separately. Data are in line with the 2006 IPCC Guidelines.

Default values for DOC content (in % of wet waste) for MSW component is taken from the 2006 IPCC Guidelines, Volume 5, Table 2.4.

Calculated value for 2015 is used for the period 2015 - 2020 (information was provided by the MESD).

Table 7.2-10: Composition of MSW and DOC for the period 2015 - 2020

Waste stream	% in the MSW (2015 - 2020)
Paper/cardboard	23.19
Textiles	3.71
Food waste	30.93
Wood	0.98
Garden and Park waste	5.68
Nappies	3.97
Rubber and Leather	0.67
Plastics	22.87
Metal	2.07
Glass	3.65
Other, inert waste	2.28
DOC	**17.58**

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 - 2020 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 - 2020 are presented in the Table 7.2-11.

Table 7.2-11: 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 – 2020

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

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 - 2020 are presented in the Table 7.2-12.

Table 7.2-12: 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 – 2020

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

The total average DOC for the entire reporting period has been calculated from the average DOC values for the period 2010 – 2020. 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).

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 0.25 - 0.59 in 2020, depending on the landfills. For landfills that reported very low F values, which deviate significantly from the proposed value by the 2006 IPCC Guidelines, it was suggested to check and correct the data as needed. For landfills that have not reported F, it was taken to be 0.5, according to proposed value by 2006 IPCC Guidelines. 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 methods and conditions for the landfill of waste, categories and operational requirements for 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, as follows:

MSW and IW (bulk waste): $k = 0.09$

Sewage sludge: $k = 0.185$

Half-life ($t_{1/2}$)

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, the following values for $t_{1/2}$ have been used:

MSW and IW (bulk waste): $t_{1/2} = 7.7$ years

Sewage sludge: $t_{1/2} = 3.7$ years

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 2020. 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 2020. The data for flared gas for the other landfills were submitted for the period 2013 - 2020 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 (Gg). 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 in a flare (without energy recovery) in the period 2004 - 2020 have 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 - 2020 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 - 2020. 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 7.2-13.

Table 7.2-13: Flared and recovered CH_4 (2004 - 2020)

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

NO – not occurring

A fluctuating trend for flared CH_4 during the period 2004 - 2020 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 in the period 2015 -2020 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 1st 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 - 2020 are presented in the Figure 7.2-2.

Figure 7.2-2: Emissions of CH_4 from 5.A Solid waste disposal (1990 - 2020)
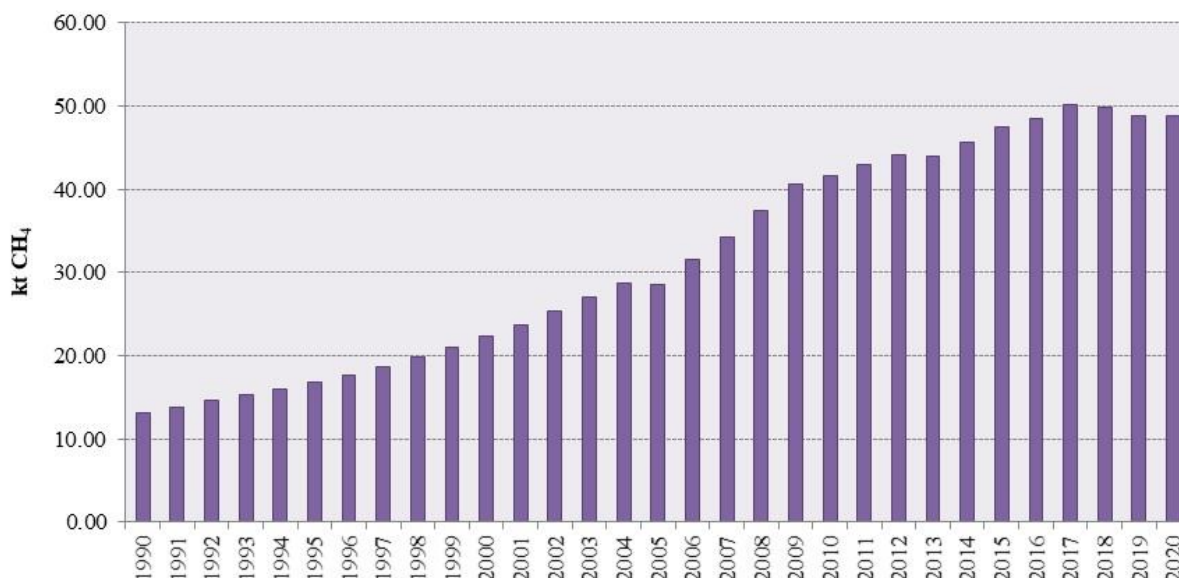
An increase in generated and disposed of solid waste exists during the reporting period. In recent years, the increasing trend is slower compared to the previous period and starts to decrease influenced by the implementation of the measures undertaken to avoid/reduce and recycle waste, which are still not sufficiently applied. Accordingly, there is an increase in CH_4 emissions during the reporting period. In recent years, the increasing trend of CH_4 emissions is slower compared to the previous period. Emissions have started to decline in 2018.

Emissions of NMVOC have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* 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 disposed at different types of SWDS and the main characteristic of SWDS as well as the usage of default IPCC parameters.

In addition, 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. It is

obvious that adjustment the country-specific to IPCC SWDS classification represents additional uncertainty in the estimation of country-specific MCF.

Likewise, uncertainty is related to the estimation of DOC for MSW (for the period 1955 – 2014) as well DOC for IW and sludge for the entire reporting period. There were several sorting of waste in Croatia, and in consequence of that these results were compared and adjust to relevant data in similar countries. Also, comparison were made with data on MSW composition for 2015 from 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", which 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). The calculated value for 2015 used for the period 2015 - 2020 is more accurate than values for the previous period. In addition, the calculated average DOC value for IW and the default DOC value for sludge influence the uncertainty estimates.

Uncertainty estimate associated with activity data amounts 50%. Based on the obtained information on activity data according the Annual data collection plan, expert responsible for emission calculation for the Waste sector has estimated uncertainty of the data, used values proposed by the 2006 IPCC Guidelines that are included in the tables in the sections on uncertainty assessment for individual categories. The process undertaken to assess uncertainties using expert judgement follows the guidelines stated in Volume 1, Chapter 3 of the 2006 IPCC Guidelines.

Uncertainty estimate associated with emission factor amounts 50%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

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 source 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 solid waste disposal were estimated using the Tier 2 method that is a good practice. The uncertainty of activity data is very high due to the high discrepancy between various data sources. 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

The CS-value of DOC for IW has been estimated for the entire reporting period and is used in both IPCC FOD models - for managed and unmanaged landfills.

Therefore, recalculations of CH_4 emissions were made for the period 1990 - 2019.

7.2.6. Category-specific planned improvements

According to the requirements of the 2006 IPCC Guidelines, Croatia included the CH_4 emissions for category 5. A Solid waste disposal from MSW, IW and sludge disposed at SWDS for the complete time series. Extrapolation and other splicing techniques have been used as per the 2006 IPCC Guidelines based on historical data on solid waste disposed at SWDS. The IPCC FOD model (single-phase model based on bulk waste) has been used to calculate CH_4 emissions from 5.A Solid waste disposal for the entire time series.

The ERT suggested Croatia to improve accuracy, completeness and transparency of inventory. According to the recommendations by the ERT, it is necessary to carry out a comprehensive research regarding activity data and parameters, in particular on population, waste generation per capita and the percentage of waste deposited to SWDS that are included in the inventory for 5.A Solid waste disposal for the entire time series.

It is necessary to research activity data and parameters for MSW, IW and sludge which are needed for using a multi-phase model based on waste composition data.

It is necessary to improve the quality of existing data and to reconstruct historical data. Due to lack of adequate information, interpolation/extrapolation methods have been applied for the estimation of waste and landfills characteristics over a long period of time. Expert judgement of historical data should be more detailed explained, using relevant scientific and professional literature and research to allow full reproduction and understanding of choices made.

MESD coordinates conducting a comprehensive research regarding activity data and parameters for category 5.A Solid waste disposal, for the entire time series. That will be part of the comprehensive research regarding system improvements and development of historical data bases for the calculation and reporting of greenhouse gas emissions from the Waste sector. The project is in preparation.

More information for uncertainty estimation associated with activity data and emission factors (parameters of the IPCC FOD model) is required, regarding more accurate and transparent uncertainty analysis. For now, uncertainty estimates are based on assessment of expert responsible for emission calculation for the Waste sector. Assessment is based on the obtained information on activity data according to the Annual data collection plan, using values proposed by the 2006 IPCC Guidelines. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data and parameters, thereby increasing transparency in the reporting.

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 short-term goals (in the next submission) or long-term goals (over 1 year).

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.

In the framework of the preparation the 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution', inventory improvement projects were performed - documents: "Report on inventory improvement for sector composting (NFR 5.B.1)"(producer: Ekonerg, client: MESD, 2021) and "Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)" (producer: Ekonerg, client: MESD, 2022) have been prepared. Amounts of feedstock treated by composting and anaerobic digestion at biogas facilities have been collected for the entire reporting period from 1990 to 2020.

7.3.2. Methodological issues

7.3.2.1. Composting

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. Data on the mass of composted waste include data on different categories of waste (according to the waste code - European List of Waste, LoW) and by-products.

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 on:

- mass of composted waste (on a wet weight basis, t),
- dry matter content of the feedstock - waste (kg kg^{-1}).

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 taking into account 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 the mass of composted waste and the dry matter content of the feedstock were collected for the period from 2000 to 2020.

Data on different types of waste (dry weight) treated by composting are presented in the Table 7.3-1. Dry matter content varies depending on the waste code - European List of Waste, LoW (Table 7.3-2).

The trend of collected and estimated data for the period 1994 - 2019 is compared with the trend of data for the period 2007 - 2019 used in the calculation of CH_4 and N_2O emissions in the previous report (data from database ROO). Deviations of data are observed in each year. From the differences in the data, it can be concluded that the operators (composting facilities) reported insufficiently accurate and incomplete data to the ROO.

Table 7.3-1: Data on different types of waste (dry weight) treated by composting (1990 – 2020)

Year	LoW, Group 02 (t)	LoW, Group 03 (t)	LoW, Group 04 (t)	LoW, Group 10 (t)	LoW, Group 15 (t) (t)	LoW, Group 17 (t)	LoW, Group 19 (t)	LoW, Group 20 (t)	Total waste (t)
1990	NO	NO	NO	NO	NO	NO	NO	NO	NO
1991	NO	NO	NO	NO	NO	NO	NO	NO	NO
1992	NO	NO	NO	NO	NO	NO	NO	NO	NO
1993	NO	NO	NO	NO	NO	NO	NO	NO	NO
1994	NO	NO	NO	NO	NO	NO	NO	1,845.5	**1,845.5**
1995	NO	NO	NO	NO	NO	NO	NO	1,953.0	**1,953.0**
1996	NO	NO	NO	NO	NO	NO	NO	2,060.5	**2,060.5**
1997	NO	NO	NO	NO	NO	NO	NO	2,168.0	**2,168.0**
1998	NO	NO	NO	NO	NO	NO	NO	2,275.5	**2,275.5**
1999	NO	NO	NO	NO	NO	NO	NO	2,383.0	**2,383.0**
2000	NO	NO	NO	NO	NO	NO	NO	2,700.0	**2,700.0**
2001	NO	NO	NO	NO	NO	NO	NO	2,179.0	**2,179.0**
2002	NO	NO	NO	NO	NO	NO	NO	2,915.0	**2,915.0**
2003	NO	NO	NO	NO	NO	NO	NO	2,085.3	**2,085.3**
2004	NO	NO	NO	NO	NO	NO	NO	2,465.5	**2,465.5**
2005	NO	NO	NO	NO	NO	NO	NO	4,464.9	**4,464.9**
2006	NO	NO	NO	NO	NO	NO	NO	3,456.7	**3,456.7**
2007	167.5	NO	NO	NO	57.1	NO	NO	6,372.0	**6,596.6**
2008	970.9	187.9	2.2	NO	979.5	16.6	444.0	10,622.4	**13,223.3**
2009	1,749.0	248.8	NO	NO	1,084.1	40.2	1,764.7	13,084.6	**17,971.4**
2010	2,325.2	472.9	28.7	NO	970.6	4.4	290.6	10,135.3	**14,227.7**
2011	2,425.5	92.1	NO	194.6	704.0	8.4	1,727.9	11,347.8	**16,500.4**
2012	2,794.4	77.0	NO	716.6	180.3	NO	2,442.8	9,629.4	**15,840.5**
2013	2,346.4	76.0	NO	NO	416.4	4.9	937.3	13,850.2	**17,631.2**
2014	1,396.8	24.0	NO	NO	118.4	1.5	154.1	16,342.4	**18,037.0**
2015	1,230.9	103.4	NO	NO	607.7	NO	560.2	12,760.7	**15,262.9**
2016	1,181.3	104.8	NO	NO	651.1	NO	1,949.1	16,006.0	**19,892.4**
2017	766.5	114.2	NO	NO	69.0	NO	608.2	15,652.6	**17,210.5**
2018	556.8	199.3	NO	NO	39.0	NO	553.6	19,377.3	**20,725.9**
2019	901.9	171.4	NO	NO	2,165.6	NO	505.6	22,190.7	**25,935.0**
2020	1,470.9	143.5	NO	NO	3,047.5	70.6	2,964.1	31,531.0	**39,227.5**

NO - not occurring

Table 7.3-2: Dry matter content of the feedstock – composted waste (kg kg^{-1})

LoW	Dry matter content (kg kg^{-1})
Group 02	0.40
Group 03	0.55
Group 04	0.55
Group 10	0.60
Group 15	0.85
Group 17	0.50
Group 19	0.45
Group 20	0.50

The resulting emissions of CH_4 and N_2O from 5.B.1 Composting in the period 1990 - 2020 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 - 2020)

Year	CH$_4$ emission (kt)	N$_2$O emission (kt)
1990	NO	NO
1991	NO	NO
1992	NO	NO
1993	NO	NO
1994	0.018	0.001
1995	0.020	0.001
1996	0.021	0.001
1997	0.022	0.001
1998	0.023	0.001
1999	0.024	0.001
2000	0.027	0.002
2001	0.022	0.001
2002	0.029	0.002
2003	0.021	0.001
2004	0.025	0.001
2005	0.045	0.003
2006	0.035	0.002
2007	0.066	0.004
2008	0.132	0.008
2009	0.180	0.011
2010	0.142	0.009
2011	0.165	0.010
2012	0.158	0.010
2013	0.176	0.011
2014	0.180	0.011
2015	0.153	0.009
2016	0.199	0.012
2017	0.172	0.010
2018	0.207	0.012
2019	0.259	0.016
2020	0.392	0.024

Notation key IE is used in the CRF 5.B.1.b for entire period 1990 - 2019. 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 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution'.

7.3.2.2. Anaerobic Digestion at Biogas Facilities

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_2bio).

Generated CH_4 is used to produce electricity, wherefore reporting of emissions from the process is done in the Energy sector. Emissions of CH_4 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). In this report, 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. Data on the mass of digested waste and by-products treated by anaerobic digestion at biogas facilities include data on different categories of waste according to the waste code - European List of Waste (LoW) and by-products.

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 on:

- mass of waste and by-products treated by anaerobic digestion at biogas facilities (on a wet weight basis, t),
- dry matter content of the feedstock (kg kg^{-1}),

The anaerobic digestion at biogas facilities has been applied in the Republic of Croatia since 2009. Data on the mass of waste and by-products treated with anaerobic digestion at biogas facilities and dry matter content of the feedstock were collected for the period from 2009 to 2020.

In the total mass of waste and by-products treated by anaerobic digestion, the largest share in all years has cattle slurry (60% - 100%, depending on the year). Other types of waste and by-products have significantly lower shares, among which the most important are pig slurry (11% - 13%), cattle solid manure (2% - 10%), poultry manure (1%), various types of waste in categories 02, 03, 15, 16, 19, 20 (1% - 12%) and silage (2% - 3%), In addition to the above, the other by-products are treated in biogas plants: food waste, milk, whey, slaughterhouse waste, blood and beer trope (Table 7.3-4).

Table 7.3-4: Data on feedstock (dry weight) treated by anaerobic digestion at biogas facilities (1990 – 2020)

Year	Cattle slurry (t)	Pig slurry (t)	Cattle solid manure (t)	Poultry manure (t)	LoW 02, 03, 15, 16, 19, 20 (t)*	Silage (t)	Other (t)	Total feedstock (t)
1990	NO	NO	NO	NO	NO	NO	NO	**NO**
1991	NO	NO	NO	NO	NO	NO	NO	**NO**
1992	NO	NO	NO	NO	NO	NO	NO	**NO**
1993	NO	NO	NO	NO	NO	NO	NO	**NO**
1994	NO	NO	NO	NO	NO	NO	NO	**NO**
1995	NO	NO	NO	NO	NO	NO	NO	**NO**
1996	NO	NO	NO	NO	NO	NO	NO	**NO**
1997	NO	NO	NO	NO	NO	NO	NO	**NO**
1998	NO	NO	NO	NO	NO	NO	NO	**NO**
1999	NO	NO	NO	NO	NO	NO	NO	**NO**
2000	NO	NO	NO	NO	NO	NO	NO	**NO**
2001	NO	NO	NO	NO	NO	NO	NO	**NO**
2002	NO	NO	NO	NO	NO	NO	NO	**NO**
2003	NO	NO	NO	NO	NO	NO	NO	**NO**
2004	NO	NO	NO	NO	NO	NO	NO	**NO**
2005	NO	NO	NO	NO	NO	NO	NO	**NO**
2006	NO	NO	NO	NO	NO	NO	NO	**NO**
2007	NO	NO	NO	NO	NO	NO	NO	**NO**
2008	NO	NO	NO	NO	NO	NO	NO	**NO**
2009	1,215.00	NO	NO	NO	NO	NO	NO	**1,215.00**
2010	3,285.00	NO	NO	NO	NO	NO	NO	**3,285.00**
2011	4,635.00	NO	NO	NO	NO	NO	NO	**4,635.00**
2012	7,646.55	NO	1,442.88	320.64	NO	NO	NO	**9,410.07**
2013	7,920.48	NO	3,976.43	883.65	1,680.09	NO	NO	**14,460.65**
2014	8,559.96	NO	3,950.33	877.85	4,509.43	NO	NO	**17,897.56**
2015	12,166.68	2,085.80	6,617.67	831.20	3,069.01	3,968.72	NO	**28,739.08**
2016	15,907.27	2,882.91	12,624.41	1,633.34	9,466.70	4,979.14	4,940.28	**52,434.05**
2017	17,084.81	2,766.18	15,229.35	1,845.81	20,974.81	4,449.59	4,465.32	**66,815.89**
2018	18,649.49	3,147.36	15,933.25	1,689.71	28,970.97	5,774.16	3,789.62	**77,954.55**
2019	20,426.83	3,608.25	17,570.89	5,030.74	37,298.21	7,313.71	3,907.51	**95,156.15**
2020	21,583.11	4,656.28	18,422.81	2,548.62	43,556.05	6,844.24	3,419.56	**101,030.66**

* the share of aggregated waste categories LoW (02, 03, 15, 16, 19, 20) in the total amount of feedstock per year is small (below 5% for the period 2009 - 2016, between 8% - 12% for the period 2017 - 2020)

NO - not occurring

Data on dry matter content of the feedstock were not provided by all biogas plants, and some of the submitted values are not comparable with the literature data (Table 3.4, EMEP/EEAGB2019, 5.B.2). Therefore, the values of dry matter content of waste and by-products were estimated using the recommended values from EMEP/EEA GB2019 and based on the collected data.

Table 7.3-5 shows dry matter content of the feedstock treated by anaerobic digestion at biogas facilities. Detailed explanation are presented in the inventory improvement projects - document: "Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)" (producer: Ekonerg, client: MESD, 2022).

Table 7.3-5: Dry matter content of the feedstock treated by anaerobic digestion at biogas facilities (kg kg^{-1})

LoW/ by-product code		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
02, 03, 15, 16, 19, 20*		0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
K3	food waste								0.40	0.40			
K3	milk								0.12	0.12	0.12	0.12	0.12
K3	whey								0.07	0.07	0.07	0.07	0.07
K3	slaughterhouse waste								0.25	0.25	0.25	0.25	0.25
K3	blood										0.10		0.10
K2	poultry manure				0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
K2	pig solid manure												
K2	pig slurry							0.04	0.04	0.04	0.04	0.04	0.04
K2	cattle slurry	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
K2	cattle solid manure				0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24
	silage							0.35	0.35	0.35	0.32	0.34	0.32
	beer trope												0.35

*for LoW together (02, 03, 15, 16, 19, 20) the value is estimated as for municipal waste from Table 3.4, EMEP/EEA GB2019, 5.B.2

default values from EMEP7EEA GB2019 - assessments for certain types of waste/by-products
delivered values (questionnaire)
estimated values

The resulting emissions of CH$_4$ and N$_2$O from 5.B.2 Anaerobic digestion at biogas facilities in the period 1990 - 2020 are presented in the Table 7.3-6.

Table 7.3-6: Emissions of CH$_4$ and N$_2$O from 5.B.2 Anaerobic digestion at biogas facilities (1990 - 2020)

Year	CH$_4$ emission (kt)	N$_2$O 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
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	0.029	NE
2014	0.036	NE
2015	0.057	NE

Year	CH$_4$ emission (kt)	N$_2$O emission (kt)
2016	0.105	NE
2017	0.134	NE
2018	0.156	NE
2019	0.190	NE
2020	0.202	NE

NO – not occurring
NE – not estimated

According to the TERT recommendation during the 2022 ESD review, Step 1, HR-5B-2022-0001, N$_2$O 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 - 2020. 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$_2$O 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 - 2020). 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 - 2020. 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$_3$ have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* 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$_2$O emissions estimates from composting are related primarily to applied default emission factors.

Uncertainty estimates associated with activity data for composting and anaerobic digestion at biogas facilities amount 5%. Based on the obtained information on activity data according the inventory improvement projects[69,70], expert responsible for emission calculation for the Waste sector has estimated uncertainty of the data, used values proposed by the 2006 IPCC Guidelines that are included in the tables in the sections on uncertainty assessment for individual categories. The process undertaken to assess uncertainties using expert judgement follows the guidelines stated in Volume 1, Chapter 3 of the 2006 IPCC Guidelines.

Uncertainty estimate associated with CH$_4$ emission factor for composting and anaerobic digestion of organic waste amount 100%, according to the provided uncertainty assessment in 2006 IPCC Guidelines. Uncertainty estimate associated with N$_2$O emission factor for composting of organic waste amounts 110%, according to the provided uncertainty assessment in *2006 IPCC Guidelines*.

More detailed information on uncertainty assessment are presented in Annex 2.

---

[69] document: "Report on inventory improvement for sector composting (NFR 5.B.1)" (producer: Ekonerg, client: MESD, 2021)
[70] document: "Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)" (producer: Ekonerg, client: MESD, 2022)

Emissions from 5.B.1 Biological treatment of solid waste - composting have been calculated using the same method for the period 1994 - 2020, in which composting was carried out. Emissions from 5.B.2 Biological treatment of solid waste - anaerobic digestion at biogas facilities have been calculated using the same method for the period 2009 - 2020, in which anaerobic digestion was carried out. The same source 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.

All input data and information relevant for the emissions calculation have been documented and archived.

7.3.5. Category-specific recalculations

Composting

For the source category CRF 5.B.1, CH_4 and N_2O emissions for the period 1990 - 2006 have not been calculated so far because activity data were not available. The composting process has been applied in the Republic of Croatia since 1994. The improvement resulted in an increase in CH_4 and N_2O emissions in the source category CRF 5.B.1 by 100% in the period from 1994 to 2006, while in the period from 2007 to 2019 the difference in emissions has a fluctuating trend and ranges from -49 % to 260%.

The implementation of the inventory improvement project has collected activity data on the plant level, which affects their transparency, accuracy and completeness.

Recalculation of CH_4 and N_2O emissions for source category CRF 5.B.1 has been performed for the period from 1994 to 2019, while for the period from 1990 to 1993 in the official reporting format (CRF) the notation key NO (not occurring) has been used.

Anaerobic digestion at biogas facilities

For the source category CRF 5.B.2, CH_4 emissions have not been calculated so far. The anaerobic digestion process has been applied in the Republic of Croatia since 2009. The improvement resulted in an increase in CH_4 emissions in the source category CRF 5.B.2 by 100% in the period from 2009 to 2019.

The implementation of the inventory improvement project collected activity data on the plant level, which affects their transparency, accuracy and completeness.

Recalculation of CH_4 emissions for source category CRF 5.B.2 has been performed for the period from 2009 to 2019, while for the period from 1990 to 2008 in the official reporting format (CRF) the notation key NO (not occurring) has been used.

7.3.6. Category-specific planned improvements

For now, there is no short-term goals for improvements regarding emissions calculations from the source categories 5.B.1 and 5.B.2.

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 is MESD that collects data from emission point sources in the Environmental Pollution Register database. According to the Ordinance on the Environmental Pollution Register, the completed forms should be submitted for the previous calendar year not later than March 1 of the current year. The new forms will come into force on January 1, 2023. 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 - 2020 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 – 2020).

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 - 2020. 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 2020, 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/ROO) to which the waste operators with issued waste management 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 GB2019 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.

In the framework of the preparation the 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution', inventory improvement project has been performed - document: "Report on inventory improvement for sector open burning of waste (NFR 5.C.2)" (producer: Ekonerg, client: MESD, 2022) has been prepared. Amounts of open burned agricultural waste have been collected for the entire reporting period from 1990 to 2020. 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. Incineration of waste

Generally, default emission factors are used for emissions calculation from category 5.C.1 Waste incineration because of insufficient data to use higher tier. Incineration of waste is not a key source.

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. 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). These values are proposed by 2006 IPCC Guidelines, Volume 5, Chapter 5.4, Table 5.2.

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 - 2020 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 - 2020 is defined as NA.

Above mentioned approach has been accepted by the TERT during the 2017 ESD review – the TERT confired 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 - 2020. Submitted data include hazardous waste and plastics. Data have been submitted in the aggregate form. For now, there is still no available information for separation the data for hazardous waste and plastic. ERT recommended extrapolating back in order to estimate CO_2 emissions from incineration of plastic waste. But, data for the whole period from 1990 - 2008 are provided in the aggregate form. It is necessary to do research in order to separate data for hazardous waste and plastic, which is included in the improvement plan. This was planned to be done in this submission (NIR 2022), however the necessary data were not provided.

Data for quantity of incinerated clinical waste for the period 1990 - 2020 were obtained by the MESD. There was no incineration of clinical waste without energy recovery in the period 2017 - 2020.

Data for CO_2 and N_2O emissions calculation from the incineration of waste (without energy recovery) for the period 1990 - 2020 are presented in the Table 7.4-1.

Table 7.4-1: Incinerated waste (without energy recovery) (1990 - 2020)

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

Year	Incinerated waste (t)	
	IW (t)	Clinical waste (t)
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

NO – not occurring

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 - 2020.

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 - 2020.

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.

Figure 7.4-1: Emissions of CO_2 from 5.C.1 Waste incineration (1990 - 2016)
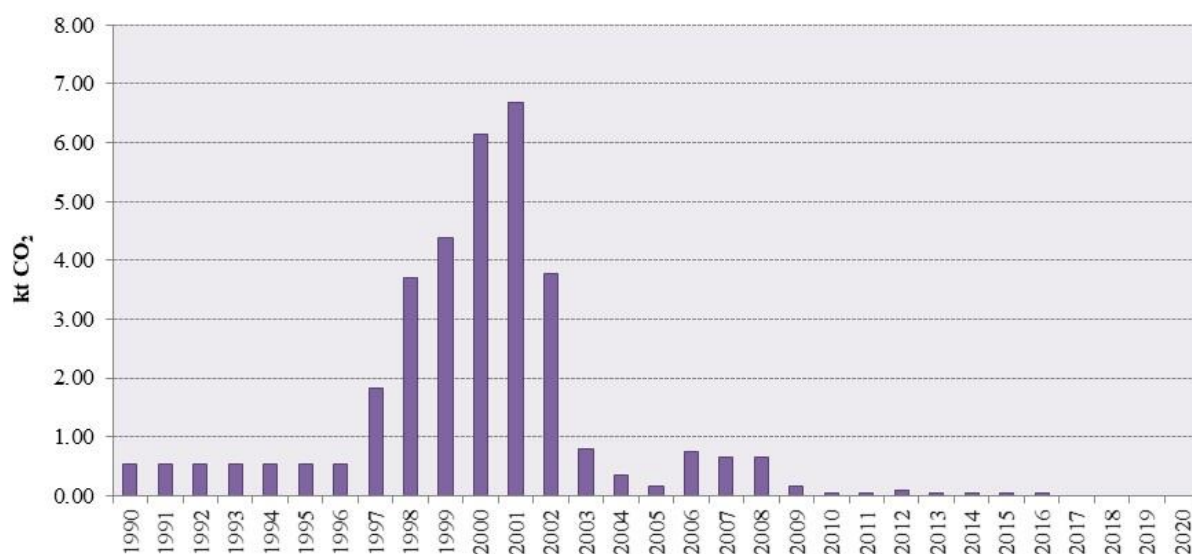
Figure 7.4-2: Emissions of N_2O from 5.C.1 Waste incineration (1990 - 2008)
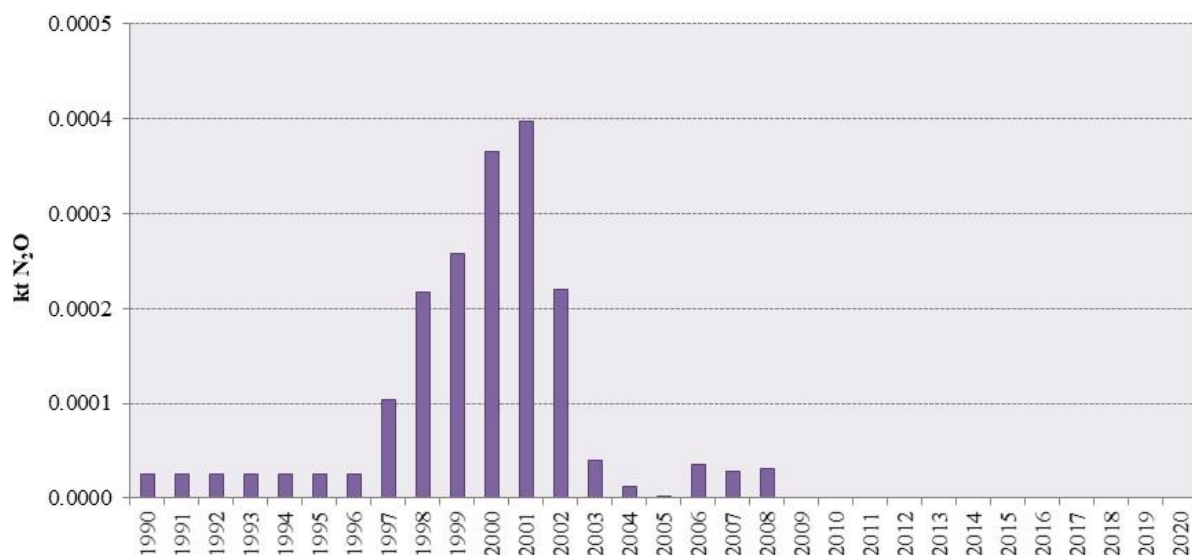
Emissions of SO_2, CO, NO_x and NMVOC have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution'.

7.4.2.2. Open burning of waste

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. Open burning of waste is not a key source. 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 amount of open-burned waste - agricultural residue. The sources of activity data are presented in table 7.4-2. 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.

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 - 2020	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 - 2020	Ministry of Agriculture, Directorate of forestry, hunting and wood industry
The area of the Republic of Croatia under forests (ha)	1990 - 2020	Ministry of Agriculture, Directorate of forestry, hunting and wood industry Source: General Forest management plan for the Republic of Croatia (1986, 1996, 2006, 2016), data on overgrown forest areas
The area of the Republic of Croatia under orchards, olive groves and vineyards	1990 - 2020	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	The area under forests (ha)	The area under orchards (ha)	The area under olive groves (ha)	The area under vineyards (ha)
1990	2053335.02	19474.35	IE	54315.75
1991	2054143.52	19544.88	IE	53667.00
1992	2054952.01	19615.40	IE	42295.50
1993	2055760.52	19685.93	IE	42493.50
1994	2056569.02	19756.45	IE	41661.00
1995	2057377.53	19826.98	IE	41514.00
1996	2058186.03	19897.50	IE	43289.25
1997	2081539.92	19968.03	IE	43527.75
1998	2104893.79	20038.55	IE	45109.50
1999	2128247.70	15880.13	5464.32	44328.00
2000	2151601.57	20179.60	5699.00	21295.50
2001	2174955.60	20596.80	5706.00	20792.25
2002	2198309.38	21119.00	5740.00	20795.25

Year	The area under forests (ha)	The area under orchards (ha)	The area under olive groves (ha)	The area under vineyards (ha)
2003	2221663.28	21632.10	5637.50	20766.00
2004	2245017.17	20594.70	6195.50	21000.00
2005	2268371.02	21196.00	6178.50	22252.50
2006	2291724.93	22264.90	6681.50	23074.50
2007	2296194.26	22904.00	7173.00	24340.50
2008	2304903.89	25153.10	7485.50	25305.75
2009	2312440.28	25661.30	7652.00	25785.00
2010	2319797.25	23022.30	8548.00	24531.75
2011	2326503.41	22792.00	8600.00	24363.75
2012	2334517.42	21592.20	9050.00	21927.75
2013	2352944.06	19874.40	9295.00	19575.00
2014	2361156.05	22206.80	9541.00	19623.00
2015	2369187.25	21078.40	9550.00	19190.25
2016	2369187.25	20633.20	9092.00	17550.00
2017	2374269.98	21443.80	8341.50	16425.00
2018	2375945.06	22705.20	9348.50	15384.00
2019	2384190.96	24173.80	9303.00	14868.00
2020	2387297.52	23220.40	10141.00	16090.50

IE (included elsewhere) - olive grove areas for the period 1990 - 1998 are included under orchard areas

Table 7.4-4. Activity dana - pruning residues from orchards, olive groves and vineyards (t)

Year	Pruning residues from forests (t)	Pruning residues from orchards (t)	Pruning residues from orchards (t)	Pruning residues from orchards (t)	TOTAL Agricultural residues (t)
1990	NO	6426.00	IE	99066.75	105492.75
1991	NO	6449.00	IE	93222.38	99671.38
1992	NO	6473.00	IE	69970.94	76443.94
1993	NO	6496.00	IE	66950.95	73446.95
1994	NO	6519.00	IE	62513.62	69032.62
1995	NO	6542.00	IE	59326.71	65868.71
1996	NO	6566.00	IE	58917.79	65483.79
1997	NO	6589.00	IE	56421.32	63010.32
1998	NO	6612.00	IE	55687.25	62299.25
1999	NO	5240.92	0.00	52116.66	57357.58
2000	NO	6659.00	21371.25	23844.98	51875.23
2001	NO	7031.00	21397.50	22172.84	50601.34
2002	NO	6940.00	21525.00	21120.04	49585.04
2003	NO	7019.00	21140.63	20086.03	48245.66
2004	NO	6123.00	22923.35	19345.11	48391.46
2005	NO	6042.00	22551.53	19522.77	48116.30
2006	NO	6049.00	24053.40	19279.94	49382.34
2007	NO	5891.00	25464.15	19841.71	51196.86
2008	NO	6084.00	26199.25	20125.42	52408.67
2009	NO	5847.00	26399.40	20006.40	52252.80
2010	NO	5376.00	29063.20	18569.77	53008.97
2011	NO	3708.00	28810.00	17992.78	50510.78
2012	NO	3174.00	29865.00	15798.81	48837.81
2013	NO	2567.00	30208.75	13759.67	46535.42
2014	NO	2696.00	30531.20	13456.99	46684.19
2015	NO	2409.00	30082.50	12839.24	45330.74

Year	Pruning residues from forests (t)	Pruning residues from orchards (t)	Pruning residues from orchards (t)	Pruning residues from orchards (t)	TOTAL Agricultural residues (t)
2016	NO	2259.00	28185.20	11455.44	41899.64
2017	NO	1851.00	25441.58	10459.63	37752.20
2018	NO	1664.00	28045.50	9557.76	39267.26
2019	NO	1516.00	25583.25	9011.89	36111.14
2020	NO	1268.00	25352.50	9515.00	36135.50

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

The resulting emissions of CH_4 and N_2O from 5.C.2 Open burning of waste in the period 1990 - 2020 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 - 2020)

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

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 assess activity data and applied default emission factors.

Uncertainty estimate associated with activity data for IW amounts 50%. Uncertainty estimate associated with activity data for clinical waste amounts 50%. Uncertainty estimate associated with activity data for open-burned agricultural waste amounts 50%. Based on the obtained information on activity data according the Annual data collection plan, expert responsible for emission calculation for the Waste sector has estimated uncertainty of the data, used values proposed by the 2006 IPCC Guidelines that are included in the tables in the sections on uncertainty assessment for individual categories. The process undertaken to assess uncertainties using expert judgement follows the guidelines stated in Volume 1, Chapter 3 of the 2006 IPCC Guidelines.

Uncertainty estimate associated with CO_2 emission factor for incineration of IW amounts 30%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with CO_2 emission factor for incineration of clinical waste amounts 30%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with N_2O emission factor for incineration of IW amounts 200%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with CH_4 emission factor for open burning of waste amounts 100%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with N_2O emission factor for open burning of waste amounts 100%, according to the provided uncertainty assessment in 2006 IPCC Guidelines.

More detailed information on uncertainty assessment are presented in Annex 2.

Emissions from 5.C.1 Waste incineration have been calculated using the same method for every year in the time series. The same source 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.

All input data and information relevant for the emissions calculation have been documented and archived.

7.4.5. Category-specific recalculations

Incineration of waste

There are no source-specific recalculations in this report.

Open burning of waste

For the source category CRF 5.C.2, CH_4 and N_2O emissions have not been calculated so far. The improvement resulted in an increase in CH_4 and N_2O emissions in the source category CRF 5.C.2 by 100% in the whole trend. Recalculation of CH_4 and N_2O emissions has been performed for the period from 1990 to 2019.

7.4.6. Category-specific planned improvements

Future improvements are related primarily to aggregation of accurate data for CO_2 and N_2O emission calculations from incineration of different types of waste as well as detailed information on technology applied for the incineration.

Data for IW, which include hazardous waste and plastics, have been submitted in the aggregate form. For now, there is still no available information for separation the data for hazardous waste and plastic. ERT recommended extrapolating back in order to estimate CO_2 emissions from incineration of plastic waste. But, data for IW for the whole period from 1990 - 2008 are provided in the aggregate form. It is necessary to do research in order to separate data for hazardous waste and plastic. This was planned to be done in this submission (NIR 2022), however the necessary data were not provided. That will be part of the project that MESD coordinates conducting comprehensive research regarding system improvements and development of historical data bases for the calculation and reporting of greenhouse gas emissions from the Waste sector. The project is in preparation.

ERT recommended Croatia to provide information on the handling of plastic waste - systems and amounts of plastic waste disposed of and/or incinerated for the entire time series, in order to improve completeness and transparency because plastic waste is an important source of CO_2. For now, there is still no available information for that issue and this need to be investigated. This was planned to be done in this submission (NIR 2022), however the necessary data were not provided. That will be part of the project that MESD coordinates conducting comprehensive research regarding system improvements and development of historical data bases for the calculation and reporting of greenhouse gas emissions from the Waste sector. The project is in preparation.

More information for uncertainty estimation associated with activity data and emission factors is required, regarding more accurate and transparent uncertainty analysis. For now, uncertainty estimates are based on assessment of expert responsible for emission calculation for the Waste sector. Assessment is based on the obtained information on activity data according to the Annual data collection plan, using values proposed by the 2006 IPCC Guidelines. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data, thereby increasing transparency in the reporting.

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 short-term goals (in the next submission).

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) 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.

Out of the total population of Croatia (official data from the census of 2011 - 4,284,889 inhabitants), 80% resides in the settlements of mentioned 260 agglomerations for whom the construction of the public sewerage system is planned in the next 5 - 7 years (it would comprise 3,424,856 inhabitants). It is estimated that 67.5% of these 3,424,856 residents are already connected to public drainage systems. Also, in the agglomerations with total generated load below 2000 PE, there is also a number of 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, which would count up to 2,345,180 inhabitants. It is considered that others (1.939.709 inhabitants) have an individual solution for collecting wastewater from households.

7.5.2. Methodological issues

7.5.2.1. Domestic wastewater

Methane (CH$_4$) and nitrous oxide (N$_2$O) emissions from the treatment of domestic wastewater are included in emission estimates for the period 1990 - 2020.

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 - 2019. Insufficient data for years between those years have been assessed by the interpolation method. Data for 2020 are not available yet. According to the explanation provided by Croatian Waters, this year the data will change a bit more, adjusted with the Census 2021. The reporting deadline is the end of June 2022 when new data will probably be provided. For now, data for 2020 are assumed according to data for 2019.

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 - 2020 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 - 2020)

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
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	21,899.78	1,919,700	42.041

* 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 - 2020. 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 - 2020.

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 - 2020.

Fraction of treated wastewater in septic tank amounts 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 - 2020.

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. 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 people 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 (the population estimate of the Republic of Croatia for the period 1990 - 2020 were taken from Statistical Yearbooks and Statistical First Releases, https://www.dzs.hr/). Data for calculation of degradable organic component in kg BOD/1000 person/yr (the same data as for septic tank) have been obtained by Croatian Water (Hrvatske vode) for 1990, 1995, 2000 and for the period 2003 - 2019. Insufficient data for years between those years have been assessed by the interpolation method. Data for 2020 are not available yet. According to the explanation provided by Croatian Waters, this year the data will change a bit more, adjusted with the Census 2021. The reporting deadline is the end of June 2022 when new data will probably be provided. For now, data for 2020 are assumed according to data for 2019.

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 - 2020 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 - 2020)

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	482,000	13.195
2001	21,899.65	474,000	12.976
2002	21,899.70	474,000	12.976
2003	21,900.16	474,000	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	473,000	12.948
2010	21,902.04	472,000	12.922

Year	DOC (kg BOD/1000persons/yr)	Population*	Total organic product (kt DC/yr)
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	21,899.78	445,000	12.182

* 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 - 2020.

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 - 2020.

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 - 2020)

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

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
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	42.041	12.182	54.223

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 - 2020 are presented in the Figure 7.5-1.

Figure 7.5-1: Emissions of CH_4 from 5.D.1 Domestic Wastewater (1990 - 2020)

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 2018 in-country review and the 2020 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 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution'.

Nitrous oxide (N_2O) emissions from wastewater

Nitrous oxide (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 - 2020 were taken from Statistical Yearbooks and Statistical First Releases (https://www.dzs.hr/). Croatian data on the annual per capita protein intake value (PIV), for the period 1992 -2018, were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. Taking into account the PIV trend, the pattern from 1992 to 1994 has been used for calculation of data in 1990 and 1991. The pattern from 2015 to 2018 has been used for calculation of insufficient data for 2019 and 2020. Data on population and PIV for the period 1990 - 2020 are presented in the Table 7.5-4.

Table 7.5-4: Data on population and PIV (1990 - 2020)

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	4,572,500	23.12
1998	4,501,000	22.83
1999	4,554,000	24.30
2000	4,381,000	24.34
2001	4,305,494	26.40
2002	4,305,384	27.81
2003	4,305,725	27.61
2004	4,310,861	27.46
2005	4,312,487	28.52
2006	4,313,530	29.38
2007	4,311,967	29.76
2008	4,309,796	30.16
2009	4,302,847	30.72
2010	4,289,857	29.44
2011	4,280,622	29.82
2012	4,267,558	30.49
2013	4,255,689	30.79
2014	4,238,389	30.95
2015	4,203,604	32.05
2016	4,174,349	32.78
2017	4,124,531	33.10
2018	4,087,843	33.07
2019	4,065,253	33.68

Year	Population	Protein intake (kg/person/yr)
2020	4,047,680	34.02

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 - 2020:

- 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;
- 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.

Regarding the TERT recommendation during the 2017 ESD review about estimation on N_2O from domestic wastewater, there is no information on the use of garbage disposal units in households in Croatia. During review, Croatia proposed to keep the Factor for non-consumed protein F (non-con) = 1.4 for developed countries instead of F (non-con) = 1.1 for developing countries. Croatia provided calculations with both factors, F (non-con) = 1.4 and F (non-con) = 1.1 and asked TERT for confirmation on proposal to keep factor for developed countries. Competent institution should confirm the assumption that less than 1% of household uses garbage disposal units. For now, information is not available. Because of that, F (non-con) = 1.4 is included in the N_2O emission calculation. Revision with F (non-con) = 1.1 will be prepared after confirmation of competent institution. This is included in the Annual data collection plan.

The resulting annual N_2O emissions from wastewater in the period 1990 - 2020 are presented in the Figure 7.5-2.

Figure 7.5-2: N_2O Emissions from Wastewater (1990 - 2020)

The trend of N_2O emissions during the reporting period depends on the protein intake value.

7.5.2.2.   Industrial wastewater

Methane 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 assessed 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).

$$t \ x \ \frac{m^3}{t} x \frac{kg \ COD}{m^3} = kg \ COD$$

Data on industrial output for the period 1990 - 2020 are presented in the Table 7.5-5.

Table 7.5-5: Data on industrial output (1990 - 2020)

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*
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	4,441,386	643,389	2,955,198

Year	Total industrial output (tonne)		
	Manufacture of food products and beverages	Manufacture of pulp, paper and paper products	Manufacture of chemicals and chemical products
2020	4,072,146	646,114	2,891,373

* insufficient data on industrial output (tonne/yr) were assessed by extrapolation or interpolation method:

- 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.

Data on wastewater output (m^3/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 taken from Statistical Yearbooks and Statistical First Releases (https://www.dzs.hr/). Data for 1997 are insufficient and assessed by interpolation. Data for the period 1990 - 1993 are available in different (aggregated) form. These data also assessed by extrapolation to enable usage of the same methodology during the time series.

Data on wastewater output for the period 1990 - 2020 are presented in the Table 7.5-6.

Table 7.5-6: Data on wastewater output (1990 - 2020)

Year	Total wastewater output (m^3)		
	Manufacture of food products and beverages	Manufacture of pulp, paper and paper products	Manufacture of chemicals and chemical products
1990	7,237,300	3,207,500	2,875,490
1991	7,127,770	3,079,150	2,883,241
1992	7,018,240	2,950,800	2,890,992
1993	6,908,710	2,822,450	2,898,743
1994	5,911,000	679,000	2,115,000
1995	6,157,000	5,224,000	1,806,000
1996	5,274,000	3,817,000	6,896,000
1997	6,470,590	2,309,050	2,929,747
1998	9,348,000	1,130,000	1,571,000
1999	9,759,000	1,065,000	2,371,000
2000	4,914,000	1,169,000	2,189,000
2001	4,715,000	1,808,000	1,577,000
2002	5,630,000	132,000	3,619,000
2003	5,037,000	3,695,000	4,936,000
2004	4,767,000	2,213,000	3,519,000
2005	6,440,000	681,000	1,864,000
2006	5,045,000	1,692,000	3,375,000
2007	4,941,000	1,646,000	1,624,000
2008	2,570,000	1,574,000	1,007,000
2009	2,553,000	1,766,000	1,332,000
2010	3,086,000	2,508,000	1,437,000
2011	2,279,000	171,000	728,000
2012	2,084,000	1,881,000	471,000

Year	Total wastewater output (m^3)		
	Manufacture of food products and beverages	Manufacture of pulp, paper and paper products	Manufacture of chemicals and chemical products
2013	2,692,000	1,744,000	483,000
2014	2,473,000	1,719,000	482,000
2015	3,136,000	1,484,000	500,000
2016	3,570,000	2,150,000	734,000
2017	3,783,000	2,720,000	677,000
2018	4,019,000	2,682,000	514,000
2019	4,071,000	2,703,000	533,000
2020	4,372,000	2,514,000	457,000

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 - 2020 (Table 7.5-7).

Table 7.5-7: Data on degradable organic component and wastewater produced (1990 - 2020)

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 disposed at landfills and used for other purposes (composting, agriculture application) was excluded from the total organic product for entire period 1990 - 2020 and reported in the CRF table 5.D.2.

Organic wastewater from industrial sources (kt COD/yr) and sludge removed (kt DC/yr) for the period 1990 - 2020 are presented in the Table 7.5-8.

Table 7.5-8: Organic wastewater from industrial sources and sludge removed (1990 - 2020)

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	16.317
1991	387.413	515.600	654.286	1,557.298	16.317
1992	389.994	536.719	641.597	1,568.310	16.317
1993	392.576	557.838	628.908	1,579.322	16.317
1994	395.157	661.537	616.219	1,672.914	16.317
1995	397.739	600.992	632.598	1,631.329	16.317
1996	400.321	542.081	585.923	1,528.326	16.317
1997	394.311	619.876	594.392	1,608.579	16.317
1998	421.646	607.538	476.548	1,505.732	16.317
1999	401.378	673.124	557.553	1,632.055	16.317
2000	409.673	788.739	584.369	1,782.780	16.317
2001	226.666	790.920	485.330	1,502.916	16.317
2002	241.490	828.475	467.511	1,537.476	16.317
2003	256.612	794.511	470.851	1,521.973	16.317
2004	272.033	826.314	559.757	1,658.104	16.317
2005	359.747	683.497	616.415	1,659.660	16.332
2006	394.959	785.560	590.784	1,771.304	16.347
2007	374.952	850.265	659.845	1,885.062	16.352
2008	374.557	868.729	628.605	1,871.891	17.384
2009	313.656	592.785	476.194	1,382.634	22.534
2010	299.631	957.178	546.217	1,803.03	19.133
2011	308.695	932.849	533.210	1,774.75	23.572
2012	304.184	815.491	488.058	1,607.73	26.526
2013	291.892	736.703	472.160	1,500.75	39.109
2014	309.164	739.051	497.168	1,545.38	32.997
2015	301.887	761.252	538.103	1,601.24	37.308
2016	309.721	871.868	530.024	1,711.613	27.014
2017	312.581	908.859	611.100	1,832.540	29.311
2018	297.844	901.603	549.970	1,749.418	33.180
2019	346.388	938.062	593.995	1,878.444	22.447
2020	321.529	942.034	581.166	1,817.998	41.397

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 2018 in-country review and the 2020 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 - 2020.

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 - 2020.

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 - 2020.

The resulting annual emissions of CH_4 from 5.D.2 Industrial Wastewater in the period 1990 - 2020 are presented in the Figure 7.5-3.

Figure 7.5-3: Emissions of CH_4 from 5.D.2 Industrial Wastewater (1990 - 2020)
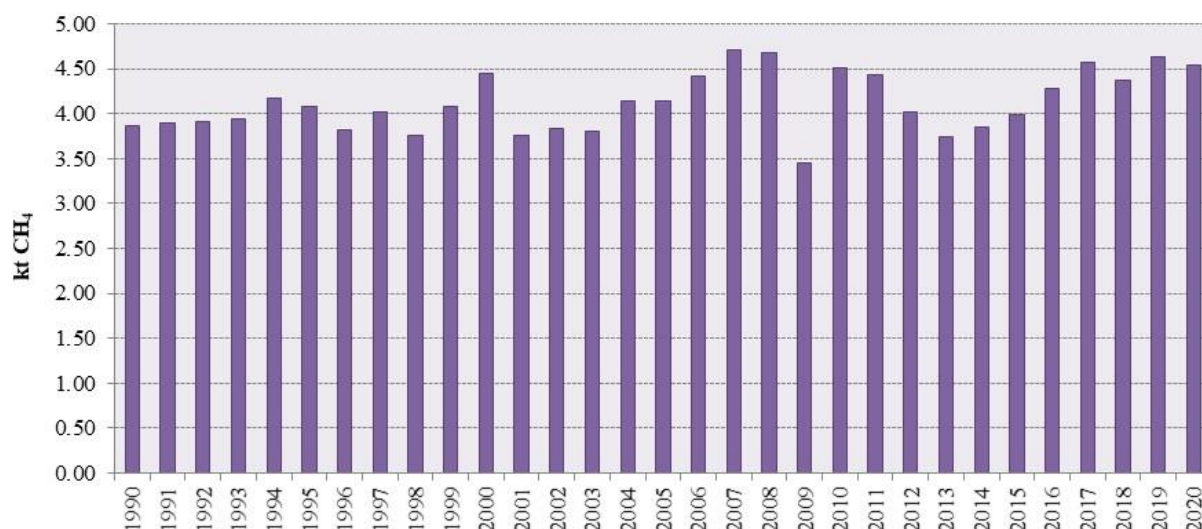
The fluctuating trend of CH_4 emissions during the reporting period depends on the data on industrial output.

Emissions of NMVOC and NH_3 have been taken from the emission inventory report 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* 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.

Uncertainty estimate associated with activity data for CH_4 emissions calculation from domestic wastewater amounts 30%. Uncertainty estimate associated with activity data for CH_4 emissions calculation from industrial wastewater amounts 30%. Uncertainty estimate associated with activity data for N_2O from wastewater amounts 50%. Based on the obtained information on activity data according the Annual data collection plan, expert responsible for emission calculation for the Waste sector has estimated uncertainty of the data, used values proposed by the 2006 IPCC Guidelines that are included

in the tables in the sections on uncertainty assessment for individual categories. The process undertaken to assess uncertainties using expert judgement follows the guidelines stated in Volume 1, Chapter 3 of the 2006 IPCC Guidelines.

Uncertainty estimate associated with CH_4 emission factor for domestic wastewater amounts 30%, according to provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with CH_4 emission factor for industrial wastewater amounts 30%, according to provided uncertainty assessment in 2006 IPCC Guidelines.

Uncertainty estimate associated with N_2O emission factor for wastewater amounts 50%, according to provided uncertainty assessment in 2006 IPCC Guidelines.

More detailed information on uncertainty assessment are presented in Annex 2.

CH_4 emissions from domestic and industrial wastewater and N_2O emissions from wastewater have been calculated using the same method for every year in the time series. Different source 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.

CH_4 and N_2O emissions from 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 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

Nitrous oxide emissions from wastewater

New data on protein intake value (PIV), for the period 2014 - 2018, were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. The pattern from 2015 to 2018 has been used for calculation of insufficient data for 2019 and 2020.

Therefore, recalculations of N_2O emissions were made for the period 2014 - 2019.

Methane emissions from industrial wastewater

New data on industrial output (tonne/yr) for Manufacture of food products and beverages was included in the emission calculation for 2019.

New data on organic component removed as sludge that is disposed at landfills and used for other purposes (composting, agriculture application) were excluded from the total organic product for the period 2008 - 2019.

Therefore, recalculations of CH_4 emissions were made for the period 2008 - 2019.

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 2018 in-country review and the 2020 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.

Data for population with an individual system of drainage and data for calculation of degradable organic component in kg BOD/1000 person/yr for 2020 are not available yet. According to the explanation provided by Croatian Waters, this year the data will change a bit more, adjusted with the Census 2021. The reporting deadline is the end of June 2022 when new data will probably be provided. For now, data for 2020 are assumed according to data for 2019. The correct value for 2020 needs to be included in the inventory.

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.

The ERT also recommends that Croatia improve quality of data on sludge produced and data on management of sludge and provide information on how sludge produced is treated, disposed in landfills or used in other purposes such as composting and agriculture application. This information should be used to estimate CH_4 emissions from wastewater treatment for each treatment pathway or system, avoiding double-counting of the degradable organic component of sludge removed and applied in other purposes.

Regarding the TERT recommendation during the 2017 ESD review about estimation on N_2O from domestic wastewater, there is no information on the use of garbage disposal units in households in Croatia. During review, Croatia proposed to keep the Factor for non-consumed protein F (non-con) = 1.4 for developed countries instead of F (non-con) = 1.1 for developing countries. Croatia provided calculations with both factors, F (non-con) = 1.4 and F (non-con) = 1.1 and asked TERT for confirmation on proposal to keep factor for developed countries. Competent institution should confirm the assumption that less than 1% of household uses garbage disposal units. For now, information is not available. Because of that, F (non-con) = 1.4 is included in the N_2O emission calculation. Revision with F (non-con) = 1.1 will be prepared after confirmation of competent institution.

More information for uncertainty estimation associated with activity data and emission factors is required, regarding more accurate and transparent uncertainty analysis. For now, uncertainty estimates are based on assessment of expert responsible for emission calculation for the Waste sector. Assessment is based on the obtained information on activity data according to the Annual data collection plan, using values proposed by the 2006 IPCC Guidelines. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data and parameters, thereby increasing transparency in the reporting.

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 short-term goals (in the next submission) or 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 CO₂ 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 2020 Submission to the Convention on Long-range Transboundary Air Pollution'.The calculations of aggregated results for the emissions of indirect gases in the period 1990-2020 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	2016	2017	2018	2019	2020
NOx Emission	111.19	88.41	170.97	91.49	73.96	66.39	64.30	114.20	53.32	52.65	50.20
Energy	97.55	72.02	80.54	78.53	63.24	49.44	49.98	49.52	44.55	43.59	40.85
Industrial Processes	2.66	2.53	2.53	2.29	1.52	1.03	0.92	1.16	0.89	0.75	0.94
Agriculture	10.35	7.43	7.91	8.67	7.70	6.87	6.54	7.26	7.08	7.12	7.12
LULUCF	0.62	6.43	79.99	2.01	1.50	9.05	6.86	56.25	0.80	1.19	1.29
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA
CO Emission	551.55	443.62	478.82	415.64	325.95	267.39	258.82	261.41	229.32	215.89	218.24
Energy	511.49	415.59	435.39	397.57	325.60	265.16	256.99	251.31	228.56	215.24	214.16
Industrial Processes	39.91	27.26	30.12	17.37	0.18	0.21	0.00	0.01	0.23	0.12	0.08
Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
LULUCF	0.15	0.76	13.30	0.70	0.18	2.02	1.82	10.09	0.53	0.52	4.00
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA	NO,NE, IE,NA
NMVOC Emission	162.03	114.46	106.57	109.39	87.84	68.90	70.05	72.19	67.06	72.80	70.35
Energy	67.22	55.81	58.95	53.42	43.65	33.97	32.72	31.49	29.60	27.86	27.21
Industrial Processes	83.67	49.08	30.58	45.89	33.82	23.91	26.52	24.94	27.56	33.73	31.07
Agriculture	10.83	8.67	8.71	9.42	9.56	9.34	9.33	9.35	9.01	9.30	9.02
LULUCF	0.10	0.63	7.94	0.21	0.15	0.92	0.71	5.62	0.10	1.13	2.29
Waste	0.21	0.27	0.38	0.45	0.66	0.75	0.77	0.80	0.79	0.77	0.77
SO2 Emission	170.10	76.82	59.99	58.33	35.02	15.51	14.39	12.29	9.84	7.36	5.87
Energy	169.37	76.55	59.54	57.92	35.01	15.50	14.39	12.29	9.83	7.35	5.87

Pollutants	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
Industrial Processes	0.72	0.27	0.44	0.41	0.01	0.01	NO,NE, NA	0.00	0.01	0.00	0.00
Agriculture	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LULUCF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO

9.3. Uncertainties and time-series consistency

For detailed information refer to 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020 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 2020 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 2020 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 2020 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 1990-2019 are described in each chapter of Inventory. Difference between emissions NIR 2022 and NIR 2021 for 1990 are shown in the Table 10.1-1 while for 2019 are shown in Table 10.1-2.

Table 10.1-1: Difference between emissions estimated in NIR 2022 and NIR 2021 for 1990

Difference between NIR 2022 and NIR 2021 submission for 1990	CO$_2$[1]	CH$_4$	N$_2$O	HFCs, PFCs, SF$_6$, NF$_3$	Total
	CO$_2$ equivalent (kt)				
Total (net emissions)(1)	477.9	19.4	7.2	NO	504.8
1. Energy	0.0	0.8	-0.8	NO	-0.1
A. Fuel combustion (sectoral approach)	0.0	0.8	-0.8	NO	-0.1
B. Fugitive emissions from fuels	0.0	0.0	0.0	NO	0.0
2. Industrial processes and product use	2.1	0.0	3.3	NO	5.7
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	2.1	NO	NO	NO	2.1
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	3.3	NO	3.6
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	475.8	0.0	0.0	NO	475.8
A. Forest land	326.4	0.0	0.0	NO	326.4
B. Cropland	236.1	NO	0.0	NO	236.1
C. Grassland	0.0	0.0	0.0	NO	0.0
D. Wetlands	-6.2	NO	0.0	NO	-6.2
E. Settlements	-64.1	NO	0.0	NO	-64.1
F. Other land	NO	NO	NO	NO	NO
G. Harvested wood products	-16.3	NO	NO	NO	-16.3
5. Waste	0.0	18.7	4.7	NO	23.4
A. Solid waste disposal	NO	1.5	NO	NO	1.5
B. Biological treatment of solid waste	NO	NO	NO	NO	NO
C. Incineration and open burning of waste	0.0	NO	4.7	NO	21.9
D. Waste water treatment and discharge	NO	0.0	0.0	NO	0.0
Total CO2 equivalent emissions without land use, land-use change and forestry					28.99
Total CO2 equivalent emissions with land use, land-use change and forestry					504.81

Table 10.1-2: Difference between emissions estimated in NIR 2022 and NIR 2021 for 2019

Difference between NIR 2022 and NIR 2021 submission for 2019	CO_2[(1)]	CH_4	N_2O	HFCs, PFCs, SF_6, NF_3	Total
	CO_2 equivalent (kt)				
Total (net emissions)(1)	281.5	29.4	-91.3	NO	1,220.5
1. Energy	83.3	-0.1	-4.7	NO	78.5
A. Fuel combustion (sectoral approach)	0.0	-0.1	-4.7	NO	-4.8
B. Fugitive emissions from fuels	83.3	0.0	0.0	NO	83.3
2. Industrial processes and product use	-3.4	NO	-87.9	NO	909.6
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	-3.4	NO	NO	NO	-3.4
E. Electronic industry	NO	NO	NO	NO	NO
F. Product uses as ODS substitutes	NO	NO	NO	NO	998.4
G. Other product manufacture and use	NO	NO	-87.9	2.48	-85.4
3. Agriculture	-1.3	0.0	0.0	NO	-1.3
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	-1.3	NO	NO	NO	-1.3
H. Urea application	0.0	NO	NO	NO	0.0
4. Land use, land-use change and forestry(1)	202.9	0.2	0.2	NO	203.3
A. Forest land	93.0	0.0	0.0	NO	93.0
B. Cropland	128.8	0.0	0.0	NO	128.8
C. Grassland	-8.1	0.2	0.2	NO	-7.8
D. Wetlands	-1.3	NO	0.0	NO	-1.3
E. Settlements	-59.9	NO	0.0	NO	-59.9
F. Other land	NO	NO	NO	NO	NO
G. Harvested wood products	50.5	NO	NO	NO	50.5
5. Waste	NO	29.4	1.1	NO	30.5
A. Solid waste disposal	NO	18.8	NO	NO	18.8
B. Biological treatment of solid waste	NO	6.3	1.1	NO	7.4
C. Incineration and open burning of waste	NO	NO	NO	NO	NO
D. Waste water treatment and discharge	NO	-1.6	-1.6	NO	-3.2
Total CO2 equivalent emissions without land use, land-use change and forestry					1,017.28
Total CO2 equivalent emissions with land use, land-use change and forestry					1,220.55

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 2020)

In 2022 Inventory recalculations are mainly made according to UNFCCC experts review teams and ESD. Detailed information on reasons for recalculations of the 1990 and 2019 referred to in Article 7(1)(e) of Regulation (EU) No 525/2013 are given in table 10.4-1.

10.3.   Implications for emission trends, including time-series consistency

In 2021 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 129/2019) 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 fuels – CO2	Check the CO2 EFs for natural gas from the countries of origin for this imported natural gas, and on that basis estimate a weighted average country-specific EF and use it for emission estimates of CO2 from natural gas consumption	E.2.	Not implemented	
1.A.2 Manufacturing industries and construction – gaseous, liquid and solid fuels – CO2, CH4 and N2O	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	E.5	Implemented	3.2.5.
1.A.2.a Iron and steel – gaseous fuels – CO2	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 CO2 emission estimates for iron and steel production by ensuring that no double counting of emissions	E.6	Not implemented	
1.A.2.g Other (manufacturing industries and construction) – gaseous, liquid and solid fuels, other fossil fuels and biomass – CO2, CH4 and N2O	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 – CO2	Strive to develop a country-specific CO2 EF for 1.B.2.b.3 (natural gas – processing) (considering that CO2 emissions from 1.B.2.b (natural gas) is a key category), taking into account data on CO2 scrubbing provided by gas field and plant operators	E.11	Not implemented	
Fuel combustion – reference approach – liquid fuels – CO2, CH4 and N2O	undertake additional research to determine the NCVs of bitumen and lubricants and use those values when calculating emissions from fuel combustion in order to avoid possible underestimation of emissions	E.12	Not implemented	
1.A.3.b Road transportation – gaseous and liquid fuels – CO2	develop country-specific EFs for CO2 emissions from fuels combusted in road transportation, thereby allowing it to use a tier 2 method for estimating these emissions, given that CO2 emissions from road transportation is a key category and that the 2006 IPCC Guidelines	E.13	Not implemented	

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
Industrial processes and product use				
2. General (IPPU) – SF₆	Correct the error in NIR table ES. 3.2-6, ensuring that emissions reported in this table are consistent with the SF6 emissions reported in CRF table summary 2 and sectoral CRF tables and within the NIR.	I.3	Implemented.	E.S.3.2.4
2. General (IPPU) – CO₂ and N₂O	Provide in NIR explanations of the inconsistencies between emission data reported in the CRF tables and those reported in the EU ETS reports, for each category, owing to different classifications of emission categories.	I.4	Implemented.	1.4., 3.1.1., 4.2.3.1, 4.3.1.2, 4.4.1.2
2.A.1 Cement production – CO₂	Include all carbonate and non-carbonate sources of CaO used for cement production.	I.6	Planned for the next submission.	
2.B.8 Petrochemical and carbon black production – CO₂	Move from a tier 1 method to a higher-tier method for estimating emissions from petrochemical and carbon black production.	I.20	Not implemented. Input data for a higher tier method for this category are not available. This issue is included in the Data Collection Plan, and depending on the available resources, further research will be conducted. Currently, this issue is categorized as a long-term plan for improvement.	
2.C.1 Iron and steel production – CO₂	Emissions from pig iron production related to coke and coal consumption are included in the Energy sector. TERT recommends to report all emissions from this activity under category 2.C.1.	I.22	Not implemented. Since all quantities of coke and coal are included in the energy balance, ie, they are already included in the Energy sector, only emissions from the use of limestone and dolomite are included in this category within this sector.	
2.C.1 Iron and steel production – CO₂	Croatia did not report disaggregated AD on the consumption of raw materials and electrodes in NIR.	I.24	Not implemented. As this is confidential data, disaggregated data on the consumption of individual raw materials by factories cannot be presented in the NIR. All input data were reviewed in detail as part of the 2018 in-country review.	
2.C.1 Iron and steel production – CO₂	Allocate the estimates of emissions from natural gas consumption from Energy sector to the IPPU sector.	I.25	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.	

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
2.C.2 Ferroalloys production – CO_2	Move to a higher Tier.	I.29	Not implemented. Input data for a higher tier method are not available. Additional information are given in 2021 and 2022 NIR.	4.4.2.6.
2.D.1 Lubricant use – CO_2	Revise AD, NCV, and allocate emissions in sectors Energy, IPPU and Waste.	I.32, I.33, I.34, I.35	Partially implemented. Results of the improvement project are included in NIR 2021, and they are related to revised AD, NCV and allocation of emissions from 2-stroke engines to Energy sector. Fraction of lubricants oxidized in the primary use and disposal, including incineration is not taken into consideration due to unavailable data needed for emission estimate.	4.5.1.
2.F.1 Refrigeration and air conditioning – PFCs, HFCs	Continue to conduct surveys on the status of disposal of refrigeration and air-conditioning equipment and include the results in the NIR.	I.37	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.1
2.F.1 Refrigeration and air conditioning – HFCs	Investigate and report in the NIR data on equipment containing HFCs and estimate and report HFC emissions from manufacturing, disposal and recovery.	I.38	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.1
2.F.1 Refrigeration and air conditioning – PFCs, HFCs	Collect accurate AD.	I.39	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.1
2.F.2 Foam blowing agents - HFCs	Research the type of foam application used in the country, and revise emissions if needed.	I.40, I.41	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.2
2.F.3 Fire protection - HFCs	Estimate emissions in accordance with the chosen tier 2a method of the 2006 IPCC Guidelines.	I.42, I.43	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.2
2.F.4 Aerosols - HFCs	Include information in the NIR on the AD, EFs, methods and assumptions used for estimating HFC emissions from 2.F.4 aerosols in accordance with paragraph 50(a) of the UNFCCC Annex I inventory reporting guidelines.	I.44	An improvement project was implemented. Additional information are included in NIR 2022.	4.7.2

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
2.G.1 Electrical equipment - SF$_6$	Revise emissions estimates.	I.45	An improvement project was implemented. Additional information are included in NIR 2022.	4.8.1
2.G.3 N$_2$O from product uses – N2O	Revise AD.	I.46, I.51	An improvement project was implemented. Additional information are included in NIR 2022.	4.8.3
2.B.8 Petrochemical and carbon black production – CO$_2$ and CH$_4$	Move to higher tier for methanol production. While the information is not available report all emissions, including from natural gas use, under the IPPU sector, not under the Energy sector.	I.47	Not implemented. Input data for a higher tier method are not available. Additional information are given in 2021 and 2022 NIR.	4.3.8
2.D.2 Paraffine wax use – CO$_2$	Undertake additional research to determine the NCV of paraffin wax or use the default emission factor to report the emissions of this sector.	I.48	Implemented.	4.5.2
2.B.8 Petrochemical and carbon black production – CO$_2$, CH$_4$ and N$_2$O	Further investigate the types of feedstock and their quantities used for ethylene production and in case fuels are use as feedstock, investigate why these fuels are not included in the energy balance and in case emissions are also reported in the energy sector, subtract these emissions in the energy sector to avoid double counting.	I.49	Not implemented. Input data for revised estimate are not available.	

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
Agriculture				
3. General (agriculture) – CH$_4$ and N$_2$O 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.12	Implemented. The reference list was updated.	References

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
	2020 ERT assessment: . Croatia has not updated the agriculture chapter reference list in its NIR (p. 444). During the review, Croatia has provided to the ERT the correct reference list for the agriculture chapter and explained that it was by mistake not updated in the NIR.			
3.B Manure management – N2O Completeness	Estimate CH4 and N2O emissions from manure management of rabbits under subcategory 3.B.4 other livestock, using default EF and parameters from tables 10.16 and 10.A.9 (vol. 4, chapter 10, pp.10.41 and 10.83, respectively) and Nex value from table 10.19 (vol. 4, chapter 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. 2020 ERT assessment: Croatia has not included CH4 and N2O emissions from manure management of rabbits or a justification for not estimating rabbit emissions in its 2020 submission. Furthermore, Croatia has used "NO" notation key in its CRF Table3.B(a)s1 and Table3.B(b) for other animal categories. Otherwise, Croatian has reported in its NIR (pages 184 and 186) that collecting activity data set for rabbits and estimating emissions from rabbits population is part of the category-specific improvement plan assumed to be implemented in the short-term (1 year). During the review, Croatia explain to the ERT that the complete dataset 1990-2018 for rabbit population was not ready in time for its 2018 submission. Croatia explained that it will include emissions from rabbit for whole period in its next submission in 2021.	A.20	Implemented. Partial AD set on rabbit population was received and interpolated/extrapolated for the missing years. Emission estimate was calculated for 3.A.and 3.B sources, gasses CH4 and N2O	NIR 2021: 5.2, 5.3
3.B.5 Indirect N2O emissions – N2O Completeness	Considering that the 2006 IPCC Guidelines do not provide a default value for FracleachMS, but instead indicate a typical range (1–20 per cent), make efforts to obtain country-specific data on FracleachMS. If this is not possible for the next annual submission, use a value from the typical range (1–20 per cent) provided in the 2006 IPCC Guidelines and justify the use of the selected value in the NIR or use the notation key "NE" for reporting N lost through leaching and run-off and indirect N2O emissions from N leaching and run-off in CRF table 3.B(b). 2020 ERT assessment: Croatia has used in its CRF table 3.B (b) the notation key "NE" for reporting N lost through leaching and run-off and indirect N2O emissions. However, the ERT noted that Croatia has not included the rationale for not estimating N lost through leaching and run-off and indirect N2O emissions from N leaching and run-off. During the review, Croatia explains to the ERT that estimations of N lost through leaching and run-off with the national calculation using the tier 2 method and Equation 10.27 from the 2006 IPCC Guidelines was identified as an existing issue an is a planned improvement. If national factor is not available for the next submission, values from the neighbouring countries will be used instead for the emission estimate.	A.13	Implemented. Estimate of N2O due to N lost through leaching and run-off was calculated and included in the inventory.	NIR 2021: 5.3.2.2

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
General (agriculture) – CH4	Croatia has reported "NE" notation key for CH4 emissions from enteric fermentation of poultry (CRF table 3.As1) and CH4 emissions from agricultural soils (CRF table 3s2). However, the ERT notes that Croatia has not provided an explanation for not estimated emissions from these categories in its NIR. During the review, Croatia explain that CH4 emissions from enteric fermentation of poultry and associated emissions from agricultural soils were not estimated since the estimation method for these categories were not developed or default EF for applying tier 1 method are not provided by the 2006 IPCC Guidelines. The ERT recommends that Croatia explicitly include, in the NIR, the rationale for not estimating CH4 emissions from enteric fermentation of poultry and associated emissions from agricultural soils, and any where any other categories are not estimated, in order to improve the transparency of its next submission.	A.21	Implemented, the rationale was added in the relevant chapters.	NIR 2021: 5.2.2, 5.5
3.B.1 Cattle – CH4	The ERT noted that total percentage of growing cattle allocation by MMS is 98.8% (CRF Table3.B(a)s2), thus 1.2% of animal population has not been assigned to a specific MMS. During the review, Croatia explained to the ERT that the remaining 1.2% of growing cattle was allocated to the anaerobic lagoon. The ERT notes that this is only a mistake in the CRF metadata, as the correct emission was calculated and attributed to this MMS. The ERT recommends that Croatia revise and reported in its next annual submission appropriate allocation percentage of growing cattle allocated in the cool climate region, assuring that total allocation must be 100%.	A.25	Implemented.	CRF
3.B.2 Sheep – N2O	Croatia has reported in its CRF Table3.B(b) the total amount of 0.138 kt N2O (41.0 kt CO2 eq) for direct N2O emissions from manure management. The ERT notes that the total amount reported by Croatia is different when individual N2O emissions by livestock categories are aggregated, accounting 0.151 kt N2O (44.9 kt CO2 eq). During the review, Croatia provided to the ERT the spreadsheet file for estimating direct N2O emissions from manure management. Croatia has estimated 137,280.8 kg N2O for total annual direct N2O emissions from manure management (composed by 135,147.2 kg N2O for solid storage MMS and 2,133.6 kg N2O for other MMS). However, the ERT noted that annual direct N2O emissions from manure management are not including direct N2O emissions from solid storage MMS of sheep, which amounted 13,540.9 kg N2O yr-1. In response to question raised by the ERT about the rationale for not including N2O emissions from solid storage MMS of sheep, Croatia explains that omission is due to an error in the spreadsheet file thus N2O emissions from solid storage MMS of sheep should be included in the total direct N2O emissions from manure management. the ERT is of the view that total direct N2O emissions from manure management reported in 2020 submission are potentially underestimated due to direct N2O emissions from solid storage MMS of sheep have not been included. Using the spreadsheet file provided by Croatia, the ERT has estimated an amount of 0.151 kt N2O (44.9 kt CO2 eq) for total annual direct N2O emissions from manure management	A.27	Implemented. 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
	including direct N2O emission from solid storage MMS of sheep. However, the ERT notes that the difference of 4.0 kt CO2 eq is lower that the significance threshold (0.05% of national total emissions without LULUCF). The ERT recommends that Croatia revise and report in its next NIR submissions the direct N2O emissions from manure management, especially N2O emissions of sheep, assuring that all direct N2O emissions from manure management of all livestock categories are including in the total amount in order to avoid potential underestimation.			
3.B.5 Indirect N2O emissions – N2O	Croatia has reported 12,209,771.4 kg N/yr as total N volatilized as NH3 and NOx in its CRF Table3.B(b). During the review, Croatia provided to the ERT the spreadsheet file for estimating indirect N2O emissions from manure management. The ERT notes that Croatia has estimated in its spreadsheet file an amount of 18,215,665.6 kg N yr-1 of N volatilized as NH3 and NOx which is higher than amount of volatilized as NH3 and NOx reported by Croatia in its CRF. In response to question raised by the ERT about the rationale for different N amounts estimated and reported, Croatia explains to the ERT that spreadsheet file provided contains revised values following the implemented correction of the Effort Sharing Decision (ESD) review findings related to the incorrect usage of FracGasMS and FracLossMS. Implemented changes resulted in a change of Total N volatilized as NH3 and NOx in its CRF Table3.B(b). However, the ERT notes also that, similar error detected in direct N2O emissions sheep (see ID# A.27 above), Croatia has not included the amount of N volatilised as NH3 and NOx from solid storage MMS of sheep (206,806.9 kg N) in the total amount of N volatilised as NH3 and NOx from all MMS and all livestock categories (18,215,665.6 kg N). Croatia explains to the ERT that omission is due to an error in the spreadsheet file. Further, the ERT notes that Croatia has reported 0.0251 (kg N2O-N/kg N) as IEF for N volatilisation and re-deposition in its CRF Table3.B(b) which is higher than the default emission factor (EF4) of 0.01 kg N2O–N from the 2006 IPCC Guidelines (Table 11.3, chapter 11, volume 4, 2006 IPCC Guidelines). Croatian inventory team has checked this difference and found that on the value entered the CRF a conversion of N2O-N emissions to N2O emissions (44/28) was performed twice, resulting in an overestimate of emissions and high IEF. Using the spreadsheet file provided by Croatia, the ERT has estimated an amount of 18,422,472.5 kt N/yr as total N volatilized as NH3 and NOx —including the amount of N volatilized from solid storage MMS of sheep— when the appropriated default EF4 (0.01 kg N2O–N) is applied, the result is an amount of 0.289 kt N2O (86.3 kt CO2 eq) which is lower than 0.307 kt N2O (91.4 kt CO2 eq) reported by Croatia in its CRF. The ERT concluded, even though Croatia underestimated the amount of N volatilized, the indirect N2O emissions due to atmospheric deposition were overestimated due to the error in the conversion factor of N2O-N emissions to N2O emissions which was applied twice. The ERT recommends that in the next NIR submission Croatia correct its calculation to include the amount of N volatilised as NH3 and NOx from solid storage MMS of sheep, and also revise the	A.28	Implemented. Solid storage MMS for sheep was correctly included in the reported estimate and the incorrect double conversion on N2O-N to N2O 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
	application of the conversion of N2O-N emissions to N2O emissions to increase the accuracy of its emissions reported.			
3.D.a Direct N2O emissions from managed soils – N2O	Croatia has performed an uncertainty analysis using approach 2. Croatia reported the use of an uncertainty value for the default emission factor (EF1) is within uncertainty range of -70% to +200% for mineral fertilizers and N-fixing crops and crop residues and within combined uncertainty range of -50% to +150% for urine and dung deposited by grazing animals (NIR, p. 198). However, the ERT noted in Table A2:3-1 (NIR Annexes, p. 41) that uncertainty value of ±30% for organic N fertilizers and mineralization/immobilization associated with loss/gain of SOM has been used by Croatia. The ERT notes that uncertainty range of ±30% for organic N fertilizers and mineralization/immobilization associated with loss/gain of SOM are not in line with the uncertainty ranges for default values of EF1 (0.003–0.03 kg N2O-N/kg N) from the 2006 IPCC Guidelines (Table 11.1, chapter 11, volume 4). During the review, Croatia recognized the issue and stated that range of -70% to +200% should be applied to organic N fertilizers and mineralization/immobilization associated with loss/gain of SOM, and explained that this issue would be corrected in the uncertainty estimates and reported in the next NIR submission.

The ERT recommends that Croatia apply the appropriate uncertainty range for the default EF1 from the 2006 IPCC Guidelines (0.003–0.03 kg N2O-N/kg N) and report a result in its next NIR submission. | A.29 | Implemented | NIR 2021: 5.5.1.3 |
| 3.D.a.2.a Animal manure applied to soils – N2O | Croatia has reported 30,214,097.1 kg N/yr as N input from manure applied to soils in its CRF Table3.D. During the review, Croatia provided to the ERT the spreadsheet file for estimating animal manure applied to soils. The ERT notes that Croatia has estimated in its spreadsheet file an amount of 24,693,615.3 kg N/yr N input from manure applied to soils which is lower than amount of N input from manure applied to soils reported by Croatia in its CRF. In response to question raised by the ERT about the rationale for different N amounts estimated and reported, Croatia explains that spreadsheet file provided contains revised values following the implemented correction of the ESD review findings related to the incorrect usage of FracGasMS and FracLossMS. Implemented changes resulted in a change of total N input from manure applied to soils. Using the spreadsheet file provided by Croatia, the ERT has estimated an amount of 0.388 kt N2O (115.6 kt CO2 eq) as N input from manure applied to soils which is lower than 0.475 kt N2O (141.5 kt CO2 eq) reported by Croatia in its CRF. Thus, the ERT concluded that direct N2O emissions from manure applied to soils were overestimated.

The ERT recommends that in the next NIR submission Croatia revise its direct N2O emissions from animal manure applied to soils estimations including appropriated values corrected in response to the ESD review findings related the incorrect usage of FracLossMS to increase the accuracy of its emissions reported. Furthermore, the ERT recommends that the Party revise indirect N2O emissions | A.30 | Implemented. | NIR 2021: 5.3.2.5, 5.5.1.5, 5.5.2.5 |

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
	from animal manure applied to soil due to changes in N input from manure applied to soils that affect directly indirect N2O emissions from atmospheric deposition and N leaching and run-off.			

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
LULUCF				
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.	L5	Planned for NIR 2022 Resubmission	LULUCF - general
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.6	Planned for NIR 2022 Resubmission	LULUCF - general
4.A.1	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.	L10	Not resolved. A specific project needs to be initiated.	
4(IV) Indirect N2O emissions from managed soils – N2	Estimate indirect N2O emissions associated with the loss of soil organic matter resulting from a change in land use or management of mineral soils	L.19	Planned for NIR 2022 Resubmission	
KP-LULUCF				

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
General	Ensure that a clear, documented and complete description of the methodologies used in the emission estimates is provided in the NIR	KL 2	Performed	Chapter 11
General	Reassess the uncertainty analysis using appropriate uncertainty values for AD and parameters used and revising the assumptions made	KL.3	Planned for NIR 2022 resubmission	

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
Waste, 5.A Solid waste disposal on land – CH$_4$, Transparency	Provide information on the type of waste disposed to solid waste disposal sites and ensure that all types of solid waste, including industrial waste, sludge and construction and demolition waste, disposed to solid waste disposal sites are included in the emission estimates.	W.1	Resolved 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 (waste code 01 xx xx), construction and demolition waste (waste code 17 xx xx), and waste from waste management facilities and wastewater treatment plants (waste code 19 xx xx). 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 - 2020 are taken from the Waste Management Information System and the Environmental Pollution Register.	7.2.2.2
Waste, 5.A Solid waste disposal on land – CH$_4$, Transparency	Provide comprehensive information on solid waste management practices in its NIR, if possible in a 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	Planned As responded to the ERT during the 2020 centralized review, data for unofficial sites, in which the waste is improperly discarded into environment, are not included in the inventory since the data for such sites are not available yet. In 2020, the electronic application for registering the locations of discarded waste was put into operation, requesting regular input of data, covering whole state territory. Municipal services monitoring officer is responsible for data entry for the respective administrative area (municipality/city) which he covers. Therefore, database should contain results – data on locations, estimated quantities and	7.2.1

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
			types of waste discarded into environment. These improvements are defined as short-term goals.	
Waste, 5.A Solid waste disposal on land – CH₄, Accuracy	Continue its 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, and document these comprehensively in the NIR, including a description of improvements made to the assumptions, in particular by referring to the annual increase of population, waste generation per capita and the percentage of waste disposed of at SWDS for different periods of time from 1955 to 1990.	W.3	Planned It is emphasized that it is necessary to carry out a comprehensive research regarding activity data and parameters, in particular on population, waste generation per capita and the percentage of waste deposited to SWDS that are included in the inventory for the entire time series. These improvements are defined as long-term goals.	7.2.6
Waste, 5.B.1 Composting – CH₄ and N₂O, Transparency	Provide in its 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.4	Resolved In the framework of the preparation the 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution', inventory improvement projects were performed - documents: "Report on inventory improvement for sector composting (NFR 5.B.1)"(producer: Ekonerg, client: MESD, 2021) and "Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)" (producer: Ekonerg, client: MESD, 2022) have been prepared. Amounts of feedstock treated by composting and anaerobic digestion at biogas facilities have been collected for the entire reporting period from 1990 to 2020. Sources of AD for composting and anaerobic digestion are composting and biogas facilities. Information on AD and sources as well calculated GHG emissions are included in this submission.	7.3.2
Waste, 5.C.1 Waste incineration – CO₂, Completeness	Extrapolate back in order to estimate CO₂ emissions from incineration of plastic waste between 1990 and 2006 to improve the consistency of the time series and transparency.	W.5	Planned Data for industrial waste, which include hazardous waste and plastics, have been submitted in the aggregate form. For now, there is still no available information for separation the data for hazardous waste and plastic. Data for industrial waste for the whole period from 1990 - 2008 are provided in the aggregate form. The need for doing research in order to	7.4.2, 7.4.6

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
			separate data for hazardous waste and plastic is included in the improvement plan. These improvements are defined as short-term goals.	
Waste, 5.C.1 Waste incineration – CO$_2$, CH$_4$ and N$_2$O, Transparency	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.	W.6	Planned It is emphasized that information on the handling of plastic waste - systems and amounts of plastic waste disposed of and/or incinerated for the entire time series should be included in the inventory, in order to improve completeness and transparency. For now, there is still no available information for that issue and this need to be investigated. These improvements are defined as short-term goals.	7.4.6
Waste, 5.D.1 Domestic wastewater – CH$_4$, Completeness	Collect more detailed and complete information on domestic wastewater treated in various systems occurring 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.7	Planned It is emphasized that 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. Accordingly, it is necessary to carry out comprehensive research regarding these issues. These improvements are defined as long-term goals.	7.5.6
Waste, 5.D.1 Domestic wastewater – CH$_4$, Accuracy	Provide transparent descriptions and accurate data in the NIR for the whole time series 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. Also provide information on how sludge produced is treated and disposed of or used in other applications, and use this information to accurately estimate and report CH$_4$ emissions from wastewater treatment for each treatment pathway or system, avoiding a double counting of the degradable organic component of sludge removed and applied in other applications and report correctly in CRF table 5.D the amount	W.8	Planned It is emphasized that transparent descriptions and accurate data should be provided for the whole time series. It refers to occurrence 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 research regarding these issues. These improvements are defined as short-term goals. Organic component removed as sludge that is disposed at landfills and used for other purposes (composting, agriculture application) was excluded from the total organic product for industrial wastewater for entire reporting period and reported in the CRF table 5.D.2.	7.5.6

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
	of the degradable organic component of sludge removed.			
Waste, 5.D.1 Domestic wastewater – CH₄, Accuracy	Provide information in the NIR on how sludge produced is treated and disposed of in the country or used in other applications, and use this information to accurately estimate and report CH₄ emissions from wastewater treatment for each treatment pathway or system, avoiding a double counting of the degradable organic component of sludge removed and applied in other applications, and report correctly in CRF table 5.D the amount of the degradable organic component of sludge removed.	W.9	Resolved Organic component removed as sludge that is disposed at landfills and used for other purposes (composting, agriculture application) was excluded from the total organic product for entire period 1990 - 2020 and reported in the CRF table 5.D.2.	7.5.2.2
Waste, 5.D.2 Industrial wastewater – CH₄, Transparency	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.10	Planned It is emphasized that 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…). These improvements are defined as long-term goals.	7.5.6
Waste, 5.A Solid waste disposal on land – CH₄, Transparency	Provide information of DOC not only for MSW but also industrial waste and sludge.	W.11	Resolved	7.2.2.2
Waste, 5.A Solid waste disposal on land – CH₄, Accuracy	Estimate CH₄ emissions from industrial waste by using amount of each waste type (e.g. paper/cardboard, textiles, food waste, wood, etc.).	W.12	Planned DOC for IW has been calculated by using country-specific data on mining waste (waste code 01 xx xx), construction and demolition waste (waste code 17 xx xx), and waste from waste management facilities and wastewater treatment plants (waste code 19 xx xx).	7.2.2.2, 7.2.6

CRF category / issue	Review recommendation		MS response / status of implementation	Chap. NIR
			It is emphasized that it is necessary to research activity data and parameters for MSW, IW and sludge which are needed for using a multi-phase model based on waste composition data. These improvements are defined as long-term goals.	
Waste, 5.A Solid waste disposal on land – CH$_4$, Transparency	Estimate CH$_4$ emissions from construction and demolition waste disposed of. Clearly describe that construction and demolition waste are included in the emissions estimates in the inventory as industrial waste.	W.13	Resolved See response #W.1	7.2.2.2
Waste, 5.A Solid waste disposal on land – CH$_4$, Accuracy	Investigate the amount of waste disposed of in unofficial site, and report emissions from unofficial site.	W.14	Planned See response #W.2	7.2.1
Waste, 5.B.1 Composting – CH$_4$ and N$_2$O, Transparency	Correctly report dry-basis activity data for composting.	W.15	Resolved	7.3.2.1
Waste, 5.C.1 Waste incineration – N$_2$O, Transparency	Clearly describe default N$_2$O emission factor of 100 g N$_2$O/t waste for industrial waste.	W.16	Resolved	7.4.2
Waste, 5.C.1 Waste incineration – N$_2$O, Accuracy	Apply default N$_2$O emission factor of industrial waste (100 g N$_2$O/t waste) alternatively to estimate N$_2$O emissions from clinical waste incineration.	W.17	Not implemented N$_2$O emission for incineration of clinical waste for the entire period 1990 - 2019 is defined as NA. This approach has been accepted by the TERT during the 2017 ESD review. Accordingly, Croatia did not calculate N$_2$O emission from clinical waste. Given that TERT and the EU Member States apply the above mentioned approach, we believes that we need to follow it in order to ensure that these emissions are monitored in a harmonized way in the EU.	7.4.2

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 2022

CRF category / issue	Review recommendation			Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
Energy sector				
1.A.3.b. Road Transport			New version of COPERT 5 model was used to calculate CH_4 and N_2O emissions. In some categories EF for CH_4 and N_2O changed so emissions were changed as well. Due to this update emissions changed les then 0.1%.	3.2.6.4.
1B2 Fugitive Emissions from Natural Gas			For the category 1B2 Fugitive Emissions from Natural Gas CO2 emission from Ivanić Grad fraction facility has been added. In addition to Molve, gas has been processed since 2013 at the Ivanić Grad faction facility as well. CO2 emission data were obtained directly from the operator via a questionnaire. Recalculation is performed for the period 2013 -2019	3.3.2.5.

CRF category / issue	Review recommendation			Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
Industrial processes and product use				
2.A.2 Lime production	-	TERT noted that CO_2 emissions from 2A2 decreased by 25% for 2005 compared to the previous inventory. Noted was an error in emission estimates and Croatia provided a revised estimate for NIR 2021.	-	4.2.2.5.
2.F.1 Refrigeration and Air Conditioning	-	TERT proposed technical correction for the years 2005, 2016, 2017 and 2018.	For NIR 2022, data for the entire time-series have been revised.	4.7.1
2.G.1 Electrical equipment	Revise extrapolated AD.	-	For NIR 2022, data for the entire time-series have been revised.	4.8.1

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 2010-2019 time period due to new AD for horses and mules/asses. Impact of recalculations on the total 3.A source emissions compared to the last submission is negligible (> ±0.1) and is presented in Table 5.2-4.	5.2.5
3.B Manure Management – N$_2$O and CH$_4$			Emissions were recalculated for 2010-2019 time period due to new AD for horses and mules/asses. Impact of recalculations on the total 3.B.1 source emissions compared to the last submission is negligible (> ±0.1) and is presented in Table 5.3-2 and Table 5.3-3.	5.3.1.5, 5.3.2.5
3.D.1.2.a Animal Manure applied to Soils – N$_2$O			Emissions were recalculated for the entire 2010-2019 period due to corrections of estimate in for 3B source. Impact of all aforementioned recalculations of the total 3.D.1 source emissions compared to the last submission is negligible (> ±0.1) and is presented in table 5.5-7.	5.3.2.5, 5.5.1.5
3.D.2. Indirect N2O Emissions from Managed Soils - N$_2$O			Emissions were recalculated for the 2010-2019 period due to AD changes and improvements made in source: Manure Management – N2O Emissions (CRF 3.B.2Impact of all recalculations of the total 3.D.2 source emissions compared to the last submission is negligible (> ±0.1) and is presented in Table 5.5-8.	5.3.2.5, 5.5.1.5, 5.5.2.5
3.G. Liming – CO$_2$			Due to a correction of AD for year 2019, emission estimate was recalulcated for year 2019.	5.8.5

CRF category / issue	Review recommendation			Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
LULUCF				

CRF category / issue	Review recommendation			Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
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		Error detected by Expert	Chapter /section in the NIR
	UNFCCC	ESD		
Waste				
5.A Solid waste disposal on land		According to the TERT recommendation during the 2020 ESD review, DOC for IW has been calculated by using country-specific data on mining waste (waste code 01 xx xx), construction and demolition waste (waste code 17 xx xx), and waste from waste management facilities and wastewater treatment plants (waste code 19 xx xx). 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 - 2020 are taken from the Waste Management Information System and the Environmental Pollution Register. The total average DOC for the entire reporting period has been calculated from the average DOC values for the period 2010 – 2020. 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'. In addition, the TERT recommended to operate two separate IPCC FOD models to calculate CH_4 emissions for the entire reporting period, instead of the one used before: 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. The CS-value of DOC for IW has been estimated for the entire reporting period and is used in both IPCC FOD models - for managed and unmanaged landfills. Therefore, recalculation of CH_4 emission was made for the period 1990 - 2019.		7.2.2, 7.2.5

CRF category / issue	Review recommendation			Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
5.A Solid waste disposal on land			The CS-value of DOC for IW has been estimated for the entire reporting period and is used in both IPCC FOD models - for managed and unmanaged landfills. Therefore, recalculations of CH₄ emissions were made for the the period 1990 - 2019.	7.2.5
5.B.1 Composting 5.B.2 Anaerobic digestion at biogas facilities		In the framework of the preparation the 'Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2020 Submission to the Convention on Long-range Transboundary Air Pollution', inventory improvement projects were performed - documents: "Report on inventory improvement for sector composting (NFR 5.B.1)"(producer: Ekonerg, client: MESD, 2021) and "Report on inventory improvement for sector anaerobic digestion at biogas facilities (NFR 5.B.2)" (producer: Ekonerg, client: MESD, 2022) have been prepared. Amounts of feedstock treated by composting and anaerobic digestion at biogas facilities have been collected for the entire reporting period from 1990 to 2020. Sources of AD for composting and anaerobic digestion are composting and biogas facilities. Information on AD and sources as well calculated GHG emissions are included in this submission. The implementation of the inventory improvement projects has collected activity data on the plant level, which affects their transparency, accuracy and completeness. Recalculation of CH₄ and N₂O emissions for source category CRF 5.B.1 has been performed for the period from 1994 to 2019, while for the period from 1990 to 1993 in the official reporting format (CRF) the notation key NO (not occurring) has been used. Recalculation of CH₄ emissions for source category CRF 5.B.2 has been performed for the period from 2009 to 2019, while for the period from 1990 to 2008 in the official reporting format (CRF) the notation key NO (not occurring) has been used.		7.3.2
5.C.2 Open burning of waste			In the framework of the preparation the 'Republic of Croatia *Informative Inventory Report for LRTAP Convention for the Year 2020* Submission to the Convention on Long-range Transboundary Air Pollution', inventory improvement project has been performed - document: "Report on inventory improvement for sector open burning of waste (NFR 5.C.2)" (producer: Ekonerg, client: MESD, 2022) has	7.4.5

CRF category / issue	Review recommendation		Error detected by Expert	Chapter /section in the NIR
	UNFCCC	ESD		
			been prepared. Amounts of open burned agricultural waste have been collected for the entire reporting period from 1990 to 2020. Data on the 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. CH_4 and N_2O emissions have not been calculated so far. The improvement resulted in an increase in CH_4 and N_2O emissions in the source category CRF 5.C.2 by 100% in the whole trend. Recalculation of CH_4 and N_2O emissions has been performed for the period from 1990 to 2019.	
5.D.1 Domestic wastewater – CH_4 emission		According to the technical correction provided by the TERT during the 2020 ESD review, for septic tanks TOW does not need to be corrected for sludge removal, only sludge removed from septic tanks is of importance (the MCF already accounts for removal of sludge, 2006 IPCC Guidelines, Volume 5. Chapter 6, Table 6.3). 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. Discharge of untreated wastewater results in indirect CH_4 emissions. These emissions have been added to the CH_4 emissions from septic tanks for the entire reporting period.		7.5.5
5.D.1 Domestic wastewater – N_2O emission			New data on protein intake value (PIV), for the period 2014 - 2018, were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. The pattern from 2015 to 2018 has been used for calculation of insufficient data for 2019 and 2020. Therefore, recalculations of N_2O emissions were made for the period 2014 - 2019.	7.5.5

CRF category / issue	Review recommendation		Chapter /section in the NIR
	UNFCCC	ESD	Error detected by Expert	
5.D.2 Industrial wastewater			New data on industrial output (tonne/yr) for Manufacture of food products and beverages was included in the emission calculation for 2019. New data on organic component removed as sludge that is disposed at landfills and used for other purposes (composting, agriculture application) were excluded from the total organic product for the period 2008 - 2019. Therefore, recalculation of CH_4 emission was made for the period 2008 - 2019.	7.5.5

Table 10.4-3: Indication on timeline of implementation

Sector-specific planned improvements

Energy

Category	Recommendation	NIR 2021	NIR 2022	Long-term
Stationary combustion	Check the CO_2 EFs for natural gas from the countries of origin for this imported natural gas, and on that basis estimate a weighted average country-specific EF			•
1.B.2.b Natural gas – gaseous fuels – CO2	Develop a country-specific CO_2 EF for 1.B.2.b.3 (natural gas – processing)			•
Reference approach	Undertake additional research to determine the NCVs of bitumen and lubricants and use those values when calculating emissions from fuel combustion in order to avoid possible underestimation of emissions			•
1.A.3.b Road transportation	Develop country-specific EFs for CO_2 emissions from fuels combusted in road transportation			•

Industrial Processes and Product Use

Category	Recommendation	NIR 2022	NIR 2023	Long-term
2.A.1 Cement production	A project which will include additional investigation and collection of all available consistent AD regarding non-carbonate sources of CaO and MgO for the whole time series is currently being prepared, and all revised information on AD, EFs, methods and assumptions used for estimating emissions will be included in the NIR (2023 submission).		•	
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			•

Category	Recommendation	NIR 2022	NIR 2023	Long-term
	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. 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.			●
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. 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 2022	NIR 2023	Long-term
Sectoral	Continued investigation of activity data (livestock population) with the purpose of gathering more detailed activity data.			●
3.A. Enteric Fermentation	Improvements and verifications of parameters for historical years and development of Tier 2 / Tier 3 methodology for relevant animal categories (emphasized on cattle). Ministry of Economy and Sustainable Development had secured funds required for the launch of this project.		●	
3.A. Enteric Fermentation	Implementation of the developed national and introduction of Tier 2 / Tier 3 methodology for cattle in the inventory emission estimate, for all years.		●	
3.B Manure management	Improvements and verifications of national parameters for Tier 2 emission calculation for relevant animal categories and MM systems. Ministry of Economy and Sustainable Development had secured funds required for the launch of this project.		●	

Category	Recommendation	NIR 2022	NIR 2023	Long-term
3.B Manure management	Implementation of the developed national parameters for Tier 2 emission calculation for relevant animal categories and MM systems in the inventory emission estimate for all years.		●	
3.D.1 Direct N2O 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 N2O 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 2022	NIR 2023	Long-term
Land converted to forest land – CO_2	Make significant efforts to use the results of CRONFI to improve the LULUCF sector inventory			●
Land converted to forest land – CO_2	Make significant efforts to use the results of CRONFI to improve the LULUCF sector inventory		●	
Cropland remaining cropland – CO_2	Implement the tier 2 approach to perennial cropland remaining perennial cropland		●	
Land converted to cropland – CO_2	Improve the cropland biomass estimates to enable it to implement a tier 2 method for estimating cropland biomass in this category		●	
Land converted to grassland – CO_2	Improve cropland biomass estimates to enable the implementation of a tier 2 method for estimating cropland biomass in this category		●	
Settlements – CO_2	Improve cropland biomass estimates to enable the implementation of a tier 2 method for estimating cropland biomass in this category		●	

Waste

Category	Recommendation	NIR 2022	NIR 2023	Long-term
5.A Solid waste disposal	Provide information on the type of waste disposed to SWDS and ensure that all types of solid waste, including industrial waste, sludge and construction and demolition waste, disposed to SWDS are included in the emission estimates.	●		
5.A Solid waste disposal	Provide information of DOC not only for MSW but also industrial waste and sludge. DOC for IW has been calculated by using country-specific data on mining waste (waste code 01 xx xx), construction and demolition waste (waste code 17 xx xx), and waste from waste management facilities and wastewater treatment plants (waste code 19 xx xx).	●		
5.A Solid waste disposal	Use two separate IPCC FOD models to calculate CH_4 emissions for the entire reporting period, instead of the one used before: one for unmanaged landfills (OX=0) and one for managed landfills (OX=0.1).	●		
5.A Solid waste disposal	Provide comprehensive information on solid waste management practices, in a 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.		●	
5.A Solid waste disposal	Carry out a comprehensive research regarding activity data and parameters included in the inventory, in particular on population, waste generation per capita and the percentage of waste disposed of at SWDS, for entire time series to improve accuracy, completeness and transparency of inventory. That will be part of the project that MESD coordinates conducting comprehensive research regarding system improvements and development of historical data bases for the calculation and reporting of greenhouse gas emissions from the Waste sector. The project is in preparation.			●
5.A Solid waste disposal	Research on activity data and parameters for MSW, IW and sludge that are needed for using a multi-phase model based on waste composition data.			●
5.A Solid waste disposal	Expert judgement of historical data should be more detailed explained, using relevant scientific and professional literature and research to allow full reproduction and understanding of choices made.			●
5.A Solid waste disposal	More information for uncertainty estimation associated with activity data and emission factors (parameters of the IPCC FOD model) is required, regarding more accurate and transparent uncertainty analysis. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data and parameters.		●	
5.B.1 Composting	The implementation of the inventory improvement project has collected activity data on the plant level, which affects their transparency, accuracy and completeness. Recalculation of CH_4 and N_2O emissions for source category CRF 5.B.1 has been performed for the period from 1994 to 2019, while for the period from 1990 to 1993 in the official reporting format (CRF) the notation key NO (not occurring) has been used.	●		
5.B.2 Anaerobic digestion at biogas facilities	The implementation of the inventory improvement project collected activity data on the plant level, which affects their transparency, accuracy and completeness. Recalculation of CH4 emissions for source category CRF 5.B.2 has been performed for the period from 2009 to 2019, while for the period from 1990 to 2008 in the official reporting format (CRF) the notation key NO (not occurring) has been used.	●		

Category	Recommendation	NIR 2022	NIR 2023	Long-term
5.C.1 Waste incineration	Data for industrial waste, which include hazardous waste and plastics, have been submitted in the aggregate form for the whole period from 1990 – 2008. It is necessary to do research in order to separate data for hazardous waste and plastic. That will be part of the project that MESD coordinates conducting comprehensive research regarding system improvements and development of historical data bases for the calculation and reporting of greenhouse gas emissions from the Waste sector. The project is in preparation.		●	
5.C.1 Waste incineration	Investigate and provide information on the handling of plastic waste in order to improve completeness.		●	
5.C.1 Waste incineration	More information for uncertainty estimation associated with activity data and emission factors is required, regarding more accurate and transparent uncertainty analysis. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data.		●	
5.C.2 Open burning of waste	Collected data under inventory improvement project for sector open burning of waste in the framework of the preparation the *Informative Inventory Report for LRTAP Convention* are included in the GHG inventory. 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 for the period 1990 – 2020.		●	
5.C.2 Open burning of waste	Collected data under inventory improvement project for sector open burning of waste in the framework of the preparation the *Informative Inventory Report for LRTAP Convention* need to be processed and included in the GHG inventory.		●	
5.D.1 Domestic wastewater	Direct discharge of untreated wastewater is added as another relevant wastewater treatment pathway. Discharge of untreated wastewater results in indirect CH_4 emissions. These emissions are included in the category 5.D.1.	●		
5.D.1 Domestic wastewater	New data on protein intake value (PIV), for the period 2014 - 2018, were obtained by the FAOSTAT Statistical Database. Extrapolation method has been used for calculation of insufficient data. The pattern from 2015 to 2018 has been used for calculation of insufficient data for 2019 and 2020. Therefore, recalculations of N_2O emissions were made for the period 2014 - 2019.	●		
5.D.2 Industrial wastewater	New data on industrial output (tonne/yr) for Manufacture of food products and beverages was included in the emission calculation for 2019.	●		
5.D.1 Domestic wastewater	Data for population with an individual system of drainage and data for calculation of degradable organic component in kg BOD/1000 person/yr for 2020 are not available yet. According to the explanation provided by Croatian Waters, this year the data will change a bit more, adjusted with the Census 2021. The reporting deadline is the end of June 2022 when new data will probably be provided. For now, data for 2020 are assumed according to data for 2019. The correct value for 2020 needs to be included in the inventory.		●	
5.D Wastewater	Transparent descriptions that 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.		●	

Category	Recommendation	NIR 2022	NIR 2023	Long-term
treatment and discharge				
5.D Wastewater treatment and discharge	Improve quality of data on sludge produced and data on management of sludge and provide information on how sludge produced is treated, disposed in landfills or used in other purposes such as composting and agriculture application. This information should be used to estimate CH_4 emissions from wastewater treatment for each treatment pathway or system, avoiding double counting of the degradable organic component of sludge removed and applied in other purposes.		●	
5.D.1 Domestic wastewater	Regarding the TERT recommendation during the 2017 ESD review about estimation on N_2O from domestic wastewater, there is no information on the use of garbage disposal units in households in Croatia. During review Croatia proposed to keep the Factor for non-consumed protein F (non-con) = 1.4 for developed countries instead of F (non-con) = 1.1 for developing countries. Croatia provided calculations with both of factors, F (non-con) = 1.4 and F (non-con) = 1.1 and asked TERT for confirmation on proposal to keep factor for developed countries. Competent institution should confirm assumption that less than 1% of household uses garbage disposal units. For now, information are not available. Because of that, F (non-con) = 1.4 is included in the N_2O emission calculation. Revision with F (non-con) = 1.1 will be prepared after confirmation of competent institution. This is included in the Annual data collection plan.		●	
5.D.1 Domestic wastewater	Carry out a comprehensive research regarding 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.			●
5.D.2 Industrial wastewater	Carry out a comprehensive research regarding industrial wastewater treatment system used, and the amount of industrial wastewater treated aerobically and anaerobically and discharged into waterways and the seas.			●
5.D Wastewater treatment and discharge	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.			●
5.D Wastewater treatment and discharge	Establishment of effectively Water Information System with base for systematic gathering/provision of insufficient data and information needed for emissions calculation.			●
5.D Wastewater treatment and discharge	More information for uncertainty estimation associated with activity data and emission factors is required, regarding more accurate and transparent uncertainty analysis. It is necessary to include more experts who are directly associated with the activity data to accurately determine the uncertainties of the data.		●	

Chapter 11: KP-LULUCF

11.1. General information

Following the establishment of the National system in 2007 required under the Decision 19/CMP.1, the Ministry of Economy and Sustainable Development (MESD) undertakes different activities in order to streamline and strengthen flow of data and information relevant for accounting of LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol.

This submission follows the previously agreed procedure between the Ministry of Agriculture and MESD that preparation of estimation in LULUCF sector should be based on data available in most recent General Forest management plan (General FMAP) and data available in plans/programs for each single management unit in Croatia (renewed every ten years).

The data coming from the General Forest Management Plans (General FMAPs) and plans/programs for the management of specific forest management unit are considered to be the best available data for the estimation of carbon stock changes in the pools of aboveground and belowground biomass. For estimating carbon stock changes in HWP pool, data available in international database (UNECE/FAO) were used as well as data available at the national level (State Bureau of Statistics).

Based on the ERT recommendation, 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 (below ground biomass, litter, soil, HWP) were not subject of this 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 KP reporting. The basic information about executed project are provided in Annex 3.2.

Under the Article 3, paragraph 3 of the Kyoto Protocol (KP) Croatia reports emissions and removals from afforestation (A) and deforestation (D) activities, while Reforestation (R) does not occur in Croatia. Under the Article 3.4 of the KP Croatia elected activity Forest management (FM) for the estimation of emissions and removals by sink.

The UNFCCC and the KP reporting are harmonized as presented in Table 11.1-1; thus, the same data division was used for emission/removal calculation. Therefore, all stated for the UNFCCC is valid also for the KP (definitions, methodology, etc.).

Table 11.1-1: The relationship between KP activities and reported UNFCCC land categories

UNFCCC		KP	
Land Use Category	Subcategories	Activities	Article
Forest land	Land converted to Forest land	Afforestation	3.3

UNFCCC			KP	
Land Use Category	Subcategories		Activities	Article
	Cropland converted to Forest Land	*Grassland converted to Forest land*		
Cropland	*Land converted to Cropland*		Deforestation	3.3
	Forest land converted to perennial Cropland			
Settlements	*Land converted to Settlements*			
	Forest land converted to Settlements			

11.1.1 Definition of forest and any other criteria

Definition of forest

Forest is a 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 (Table 11.1-2.)

Table 11.1-2: Thresholds in defining forest

Parameter	Range	Selected value
Minimum land area	0.05 - 1 ha	0.1 ha
Minimum crown cover	10 - 30 %	10 %
Minimum tree height	2 - 5 m	2 m

In pursuit of the selected values for KP reporting, forest includes the following forest stands: high forests, plantations, forest cultures, coppice, maquis and shrub forests.

Based on ERT's request from 2012, since NIR 2014 Croatia performs estimation for all types of forests (including Maquis and shrub forests) that meets thresholds for defining forests under the Kyoto protocol (see also subchapter 6.2).

Based on the Forest Act (Article 4), forests also allude forest nurseries and seed orchards in cases when they are an integral part of the forest; forest infrastructure; fire breaks and other less open areas within forests; forests in protected areas under a special regulation; forests of special ecological, scientific, historical or cultural interest; windshields and buffer zones in area larger than 10 acres and a width greater than 20 m. Thus, these areas are also included under the LULUCF and KP reporting.

A separate group of forest trees in the area up to 10 acres, forest nurseries and seed orchards, which are not part of the forest, windbreaks and buffer zones - protective tree belt area of less than 10 acres and a width of less than 20 m, tree rows and parks in urban areas do not present forest and these areas are not subject of this reporting.

According to the same legislative act, areas covered by garigues, and scrub forests (degraded stages of maquis and shrub forests) also belongs to forest category. However, since these types of forests are not able to reach thresholds defined by Croatia under the KP, these areas are excluded from the estimation and are not subject of reporting under the KP.

11.1.2 Elected activities under Article 3, Paragraph 4, of the Kyoto Protocol

Croatia has elected Forest Management (FM) as an activity under Article 3.4 for inclusion in the accounting for the first commitment period in accordance with Paragraph 6 of the Annex to Decision 16/CMP.1. Credits from Forest Management are capped in the first commitment period. Following the Decision 22/CP.9, the cap was equal to 0.265 Mt C (0.972 Mt CO_2) per year, or to 1.325 Mt C (4.858 Mt CO_2) for the whole commitment period.

According to the Annex of Decision 2/CMP.7 for the second commitment period the reporting of FM under the Article 3.4 has become mandatory. No additional activities were elected by Croatia for the second commitment period.

According to the Appendix of the same decision Forest management reference level defined for Croatia equals -6.289 MtCO$_2$eq/year for the second commitment period.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity Under article 3.4 have been implemented and applied consistently over time

The time consistency is achieved due to the fact data were collected for the entire period from 1990 to 2020 based on definitions presented further in this subchapter. Applied definitions are as follows:

11.1.3.1.   Definition and identification of Afforestation/Reforestation areas since 1990.

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.

Following request given by the ERT in ARR 2012 to trace and identify all lands under the Article 3.3 and Article 3.4 of the KP, Croatia conducted special survey under 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" (abbreviated LULUCF 1). Basic information about the tasks of the LULUCF 1 project are presented in Annex 3.2.

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 areas under the forest management as defined by KP regardless the ownership and forest types.

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 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 1990-2020 are presented in Figure 11.1-1.

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 11.1-2.

Figure 11.1-1: Areas afforested in Croatia through seeding and planting in 1990-2020 (marked yellow-period 1990-2013, marked green 2014-2020)
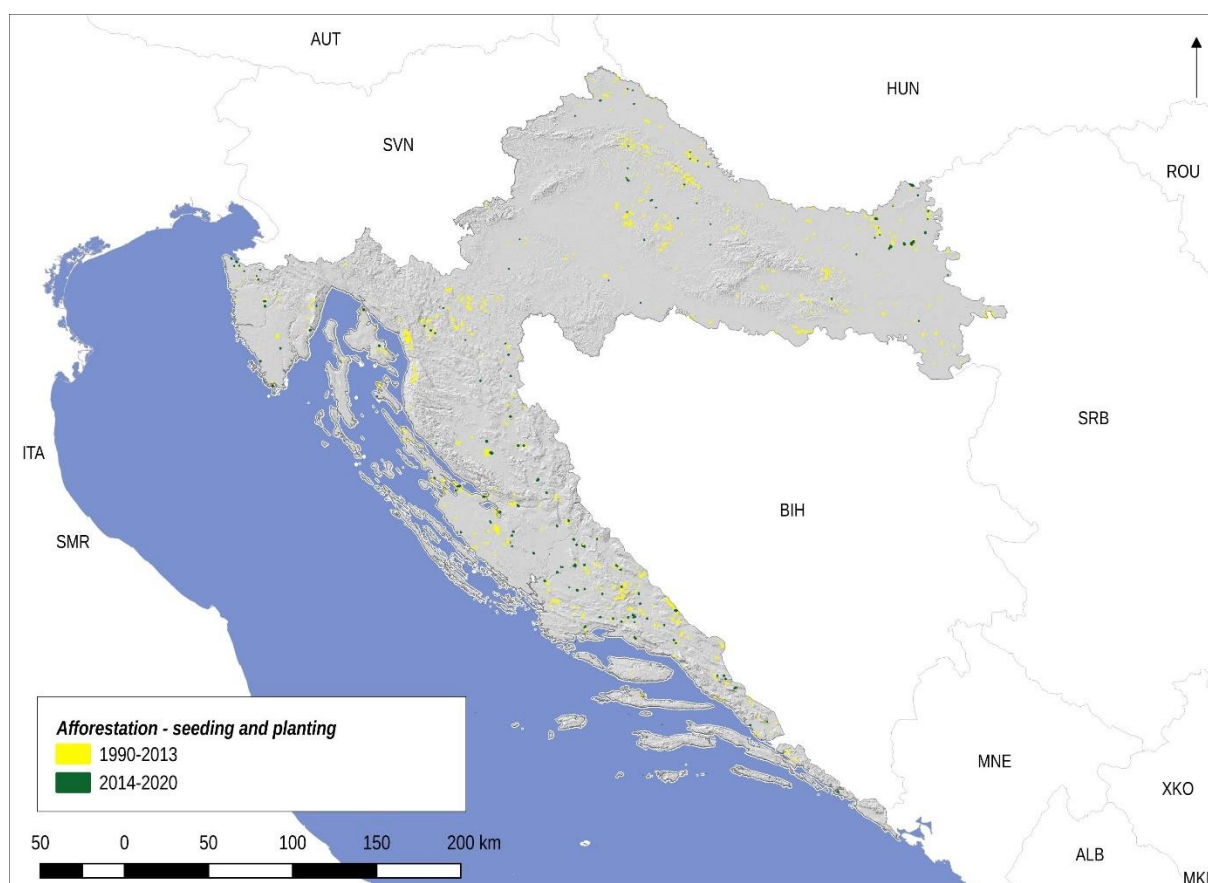
When performing this work, all areas that were previously reported as afforestation areas and for which was found mismatch with IPCC definition of term afforestation in fully, exclusion from the areas eligible for KP reporting was done.

Figure 11.1-2. 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 sume, sub-compartments 88 a and b, year of afforestation 1993, afforested area 10.01 ha)
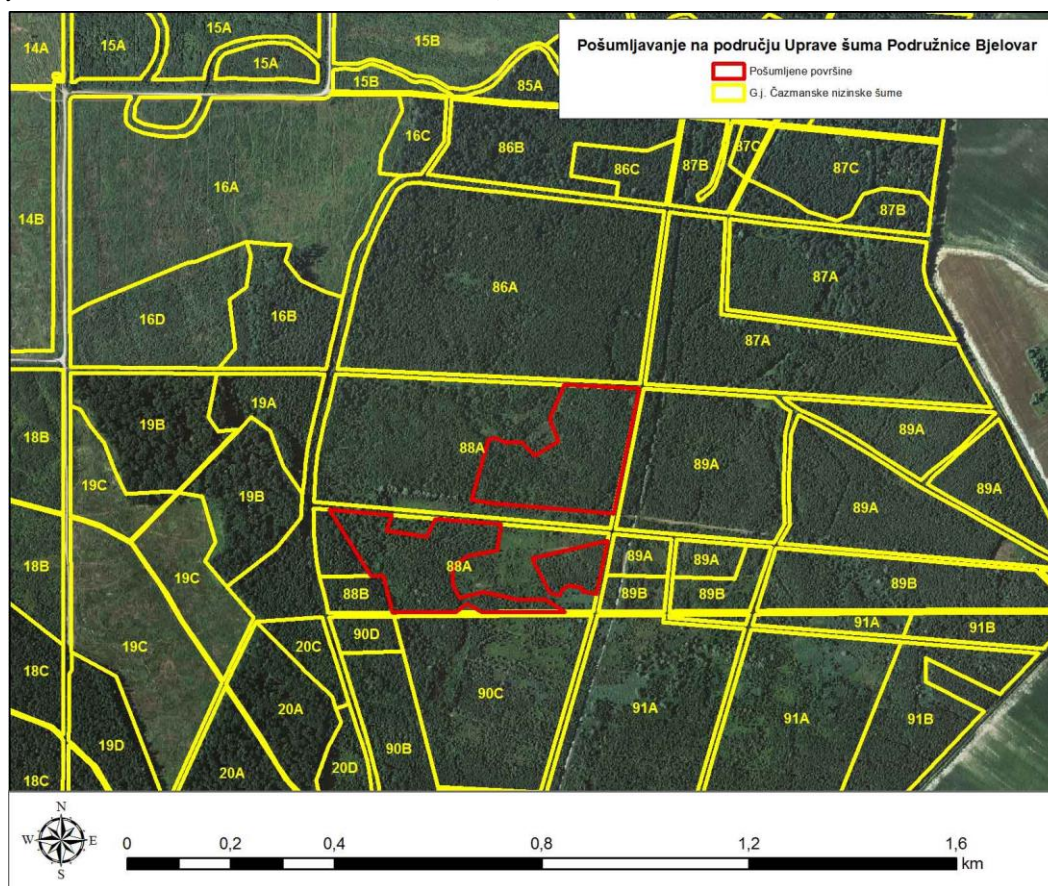
Croatia believes that collecting the data on the level of a part of area of sub-compartment on which afforestation was successful, complete and detailed analyses of afforestation through seeding and planting was performed.

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 11.1-3)

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 11.1-4)

Step 3: All areas that are not cover by forests are detected in order to be removed from the maps and future analyses (Figure 11.1-5)

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 11.1-6) 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 11.1-7)

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 11.1-8)

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 11.1-9)

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 11.1-10)

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 11.1-11)

Figure 11.1-3: Forest Administration Našice (boundary of Administration marked in green dots, forests area according to national definitions in 2014 marked in green)
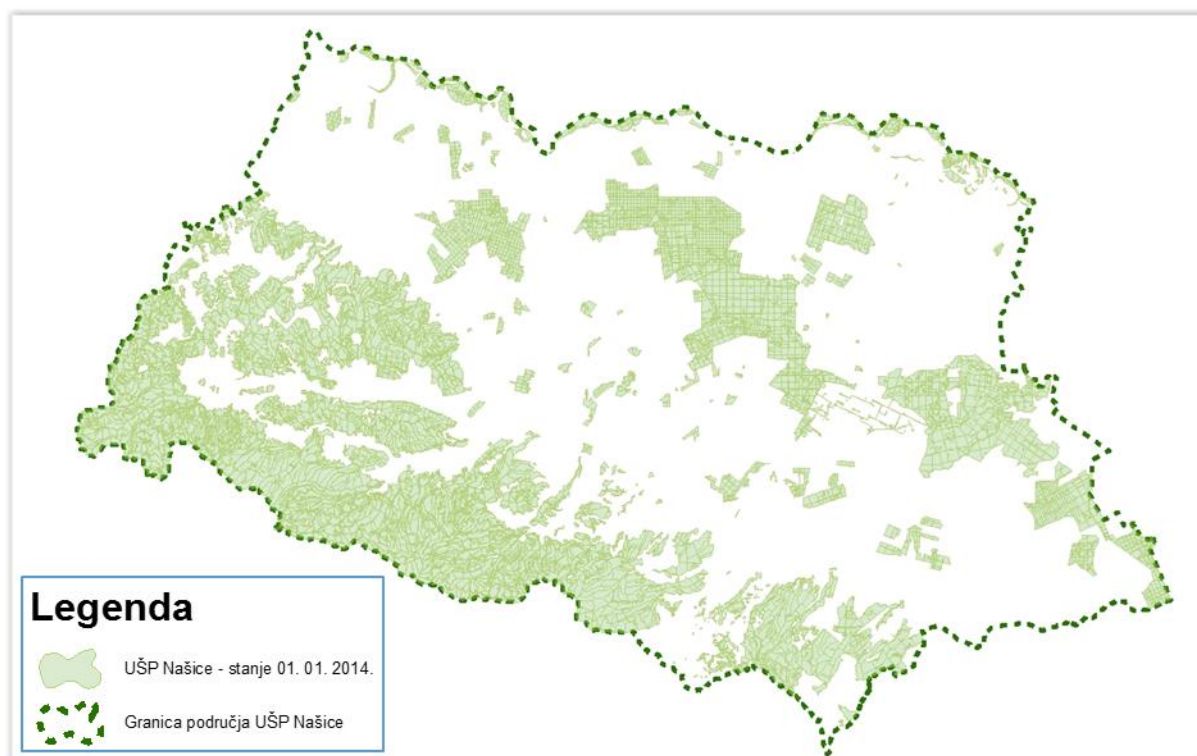
Figure 11.1-4: Forest Administration Našice (boundary of Administration marked in green dots, forests area according to KP definition of forests marked in pink, area not complying with KP definition of forests marked in green)
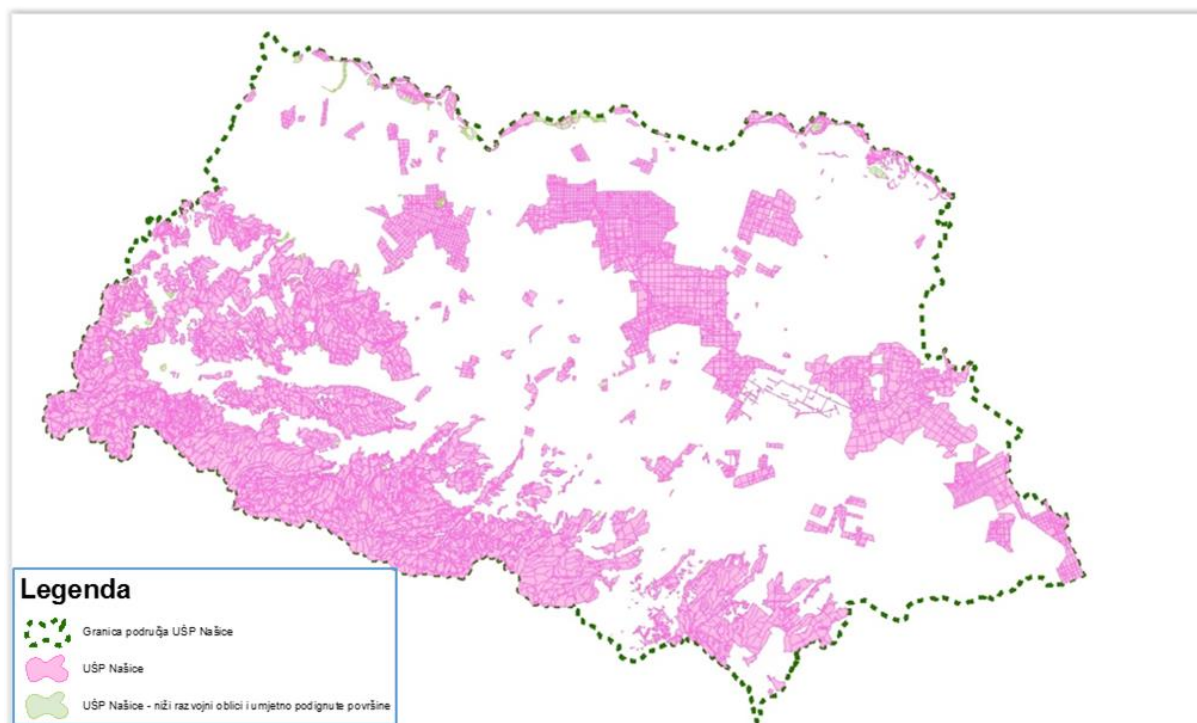
Figure 11.1-5: Forest Administration Našice (boundary of Administration marked in green dots, forests area marked in yellow, non-stocked forest area (i.e. clearings) marked in green)
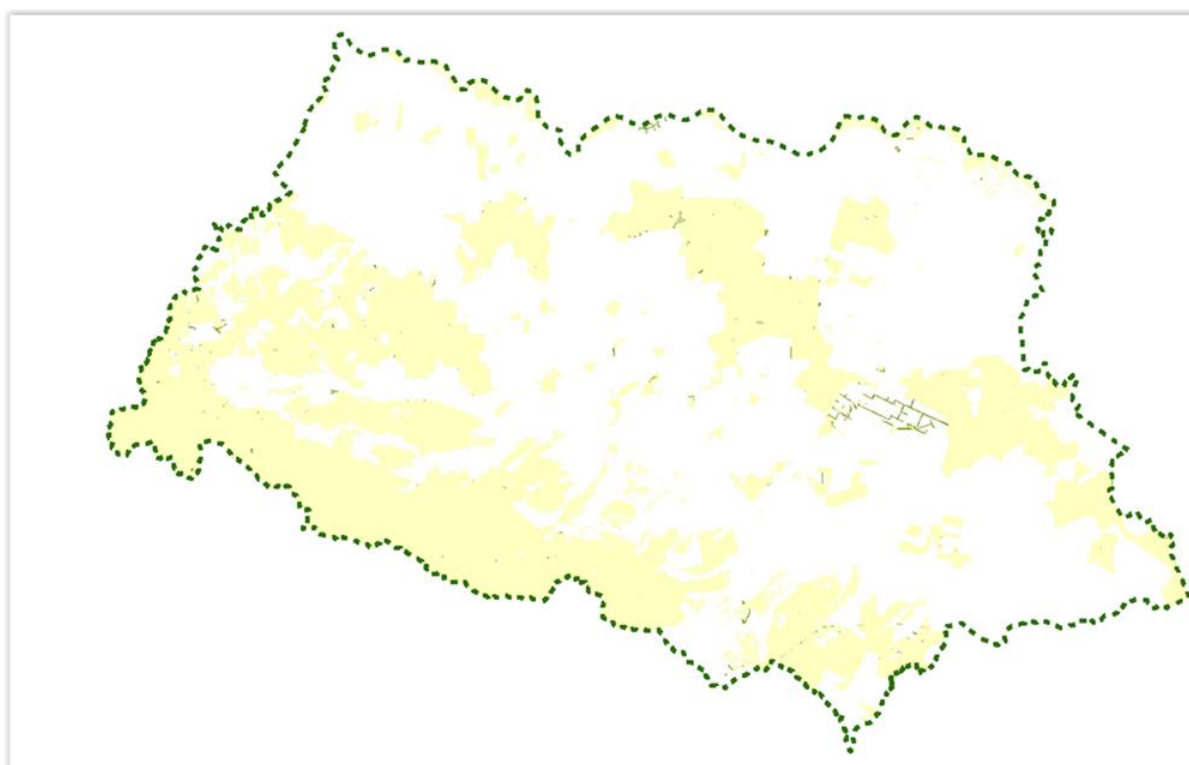
Figure 11.1-6: Forest Administration Našice (boundary of Administration marked in green dots, forests older than 24 years marked in green, remaining forest area marked in pink)
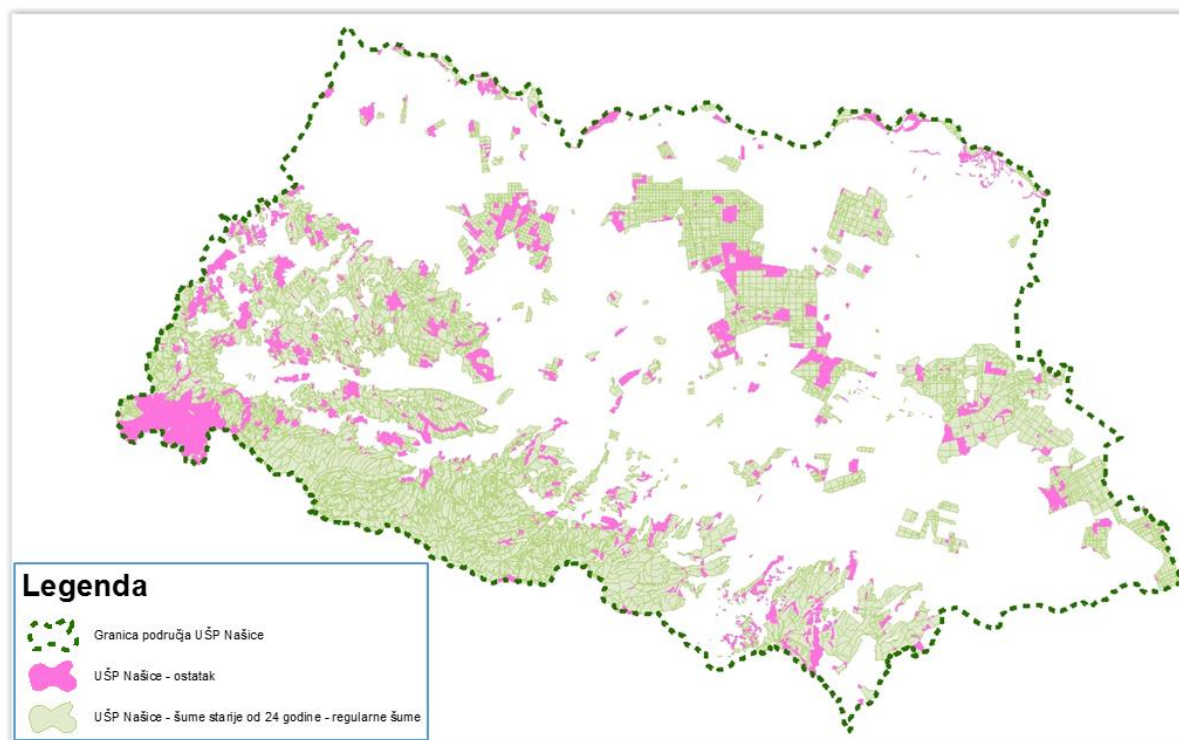
Figure 11.1-7: Forest Administration Našice (boundary of Administration marked in green dots, forests according to polygons of forests from topographical map marked in green, remaining forest area marked in pink)
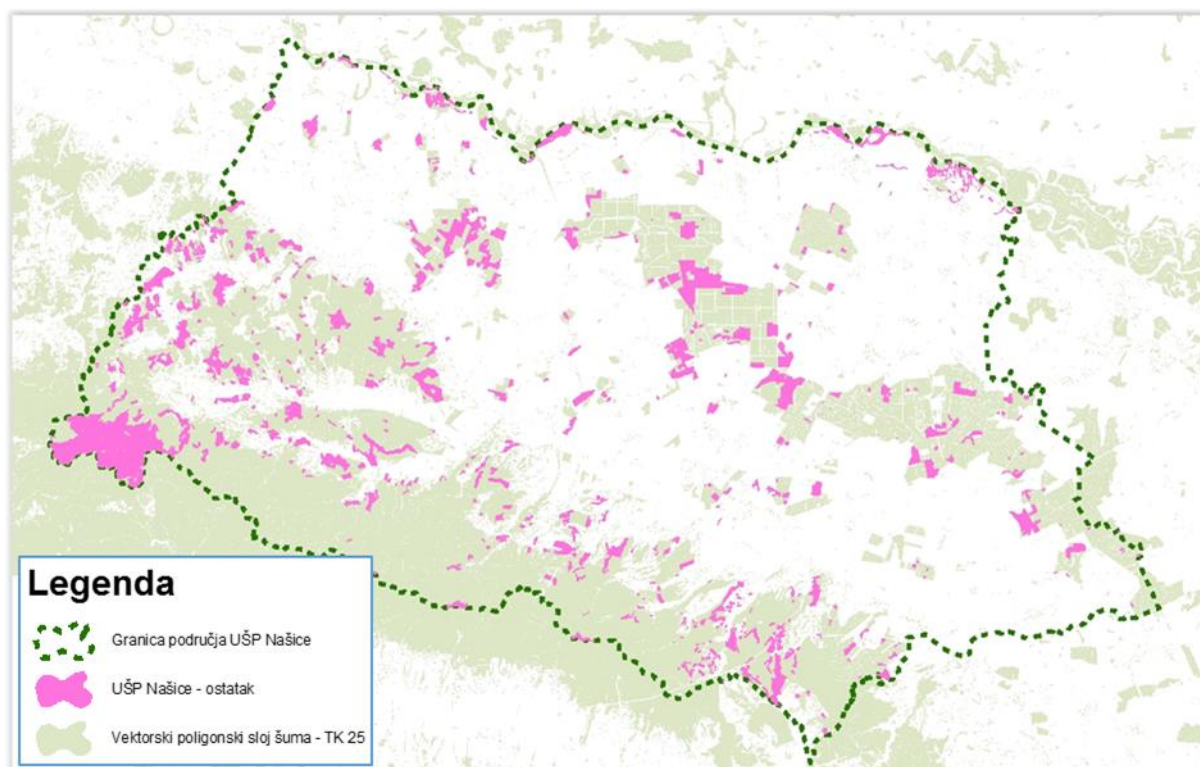
Figure 11.1-8: Forest Administration Našice (boundary of Administration marked in green dots, forests according to topographical map marked in green, remaining forest area after overlapping with topographical map marked in pink)
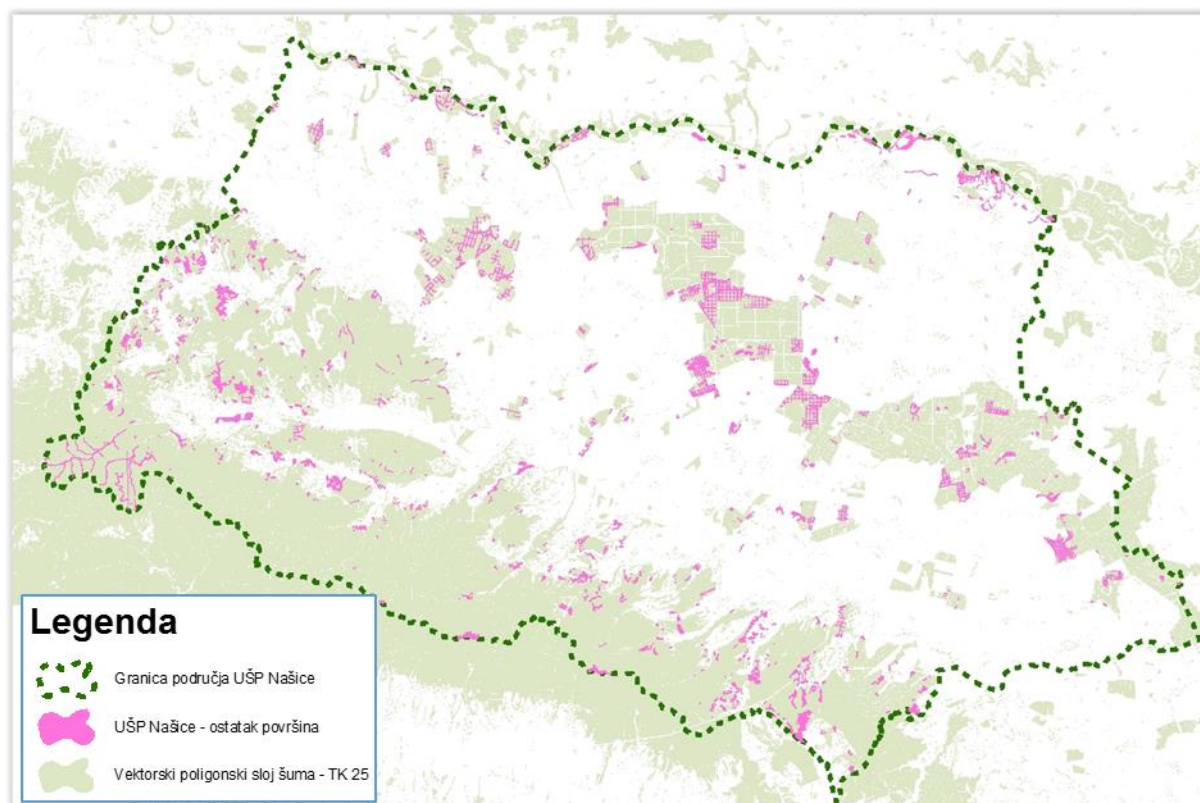
Figure 11.1-9: Forest Administration Našice (boundary of Administration marked in green dots, forests according to topographical map marked in green, remaining forest area after conducting step No. 6 marked in blue)
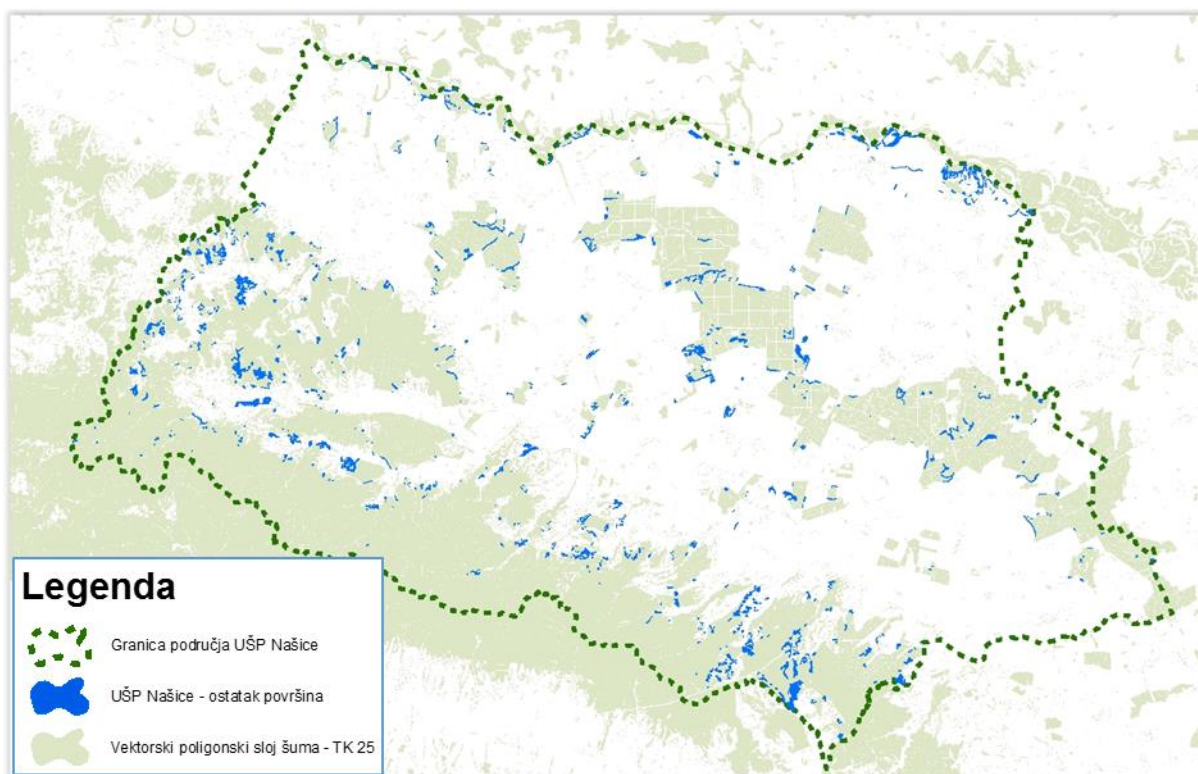
Figure 11.1-10: Forest Administration Našice (boundary of Administration marked in green dots, forest areas younger than 24 years marked in blue, remaining forest area marked in purple)
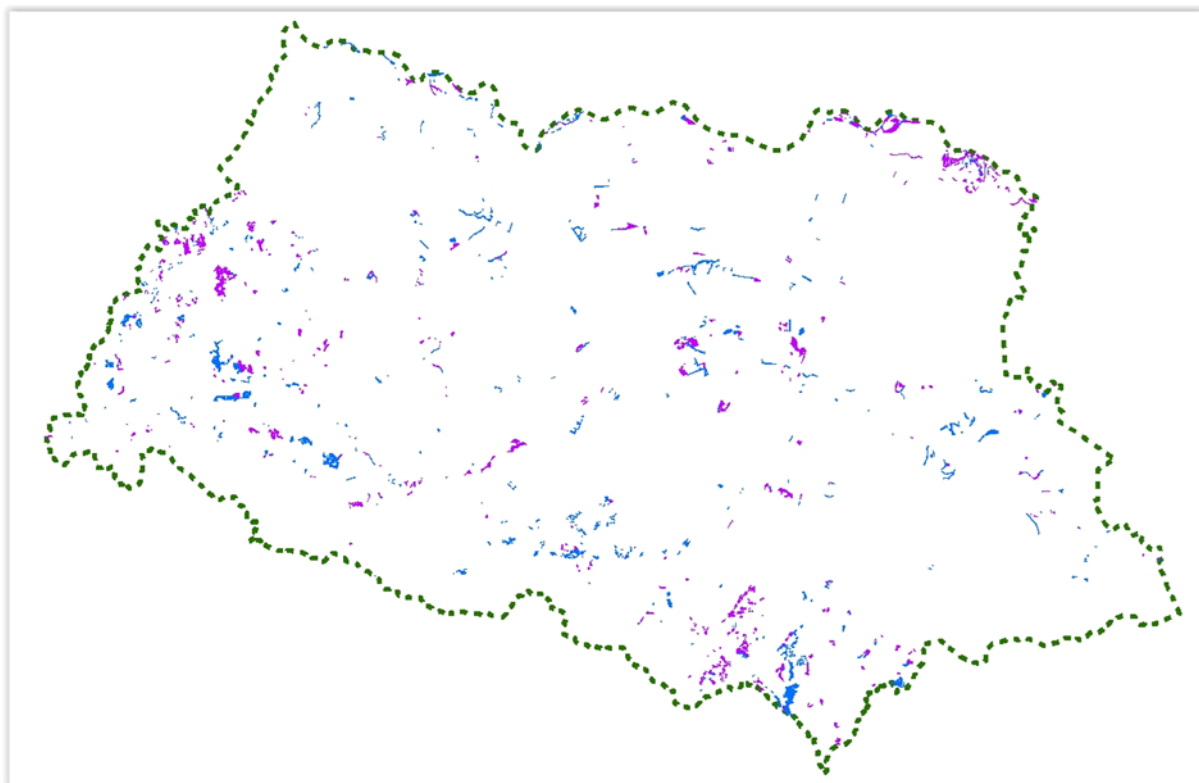
Figure 11.1-11: Forest Administration Našice (boundary of Administration marked in green dots, areas identified as not forests after step No 8. marked in red, areas identified as afforested after steps No1-No8 were performed marked in green)
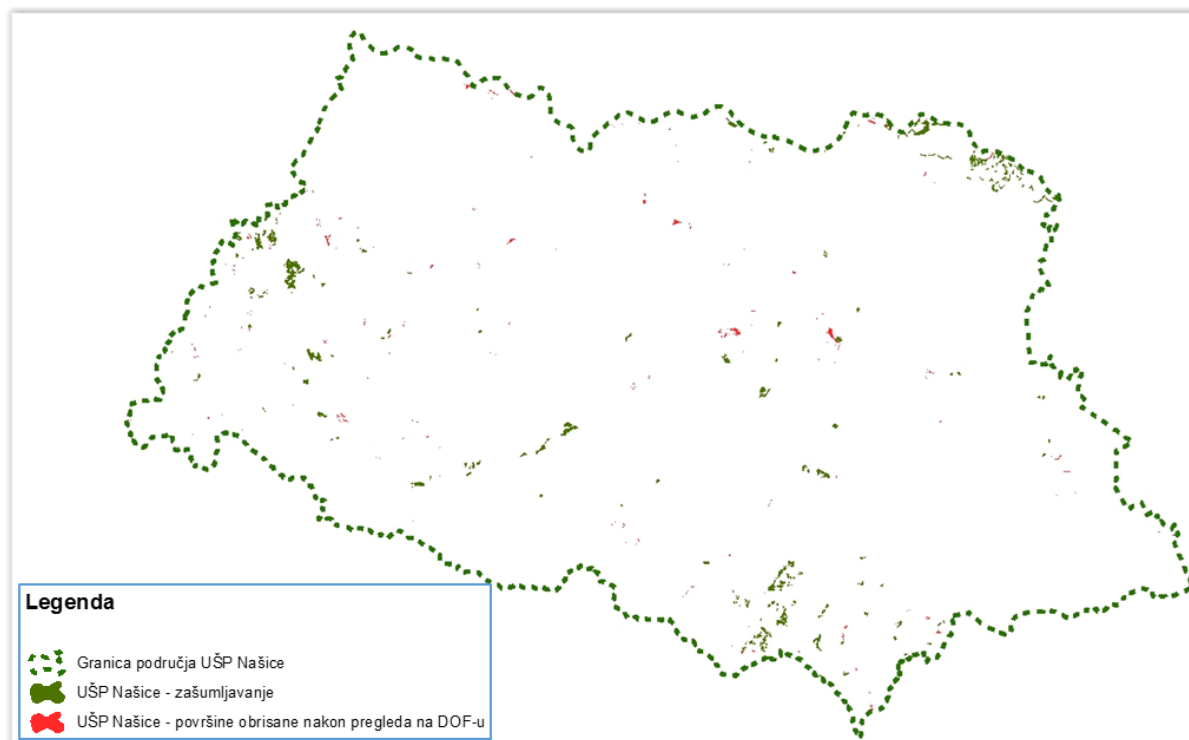
After analyses were done, forests area that are identified as a result of afforestation due to human induced natural promotion of seed sources in state owned forests were presented in below map (Figure 11.1-12).

Figure 11.1-12: 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)
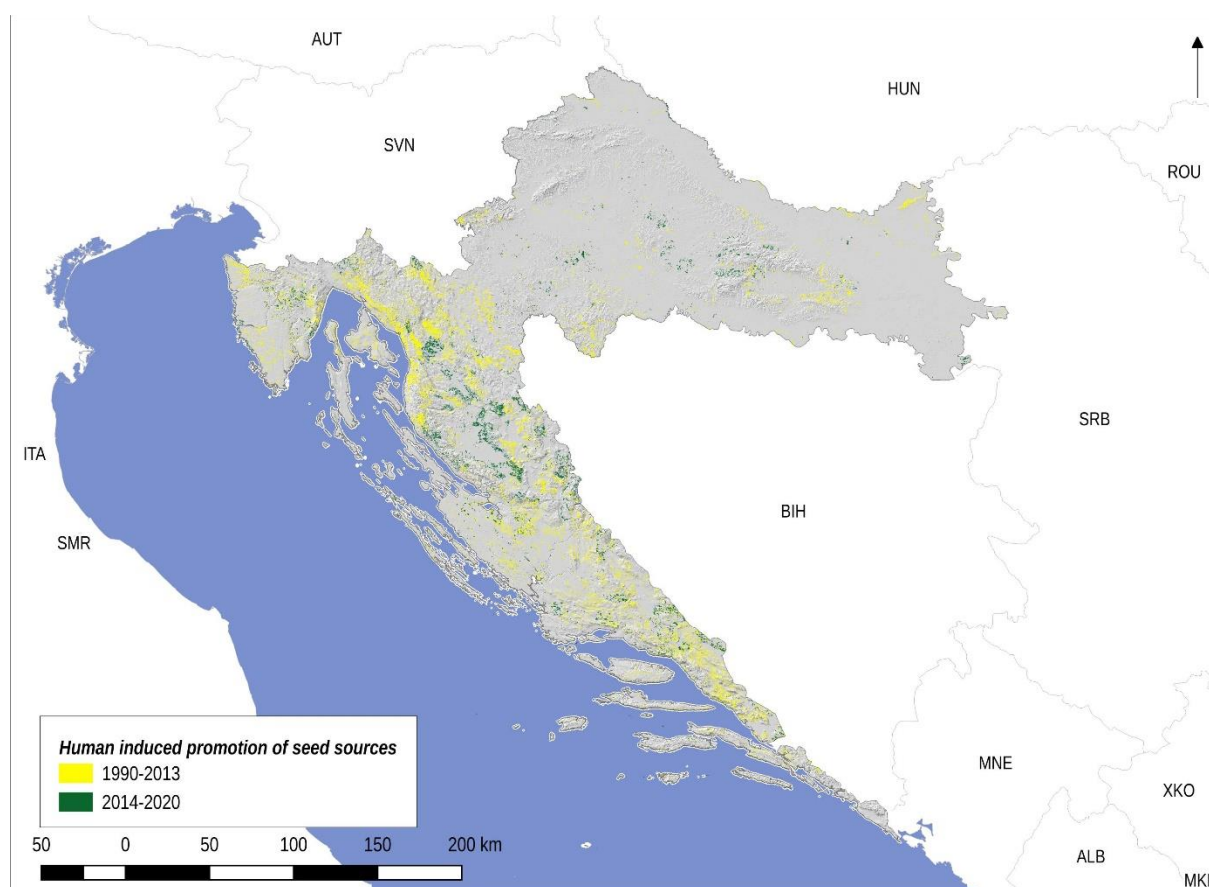
According to the national legislation and forest practices applied in Croatia, afforested areas on which seeding/planting are conducted have to be separately registered. This means that these areas were well known before the LULUCF 1 project was conducted in Croatia. Regarding the identification of afforested 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 this 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.

Reforestation, as defined by Kyoto, does not exist in Croatia due to strict legal provisions.

11.1.3.2. Definition and identification of Deforested areas since 1990

According to the Croatian *Forest Act*[71], deforestation implies clear cutting of forest in order to use area for other non-forestry purposes. It must 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

---

[71] Ibid

land owned by the Republic Croatia to cultivation of perennial crops[72]. Therefore, for an activity to be referred as 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.). The national definition is in line with the KP definition.

Based on the recommendations given by the ERT in ARR 2012, Croatia carried out a special survey 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[73] as one of outcomes of the LULUCF 1 project. The same procedure was applied for identification of these areas in years 2013-2020.

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 those areas which were deforested were forest according to the thresholds set by Croatia for KP 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 KP 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 Figures 11.1.-13.

---

[72] OG 12/2008, Article 1.

[73] 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 11.1-13: Map of forest management unit with deforested area marked in red (Forest Administration Požega, Management unit Požeška gora, total deforested area 22.47 ha)
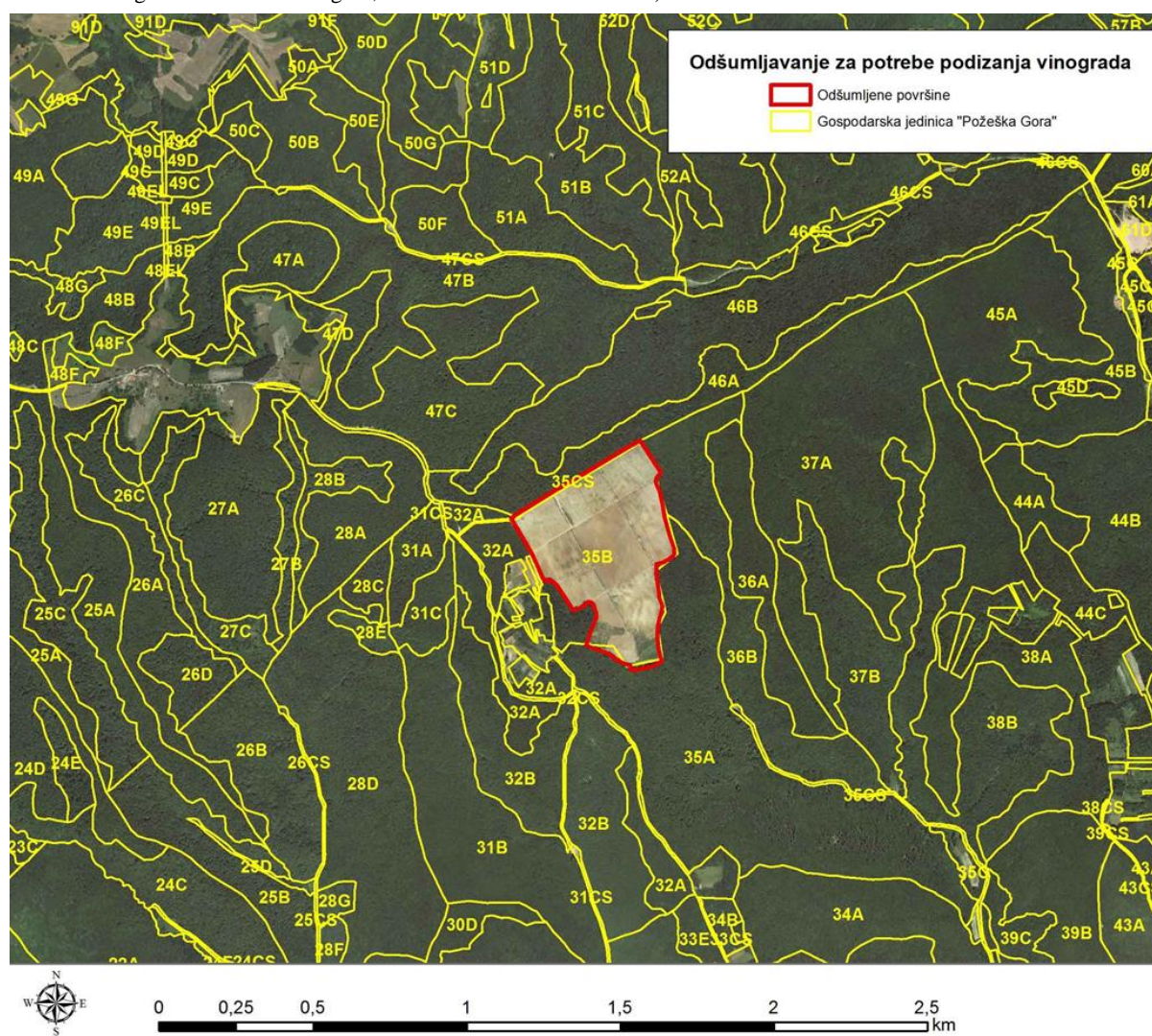
Deforested areas in the period 1990-2012 in private forests were identified on the level of forest sub-compartment in each single forest office by using maps of forest management units or by cadastral maps in cases where forest management program for private forests has not been developed yet. Areas 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.

408

The whole process was performed in several steps on different levels of Croatian forests Ltd. administration. In order to support Croatian reporting in KP, new recording system for identification and traceability of deforested lands after 2012 was introduced.

Table 11.1-3: Area deforested in Croatia in period 1990-2020 (ha/year)

Year	Deciduous	Coniferous	Maquies and shrub	Total
1990	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00
1994	23.79	34.56	0.96	59.31
1995	0.00	3.01	0.00	3.01
1996	0.00	0.00	0.00	0.00
1997	3.68	8.02	66.80	78.50
1998	55.84	48.92	0.00	104.76
1999	27.56	0.48	4.39	32.43
2000	143.60	23.22	1.43	168.25
2001	50.65	28.44	275.24	354.33
2002	85.42	109.16	32.90	227.48
2003	46.50	19.08	29.89	95.47
2004	136.89	52.02	158.63	347.54
2005	106.17	37.50	221.13	364.80
2006	51.24	17.59	283.43	352.26
2007	56.38	39.21	129.56	225.15
2008	122.57	69.80	217.18	409.55
2009	92.52	18.77	494.68	605.97
2010	69.00	57.12	223.25	349.37
2011	18.37	19.03	154.14	191.54
2012	49.54	94.32	101.01	244.87
2013	79.12	3.39	84.08	166.59
2014	17.14	0.81	26.57	44.52
2015	128.80	8.02	104.23	241.05
2016	21.74	12.01	0.42	34.17
2017	6.45	1.39	0.00	7.84
2018	6.56	0.00	2.00	8.56
2019	30.04	0.03	3.61	33.68
2020	20.09	0.52	0.29	20.90

Year	Deciduous	Coniferous	Maquies and shrub	Total
Total	**1449.66**	**706.42**	**2615.82**	**4771.90**

Results of work performed on complete forest management area are presented in Table 11.1-3 and Figure 11.1-14.

Figure 11.1-14: The spatial distribution of deforested land in period 1990-2020 (areas marked in light brown)
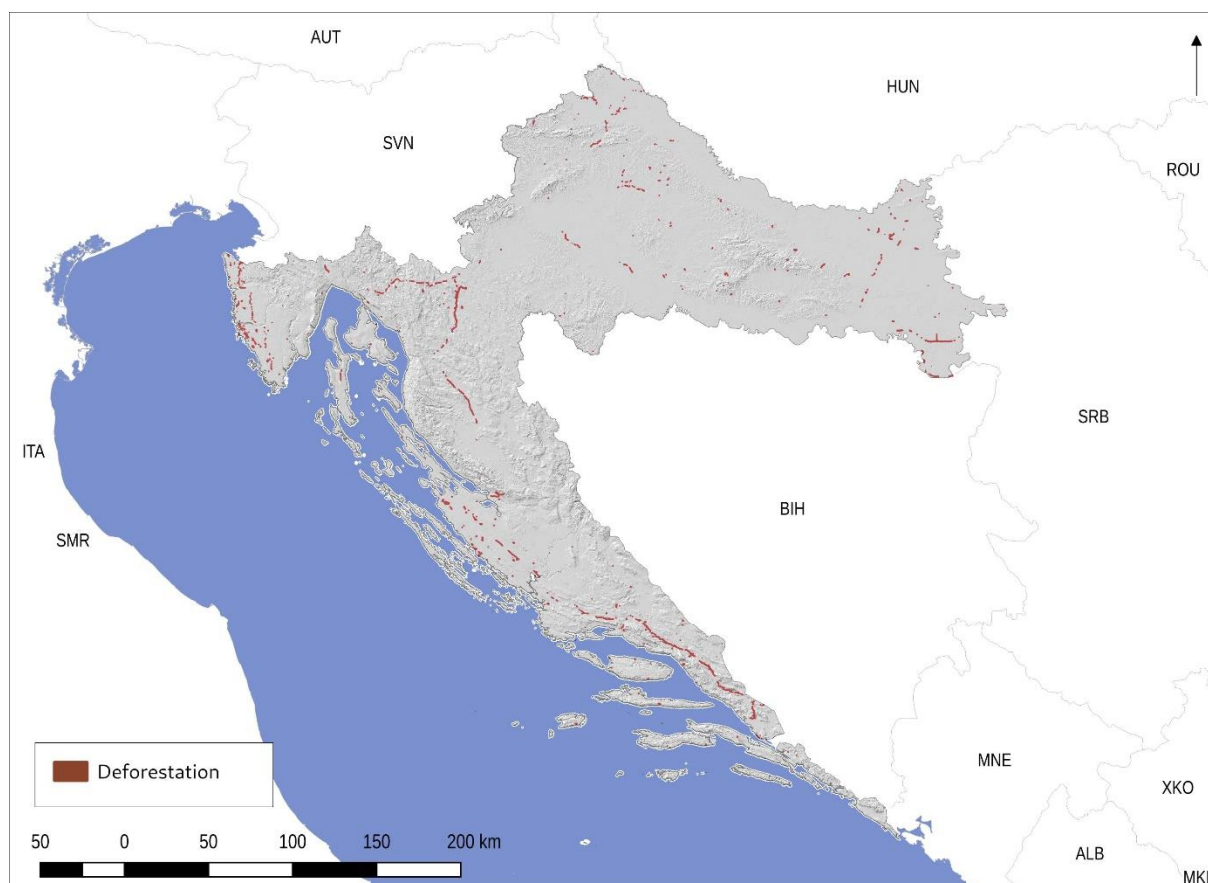
11.1.3.3.   Definition and identification of Forest Management areas since 1990

According to the national legislation, forest management has been interpreted in a same way as described in 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 Kyoto Protocol. 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 management according to the criteria set for KP reporting is not identical to forest management area in the national framework (Figure 11.1-15).

Croatian forest land area reported under forest management for the purposes of KP 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 11.1-2 are managed. Area of these forests is eligible area under forest management activity since the entire Croatian forest area is defined as managed forest lands.

Figure 11.1-15: Forest management area under the KP and within the national framework (based on the relative share of forest types in total forest management area in Croatia)
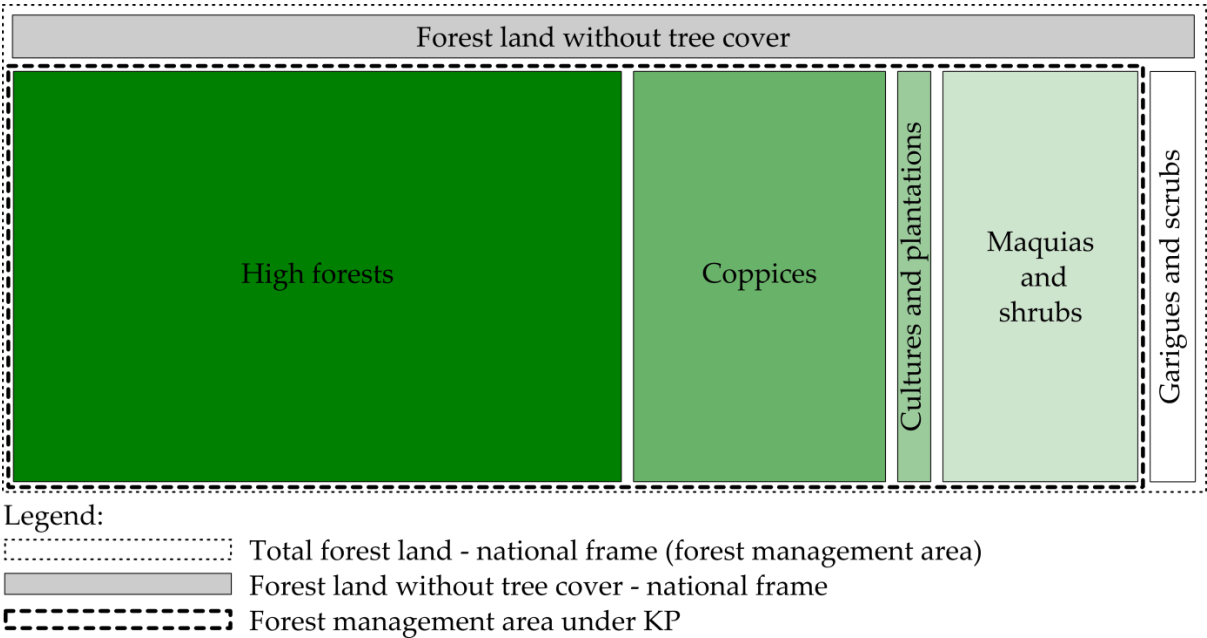
Based on the results of conducted survey under the LULUCF 1 project and followed upgrade of databases in Croatian Forests Ltd., all areas detected as afforested and deforested in period 1990-2020 were subtracted from the forest land area to estimate the FM area.

To complete the analyses, the increase in forest area on basis of afforestation that happened before 1st January 1990 needed to be determined since some of these areas were already included in FM areas and emissions/removals were accounted under single years from period 1990-2012. One of reason for this was that in 1993 a regulation[74] by the Croatian law gave the obligation to Croatian forests to take over all existing forest meeting the forest definition that were not registered as forests before 1993 into the forest land (including the forests managed by holdings or enterprises). The background for this law was that all forest area in Croatia should be under forest management plans. As a result of this regulation also mature forests were for the first time counted as forest land under the new forest management plans.

All these areas previously reported under FM that were detected by the described current survey as afforested due to human induced promotion of natural seed sources that happened before 1990, were shifted from the years where they were previously reported for the first time to the FM area in 1990.

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

As Croatia has elected only the forest management under Article 3.4 activities, there is no need to develop a hierarchy between forest management and other Article 3.4 activities.

---

[74] 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)

11.2. Land-related information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit used for determining the area of the units of land under Article 3.3 is 0.1 ha, which corresponds to the minimum area of forest defined by FAO. There is no need for further stratification of forests on more specific forest type (Coniferous, Deciduous and Out of yield forests (maquies and shrub)) due to the facts that Croatian territory is relatively small, Croatian forests create one unique area and all data related to the forestry sector are available form one source (Croatian Forests Ltd.).

11.2.2 Methodology used to develop the land transition matrix

Activity matrices are presented for years 2008-2020 (Tables 11.2-1, 11.2-2, 11.2-3, 11.2-4, 11.2-5, 11.2-6, 11.2-7, 11.2-8, 11.2-9, 11.2-10, 11.2-11, 11.2-12, 11.2-13:) based on the results of survey conducted under the LULUCF 1 project and a new registration system for ARD areas introduced in Croatian forests Ltd after 2014, as it was presented in subchapters 11.1.3.1 -11.1.3.3 of this Chapter.

Corrections have been made in comparison to matrix presented in previous NIRs of Croatia. The matrix was developed by adding and subtracting the conversion areas to and from land use category areas using the data from different databases available in Croatia (i.e. Croatian Forests Ltd., Croatian Bureau of Statistics, Corine Land Cover). Detailed information on approaches used to define the land use change area of each IPCC Land use category are given in parts 6.2-6.9 of the report.

Based on the Forest Law[75] and Ordinance on forest management[76] afforestation activities have to be prescribed by the Forest Management Plan for management units (FMAP). According to the Articles 38, 39 and 51, 51, 52 and 53 of Forest Act, deforestation is strictly regulated and allowed in very limited circumstances for all forest under forest management regardless the type of forests and ownership.

The data for total forest area for the single year as well as the relative share of coniferous and deciduous forests are presented. Out of yield forests (maquies and shrub) are fully assessed in high resolution (0.05 ha grid) and amply described in the forest management plans for the management subunits. Maps of silvicultural activities are integral part of the programs according to the legislative acts. This is also applicable to the activities on ARD areas in Croatia since afforestation of new areas are the part of silvicultural activities.

The forest management system is organized so complete Croatian territory is divided into 17 forest districts – Forest Administrations (organizational and territorial units). This division was established in 1996 and updated in 2018. Forest Administrations consist of Forest offices, currently of 169 altogether. The single Forest office is the basic organizational unit for performing all forest management activities (see Chapter 6.3).

An increase of forest area was assessed within the reporting period. Total area of forest land in Croatia is known as well as total areas of forest land converted to settlement and cropland categories thanks to FMAP system and strict national legislation. Also, the grassland area converted to forest land is well known due to the fact that afforestation in Croatia has been done strictly on land under the forest management plans (without tree cover) which belongs to the grassland category according to the 2006

---

[75] Forest Law (OG 68/2018, OG 115/2018)
[76] Ordinance on forest management (OG 97/2018)

IPCC Guidelines. At the same time, the decrease in area of grassland was detected during the reporting period.

In order to identify and trace forest areas in accordance with provisions of decision 15/CMP.1 and requirements set in ARR 2012, Croatian Ministry of Economy and Sustainable Development initiated the LULUCF 1 project. The survey conducted during the project addressed the issue of increasing forest area in a way that:

1. Forest area increase on basis of afforestation that happened before 1st January 1990 was determined (e.g., in 1993 a regulation[77] 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 the first time counted as forest land under the new forest management plans). Croatia counted these lands under Art. 3.4 FM.
2. Afforestation and the former land use after 1st January 1990 and direct human induced LUC were identified. These areas are counted under Art. 3.3 AR.
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. Results of this study have significantly changed previously reported information under the Article 3.3 and 3.4 of the KP (NIR 2013). The same procedure was applied for years 2013-2020.

Table 11.2-1: Land transition matrix for year 2008, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2008
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	13.85							13.85
	D		2.41						2.41
Article 3.4 activities	FM		0.41	2,323.37					2,323.78
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		1.83	0.00	0.00	0.00	0.00	0.00	3,317.52	3,319.35
TOTAL (end of 2008)		15.69	2.82	2,323.37	0.00	0.00	0.00	3,317.52	5,659.40

---

[77] 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)

Table 11.2-2: Land transition matrix for year 2009, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2009 |
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	15.69							15.69
	D		2.82						2.82
Article 3.4 activities	FM		0.61	2,322.76					2,323.37
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		4.45	0.00	0.00	0.00	0.00	0.00	3,313.07	3,317.52
TOTAL (end of 2009)		20.14	3.43	2,322.76	0.00	0.00	0.00	3,313.07	5,659.40

Table 11.2-3: Land transition matrix for year 2010, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2010 |
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	20.14							20.14
	D		3.43						3.43
Article 3.4 activities	FM		0.35	2,322.41					2,322.76
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		4.81	0.00	0.00	0.00	0.00	0.00	3,308.26	3,313.07
TOTAL (end of 2010)		24.94	3.78	2,322.41	0.00	0.00	0.00	3,308.26	5,659.40

Table 11.2-4: Land transition matrix for year 2011, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2011 |
		A/R	D	FM	CM	GM	RV		
	A/R	24.94							24.94

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2011
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	D		3.78						3.78
Article 3.4 activities	FM		0.19	2,322.22					2,322.41
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		6.04	0.00	0.00	0.00	0.00	0.00	3,302.22	3,308.26
TOTAL (end of 2011)		30.99	3.97	2,322.22	0.00	0.00	0.00	3,302.22	5,659.40

Table 11.2-5: Land transition matrix for year 2012, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2012
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	30.99							30.99	30.99
		3.97						3.97	
Article 3.4 activities		0.24	2,321.98					2,322.22	
	NA	NA		NA	NA	NA		NA	NA
	NA	NA		NA	NA	NA		NA	NA
	NA			NA	NA	NA		NA	NA
Other		5.03	0.00	0.00	0.00	0.00	0.00	3,297.19	3,302.22
TOTAL (end of 2012)		36.02	4.21	2,321.98	0.00	0.00	0.00	3,297.19	5,659.40

Table 11.2-6: Land transition matrix for year 2013, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2013
		A/R	D	FM	CM	GM	RV		
	A/R	36.02							

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2013
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	D		4.21						
Article 3.4 activities	FM		0.17	2,321.81					
	CM	NA	NA		NA	NA	NA		
	GM	NA	NA		NA	NA	NA		
	RV	NA			NA	NA	NA		
Other		7.14	0.00	0.00	0.00	0.00	0.00	3,290.05	3,297.19
TOTAL (end of 2013)		43.16	4.38	2,321.81	0.00	0.00	0.00	3,290.05	5,659.40

Table 11.2-7: Land transition matrix for year 2014, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2014
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	43.16							43.16
	D		4.38						4.38
Article 3.4 activities	FM		0.04	2,321.77					2,321.81
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		8.35	0.00	0.00	0.00	0.00	0.00	3,281.70	3,290.05
TOTAL (end of 2014)		51.51	4.43	2,321.77	0.00	0.00	0.00	3,281.70	5,569.40

Table 11.2-8: Land transition matrix for year 2015, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2015
		A/R	D	FM	CM	GM	RV		
	A/R	51.51							51.51

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2015
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	D		4.43						4.43
Article 3.4 activities	FM		0.24	2,321.53					2,321.77
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		6.38	0.00	0.00	0.00	0.00	0.00	3,275.32	3,281.70
TOTAL (end of 2015)		57.89	4.67	2,321.53	0.00	0.00	0.00	3,275.32	5,659.40

Table 11.2-9: Land transition matrix for year 2016, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2016
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	57.89							57.89
	D		4.67						4.67
Article 3.4 activities	FM		0.03	2,321.49					2,321.53
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		1.43	0.00	0.00	0.00	0.00	0.00	3,273.89	3,275.32
TOTAL (end of 2016)		59.31	4.70	2,321.49	0.00	0.00	0.00	3,273.89	5,659.40

Table 11.2-10: Land transition matrix for year 2017, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2017 |
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	59.31							
	D		4.70						
Article 3.4 activities	FM		0.01	2,321.48					
	CM	NA	NA		NA	NA	NA		
	GM	NA	NA		NA	NA	NA		
	RV	NA			NA	NA	NA		
Other		3.93	0.00	0.00	0.00	0.00	0.00	3,269.96	3,273.89
TOTAL (end of 2017)		63.24	4.71	2,321.48	0.00	0.00	0.00	3,269.96	5,659.40

Table 11.2-11: Land transition matrix for year 2018, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2018 |
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	63.24							63.24
	D		4.71						4.71
Article 3.4 activities	FM		0.01	2,321.48					2,321.48
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		1.73	0.00	0.00	0.00	0.00	0.00	3,268.23	3,269.96
TOTAL (end of 2018)		64.98	4.72	2,321.48	0.00	0.00	0.00	3,268.23	5,659.40

Table 11.2-12: Land transition matrix for year 2019, kha

| | | Article 3.3 activities | | Article 3.4 activities | | | | Other | TOTAL 2019 |
		A/R	D	FM	CM	GM	RV		
	A/R	64.98							64.98

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2019
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	D		4.72						4.72
Article 3.4 activities	FM		0.03	2,321.44					2,321.48
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		0.54	0.00	0.00	0.00	0.00	0.00	3,267.69	3,268.23
TOTAL (end of 2019)		65.51	4.75	2,321.44	0.00	0.00	0.00	3,267.69	5,659.40

Table 11.2-13: Land transition matrix for year 2020, kha

		Article 3.3 activities		Article 3.4 activities				Other	TOTAL 2020
		A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	65.51							65.51
	D		4.72						4.72
Article 3.4 activities	FM		0.02	2,321.42					2,321.44
	CM	NA	NA		NA	NA	NA		NA
	GM	NA	NA		NA	NA	NA		NA
	RV	NA			NA	NA	NA		NA
Other		0.34	0.00	0.00	0.00	0.00	0.00	3,267.39	3,267.73
TOTAL (end of 2020)		65.86	4.74	2,321.42	0.00	0.00	0.00	3,267.39	5,659.40

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

All forest lands are assessed by Croatian Forests' Forest land assessment system. Croatian Forests have a legal duty to assess the total area of forest land of Croatia every ten years. Thus, estimations provided in this report are based on reliable data referring to the total territory of Croatia and irrespective to the type of forest or ownership.

Geographical units used for reporting are based on the forest ownership (state and private forests). The annexes of FMAPs contain thematic maps including map on the forest ownership. This map is prepared

by merging digital spatial data with HS-Fond's database, scale 1:100.000 Therefore, the ownership is also spatially located (See Chapter 6.3).

Forests maps that are prescribed by the Ordinance[78] as part of the FMAP 2016-2025 are:

- Geological map
- Phytocoenological map
- Soil Map detecting erosion and floodplains, rivers and water bodies
- Forest ownership overview map
- General maps of the spatial distribution of forests at the forest management unit especially for state-owned forests (showing boundaries of management units, forest offices, the forest administration, counties, specifically designated karst) and private forests (showing boundaries of cadastral municipalities or economic units, municipalities, counties, with specially designated karst).
- Forest map according to their purpose (commercial, protective, special purpose)
- Forest map by origin and the method of management (even-aged, uneven-aged forests)
- Forest map of main tree species
- Map of forest infrastructure (existing and planned forest infrastructure)
- Forest fire risk map
- Map of forest ecosystem services including larger settlements, industrial plants, agricultural areas, transport corridors

The maps are in scale 1:300,000 and repeatedly produced every 10 years at FMAP regular revision or renewed during the FMAP's additional or intermediate audits if required, except geological, soil and phytocoenological map which had been produced just once (during the development of first FMAP).

In order to comply with the ERT findings presented in ARR 2012 regarding the traceability and identification of lands as defined in paragraphs 6(a), 6(b), 6(e), 8(c), 9(a), 9(c) and 9(d) of the annex to decision 15/CMP.1, separate project was designed. Through surveys conducted within the framework of LULUCF 1 project Croatia managed to identify and trace lands that should be reported under paragraphs 3.3 and 3.4 of the Kyoto Protocol (see points 11.1.3.1-11.1.3.3 of the report). The survey was conducted on all Croatian forest areas that met thresholds for forests defined under the KP regardless the ownership and forest types (this includes maquies and shrubs). All data and information from conducted survey are presented in a separate document[79] as one of outcomes of LULUCF 1 project.

To conduct this work detailed analyses of spatial data and all relevant data available in official forest database HS Fond were performed consulting the forest management plans and programs valid in previous periods during the analysis and making field checks in forms of site visits on a level of forest sub-compartment when it was needed.

All identified areas that belong to ARD areas were incorporated into a GIS database of Croatian forests Ltd. as geospatial ESRI Shapefile (.shp) files. These are polygon layers with accompanying descriptive (attribute) data projected in HTRS96/TM coordinate system. Descriptive data use as a link between layer polygons and existing databases of Croatian forests Ltd.

Therefore, all reported ARD areas are geographically explicitly determined (Figure 11.2-1, Figure 11.2-2 and Figure 11.2-3) and traced as described.

Regarding geographical identification of afforested areas and their traceability in private and state forests that area managed by other legal bodies, it should be emphasized that performed work had proved increase in forest area due to promotion of natural seed resources while afforestation through planting and seeding activities do not occur in these forests (explanation provided under the Chapter 6.4.2.2).

---

[78] Ordinance on Forest Management (OG 97/2018)

[79] Janeš *et al.* Separation of areas under the Article 3.3 and 3.4 of the Kyoto Protocol

Examples of areas registered as areas subject of ARD activities are presented in Figure 11.2-1 and Figure 11.2-2.

Figure 11.2-1: A map of one forest district in Croatia presenting areas that are afforested in period 1990-2010 (marked green) and areas that are foreseen for the afforestation in period 2011-2020 (marked yellow)
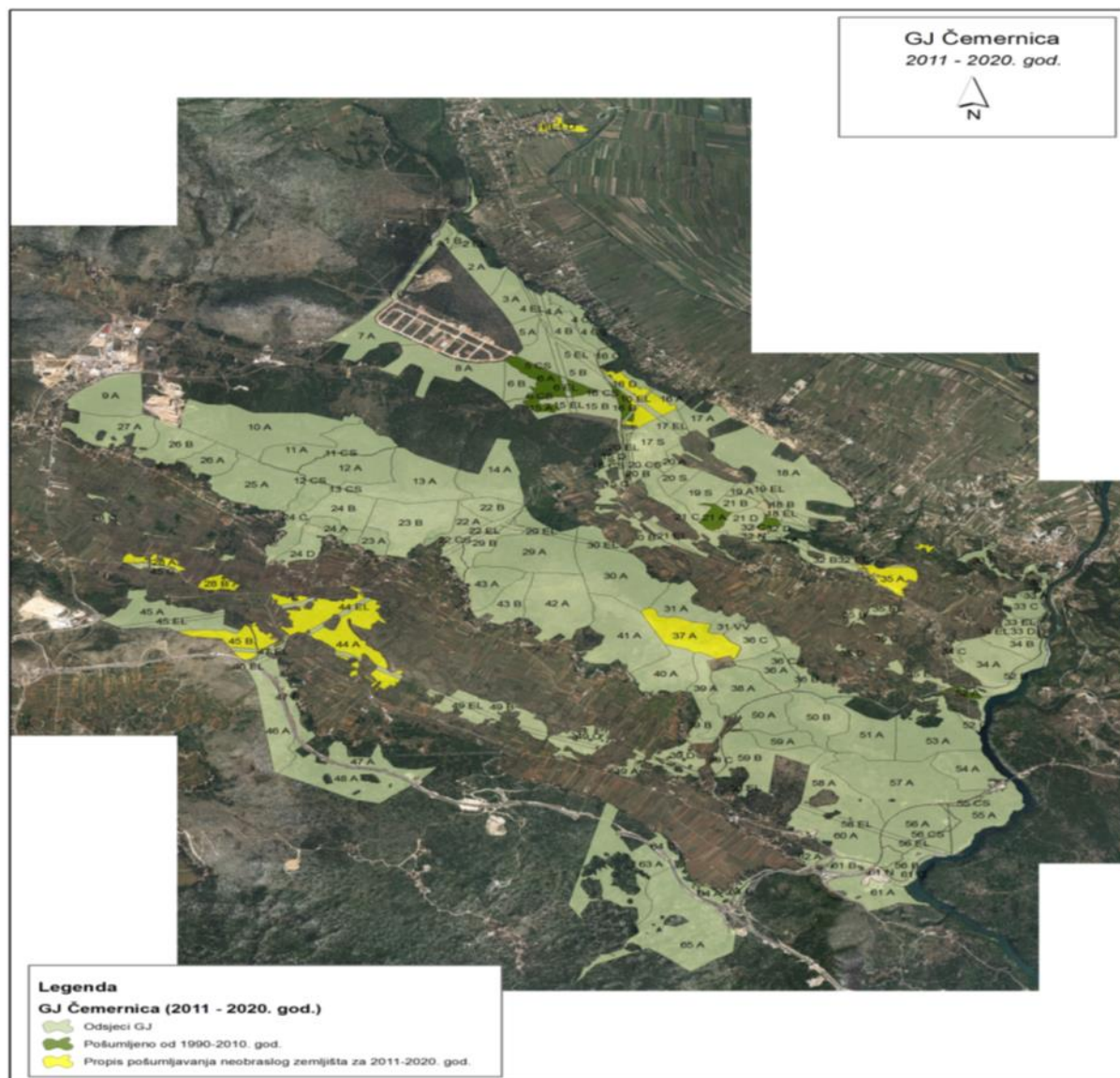
Figure 11.2-2: A map of the area with traced changes in the territory (area which was excluded from forest land in period 1997-2006 presented in red and situation in FMAP 2006-2015 presented in green)
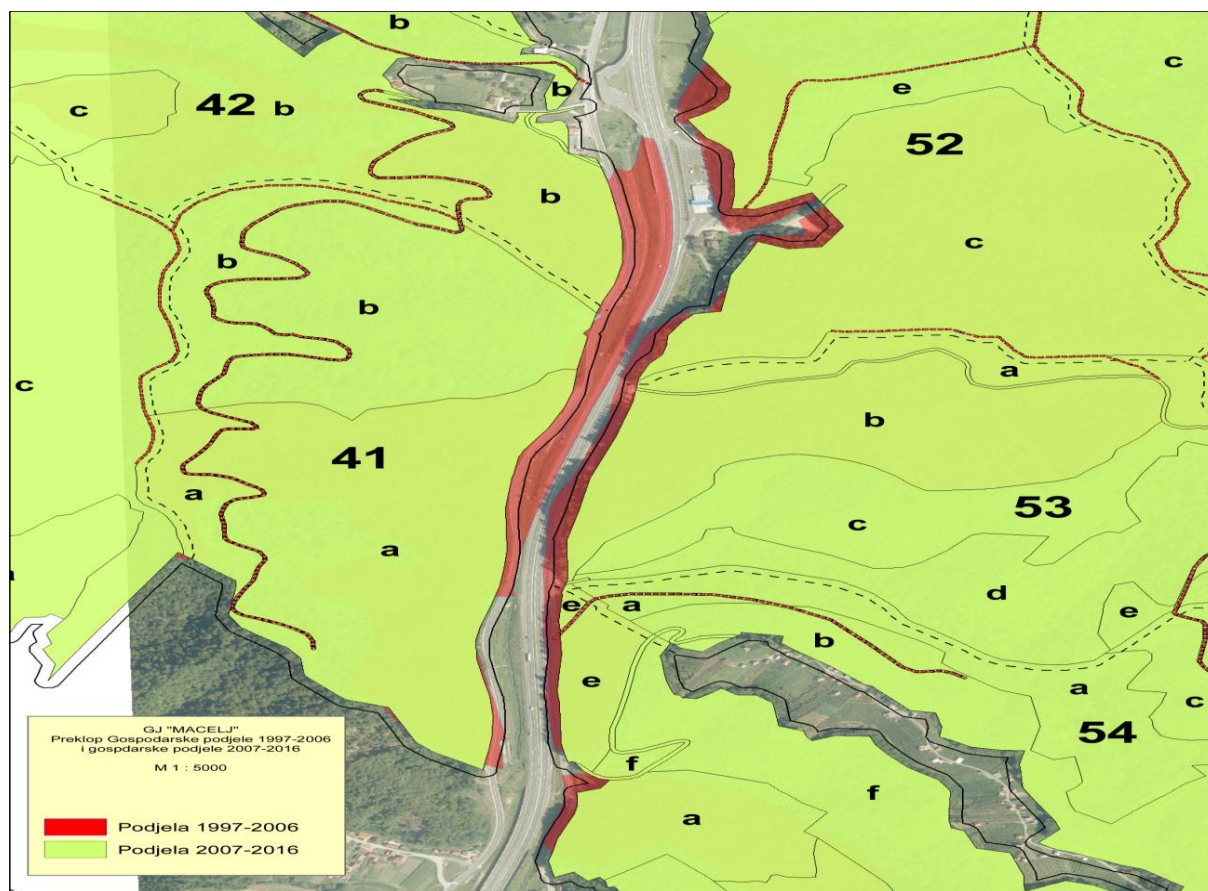
11.3. Activity-specific information

Data used in the calculations are attained from FMAPs in case of forest areas and also they are derived from the projects specially designed for determining carbon stocks in dead wood and litter pools. Basic information about tasks of these projects are presented in Annex 3.2. The data were categorised according to forest type and reported as Deciduous, Coniferous and Out of yield forests (maquis and shrub). This disaggregation of data was used for presenting the carbon stock in living biomass and dead wood pool (for the estimation of CSC in afforested and deforested areas). Data on carbon stocks changes in soil and litter pools on afforested and deforested areas are presented as aggregated and without division by type of forests.

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1. Description of the methodologies and the underlying assumptions used

Methods and assumptions for estimating carbon stock changes in forests on areas under the Article 3.3 (afforestation/reforestation and deforestation) and Article 3.4 (forest management) of the Kyoto Protocol follow those applied for the UNFCCC reporting (see chapter 6.3).

In order to comply recommendations given by the ERT, emissions from forest fires are reported separately for FM and ARD areas since NIR 2014 reporting. This has been performed using officially submitted data from Croatian Forests Ltd gained through the activities of LULUCF 1 project and using

the data from newly established data recording system introduced by Croatian forests Ltd to support Croatian KP reporting during the 2nd CP.

GHG Emissions on FM areas are estimated using the 2006 IPCC Guidelines default values for Other temperate forests. When estimating emissions form fires in afforested areas, values for biomass consumption and emission factors that also refer to Other temperate forests (2006 IPCC Guidelines, Table 2.4 and 2.5) are used. Estimate of emissions from wildfires cover also Out of yield forests (maquies and shrub) but high forest biomass losses are used in estimation during the complete reporting period that represents overestimation of emissions under this type of forests. It is known that maquies and shrub forest have significantly lower C stock, thus this approach is source of overestimation of emissions form fires in Croatian reporting. Additionally, due to the officially prescribed data collection methodology, it was not possible to distinguish areas affected by fires in case of maquies and shrub forests from scrub areas (degraded forms of shrub forests) in period 1990-2012. Therefore, areas of scrub forests affected by fires in period 1990-2012 make part of areas of maquies and shrub forests and estimation were done using the same values as for high forests. This represents another source of emission's overestimation in period 1990-2012 due to the fires. Improvements made in Croatian Register of forest fires enabled reporting on forest fires emissions from areas of maquies and shrub forests excluding scrub areas starting with 2013 forest fire data. Estimation of emissions in maquies and shrub forests in period 2013-2019 has been performed using the values for high forests, as mentioned above.

Emissions of CO_2, N_2O and CH_4 are calculated using the above-mentioned parameters and areas detected as burnt under the FM or afforested areas and reported in corresponding CRF tables.

Detailed description of method used for estimation has been described in Chapter 6.15.2.

CO_2 emissions from biomass burning in areas subject to Article 3.3 and Article 3.4 are included in CRF tables 5(KP-I) A.1.1 Losses and 5(KP-I) B.1 Losses, accordingly.

1) ARD activities

Emissions and removals from ARD activities have been calculated using Tier 1 method for biomass gains, litter and dead wood pools and Tier 2 method for biomass losses and soil pools. The activity data obtained and referring to the mentioned polls are as follows:

- For afforestation – afforested area
- For deforestation – deforested area and related volume felled

As regarding the afforestation, on the land units that were subject to this activity and were harvesting operations were performed since the beginning of the First commitment period, only the wood for fire consumption was produced.

A) Biomass

In order to determine the changes in biomass carbon stocks in ARD areas in Croatia, results and outcomes of the conducted survey under the LULUCF 1 project were used as presented below:

1. During the reporting period, afforestation by seeding and planting as well as supporting natural spreading of forests through human decision, did not happen in state owned forest areas that are managed by other legal bodies.
2. Only afforestation due to human decision to support natural spreading of forests on new areas occurred in private forests during the reporting period (see also Chapter 6.4.2.2)
3. In case of state-owned forests managed by Croatian forests Ltd. afforestation through seeding and planting activities occurred. Also, natural spreading of forests on new areas were recorded as result of human decision to support increase of forest areas

4.   Afforestation that occurred in state owned and private forests refers to conversions from grassland and cropland (annual and perennial) to forest land.

Values presented below were used for estimations according to the type of conversion (from Grassland or Cropland) and type of forests:

1.   Average annual increments from the IPCC 2006 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 t d.m./ha annually (for coniferous), 4 t d.m./ha (for deciduous), and 0.5 t d.m./ha (for maquies and shrub)
4.   Mean values of the average Root to Shoot ratio from IPCC 2006 Guidelines were used (0.4 (for coniferous in age class ≤ 20 years), 0.29 (for coniferous in age class ≥ 20 years), 0.46 (for deciduous)). Regarding the maquies and shrub forests the expert judgement was applied using the value 0.46.
5.   Applied Carbon fraction values were the same one 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. This constant value was used for all afforested coniferous areas of the first age class and multiplied by the total AR area of the first age class. The estimates for the second age class (AR areas that have been changed into the second age class since 1990) were calculated by multiplying the average biomass stock of the second age class by the area of the second age class. The same procedure was used when calculating gains for deciduous and maquies and shrub forests. Values of 2.8 tC/ha and 0.34 tC/ha as average biomass growth for deciduous and maquies and shrub forests were used accordingly.

Moreover, average annual increment in biomass calculation was separately done for above-ground biomass (AGB) and below-ground (BGB) biomass as presented in Table 11.3-1.

Table 11.3-1: Annual increment in biomass (tC/ha)

Forest type	Age class	Annual increment in biomass (TOTAL)	Annual increment in biomass (AGB)	Annual increment in biomass (BGB)
Coniferous	<20	2.14	1.53	0.61
	>20	1.97	1.53	0.44
Other Broadleaves	<20	2.80	1.92	0.88
	>20	2.80	1.92	0.88
Out of yield (maquies and shrub)	NS	0.34	1.15	0.11

The value of 107 m³/ha were used for deciduous and coniferous forests for determining biomass growth per each forest type and lowest value from the range defined in IPCC 2006 Guidelines was used for maquies and shrub forests. In order to determine which R factor from the IPCC 2006 GL Table 4.4 to use, information on growing stock was needed. According to the recent national data the growing stock in the forests of second-class age is 107 m³/ha. This value was used as an input data for the estimation of above-ground biomass and the corresponding R factor.

To determine above-ground biomass growth in maquies and shrub forests, the lowest value defined in 2006 GL (Table 4.9) for Temperate continental forests (0.5 tonnes d.m./ha*y) was used.

In order to calculate the biomass carbon stock losses as a result of grassland and cropland conversions 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. Default value of 63.0 tC/ha (IPCC 2006 Guidelines) annually was used for estimating carbon stock losses due to conversion of perennial Cropland to forestland.

As regarding D areas, the losses in living tree biomass per ha are calculated in the year of D using national information such as average harvested volume in period 1990-2020 by forest type and wood densities and also IPCC values (2006 IPCC Guidelines) as presented in Table 11.3-2.

Table 11.3-2: Parameters used for the carbon losses estimation on deforested areas

Forest type	Average harvested volume (m³/ha)	Wood density (t.d.m./m³)	BEF 2	R/S	CF (tC/t d.m)⁻¹
Deciduous	144.41	0.56	1.197	0.23	0.48
Coniferous	108.95	0.39	1.039	0.29	0.51
Out of yield (maqies and shrub)	13.66	0.68	1.15	0.46	0.47

Regarding the maquies and shrub forests, conservative approach was applied when using value of 1.15 as a lowest value from a range defined for Temperate coniferous species in IPCC. Also, in case of R/S factor Croatia used value of 0.46 from the range defined in 2006 Guidelines for Other broadleaf forests with aboveground biomass less than 75 tonnes/ha (0.12-0.93) because it is considered that R/S factor in maquies and shrub forests is much higher since these forests come in Mediterranean parts of Croatia with dry climate and in order to survive they have to struggle for water and because of it is known by studies that they have very large roots. Based on the national data on stocks in deciduous and coniferous forests and ranges defined in 2006 Guidelines (Table 4.4), R factor of 0.23 and 0.29 were used accordingly.

2006 IPCC Guidelines' default values for BEF2 and R/S factor for deciduous and coniferous forests are used for estimation of aboveground biomass (t/ha) which is calculated using national level derived values for average growing stocks and wood densities of each forest type. Considering that 2006 Guidelines does not provided figures for BEF 2, Croatia used BEF 2 as it was prescribed in GPG 2003. 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. Amount of total volumes harvested in these forest types were corrected with corresponding percentages. BEF 2 values from GPG 2003, Table 3A 1.10 was corrected with % of wood that remains in forests after harvesting operations. For the estimation purposes R/S factors were obtained from IPCC 2006 GL Table 4.4.

In period 2008-2020 harvesting rates were as presented in below Table 11.3-3.

Table 11.3-3: Volume harvested on deforested areas according to the forest types (m^3/ha)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Deciduous	114.45	42.38	180.28	182.80	180.74	181.37	242.24	914.27	200.86	58.95	19.50	78.23	284.42
Coniferous	287.48	287.48	287.48	287.48	287.48	287.48	287.48	287.48	287.48	287.48	287.48	287.48	371.10
Out of yield (maquies and shrub)	16.34	13.05	14.68	14.53	4.1	6.93	14.3	3.6	0.00	0.00	4.00	6.37	105.83

Values of carbon stock in total biomass (AGB+BGB) are determined based on nationally determined average values for deforested volume in period 1990-2020 by each forest type as follows:

1. 56.93 tC/ha for deciduous forests
2. 29.63 tC/ha for coniferous forests
3. 7.36 tC/ha for Out of yield forests (maquies and shrub)

Approach 3 was applied when identifying all deforested forest areas in Croatia in period 1990-2014. Results from the analyses conducted through the project LULUCF 1 suggest that deforestation happens in Mediterranean (on 50.3% of all deforested areas with the 26.6 m^3/ha average volume deforested) and continental part of Croatia (on 49.7% of all deforested areas with the 180.1 m^3/ha average volume deforested). Most of harvested coniferous species are in the class of younger coniferous forests (more than 55% of volume deforested refers to young Aleppo pine forests) leading to the conclusion that carbon stock in coniferous forest is relatively small.

This is in line with stipulation of Forest Law (Article 57) which determines conversion of forest land to cropland category of land can be performed primarily on: 1) land under the forests management (land without tree cover) 2) forest land with woody (shrub) vegetation and 3) young forests.

When calculating gains due to biomass growth on deforested area, below presented values were used:

1. 0.19 tC/ha - for annual plants in area of Settlement (nationally determined)
2. 0.0256 tC/ha – for perennial plants in area of Settlement (nationally determined)
3. 2.10t C/ha – for perennial Cropland (IPCC 2006 Guidelines)

Description of the underlying methods and assumptions can be found in related part of the report (Chapters 6.8.2.1.1 and 6.5.2.2.1).

B) Dead wood (DW)

Data on dead wood at **AR lands** were obtained after analyses of measured data from samples taken during regular forest measurements (stand-level forest inventory). These measurements were used for preparation of forest management plans and programs, one for each FMU. The work was performed according to the guidelines from the Ordinance of forest management (OG 79/2015), and a dead wood stock was determined in plans and programs with an initial validity year of 2017. Good practice that has been implemented in forestry field in Croatia is that each year 10% of forestry plans/programs are renewed. With the renewal of plans/programs on annual basis, 10% of the total forest area in Croatia is covered.

When calculating gains due to accumulation of dead wood at afforested areas following values for DW carbon stock were used:

- Deciduous forests - 1.05 tC/ha
- Coniferous forests - 0.01 tC/ha
- Maquies and shrub - 0.09 tC/ha

The above listed figures are determined using the national data on DW stock in afforested areas for each type of forests (Deciduous, Coniferous and Maquies and Shrub) for lying and standing DW stock. In order to determine tC/m^3 the lying DW stock data are multiplied with the wood densities for each type of the forests as defined in LULUCF Chapter of this report and using 0.5 as a value for CF factor for DW. Standing DW stock data are multiplied with the wood densities, R/S and BEF 2 for each type of the forests as defined in LULUCF Chapter of this report and using 0.5 as a value for CF factor for DW. Finally, determined tC/m3 for each type of forests were multiplied with the corresponding determined laying and standing DW stock per ha and summed up.

In order to estimate carbon stock changes on **D areas** a specially designed project was executed. Basic information of the tasks of this project are presented in Annex 3.2. and project's results are published in a separate document[80]. Within the scope of this project CRONFI data were thoroughly analysed, aggregated according to the forest stratification used for the UNFCCC and KP reporting, determined and used in this report. For D lands, these data refer to both, lying and standing dead wood stock.

For determining the DW carbon stock of each forest type, the same approach as described for defining DW carbon stock on afforested areas were used. The following values of DW carbon stocks are:

- Deciduous forests - 4.43 tC/ha
- Coniferous forests - 3.40 tC/ha
- Maquies and shrub - 0.46 tC/ha

Equation 2.23 from the 2006 GL has been applied in order to estimate carbon stock change in DW pool.

C) Litter

For the estimation of CSC in litter pool data used from the scientific investigation on determining carbon stock in litter pool are used (Chapter 6.8.2.1).

Annual carbon stock changes in litter at ARD areas are calculated using the Equation 2.23 form the 2006 GL as follows:

$$\Delta C_{LT} = A* (C_{LTo} - C_{LTo-t})/T$$

ΔC_{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_{LTo} = carbon stock in litter after conversion, (4.57 t C/ha in case of A areas and 0.00 in case of D areas))

C_{LTo-t} = carbon stock in litter before conversion, (0.0 t C/ha in case of A areas and 4.57 tC/ha in case of D areas)

T = transition period for the litter carbon stock changes (1 year for D areas, 20 years for AR areas)

D) Soil

The estimates of the soil carbon stock changes at ARD areas follow the Equation 2.25 from the 2006 GL as presented below:

---

[80] Document „Primjena više razine proračuna (Tier 2) IPCC metodologije u izračunu promjene zalihe ugljika u spremištu mrtvog drva na iskrčenim površinama u Republici Hrvatskoj"

$$\Delta C_{LFMineral} = [\,(SOC_{ref} - SOC_{before\ ARD}) \times A_{ARD}]/T_{ARD}$$

where:

$\Delta C_{LFMineral}$ = annual change in carbon stock in mineral soils for inventory year

SOC_{ref} = reference carbon stock

$SOC_{before\ ARD}$ = stable soil organic carbon on previous land use

T_{ARD} = duration of the transition from SOC before ARD to SOC_{ref} (20 years)

A_{ARD} = total AR or D area after conversion still in SOC transition of 20 years

The values of soil carbon stock determined through the national scientific investigation performed in 2017 were used in order to estimate the carbon stock changes in soil due to afforestation activity. The investigation was done taking the samples on 30 cm depth and excluding the litter pool from the sample.

Conversion that happens in the Croatian case refers to grassland and perennial cropland converted to forestland with following soil C stocks:

- Grassland: 75.7 tC/ha
- Forestland: 69.9 tC/ha
- Annual Cropland: 52.7 tC/ha
- perennial Cropland: 71.0 tC/ha

Soil removal/emission factors determined in this case were 0.85 tC/ha, -0.057 tC/ha and -0.29 tC/ha annually.

The values of soil carbon stock determined through the above mentioned national scientific investigation were used in order to estimate the carbon stock changes in soil due to conversion Forest land to perennial Cropland. Soil C stocks are:

- Forestland: 69.9 tC/ha
- Perennial Cropland: 71.0 tC/ha

Soil emission factor determined in this case is 0.006 tC/ha annually.

For determination of soil carbon stock changes due to deforestation activity to settlement, the used values for soil carbon stocks are presented below, and emission factor was calculated to be 2.6 tC/ha annually:

- Settlements: 17,8 tC/ha
- Forestland: 69.9 tC/ha

Detailed description of the methodologies and the underlying assumptions used are presented in Chapters 6.5.2.2.1 and 6.8.2.1.1 and Chapter 6.4.2. Methodological issues.

2) FM activities

Emissions and removals from FM activity were calculated based on the related 2006 IPCC Guidelines equations. In order to estimate biomass carbon losses in Out of yield (Maquis and Shrub) forests only data on volume lost due to the forest fires in these forests has been used. National legislative framework in forests filed stipulates monitoring of forest health conditions. Based on the available data from this monitoring, there has not been a significant pest attack in these forests during the reporting period as

well as significant damage from wildlife or other kind of natural disturbance than forest fires. Thus, biomass carbon losses in this forest type occur only due to the volume lost during the forest fires.

The entire description of the methodological approach is presented in Chapter 6.4.2.

The estimates under the forest management for the KP reporting refer to high forests, cultures, plantations, coppice, maquies and shrub forests.

Based on the ERT recommendations given in 2012 during the In country review, CO_2 emissions/removals in period 2008 – 2020 were estimated using the per ha values for increment and harvest for all types of forest and presented for whole forests types in Croatia regardless the ownerships type.

11.3.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

Omitting GHG emissions/removals

Table 5(KP-I) A.1.2 Article 3.3 activities: Afforestation and Reforestation. Units of land harvested since the beginning of the commitment period

With respect to ensure determination of harvesting or future deforestation on afforested land, country wide forest management plans secure that all forest management activities are transparent and prescribed. Each of these plans define all measures and activities for the period of its validity (10 years), and they also give a description of the measures that are required in the following 10 years period. Based on the legislation[81] execution of each activity prescribed under forest management plans must be recorded on yearly basis (which refers also to afforested areas) and at the end of forest management plan officially registered by the Ministry of Agriculture. Following national forest legislation[82], only pre-commercial thinning is defined as possible harvesting operation in forests of the first age class. In case of the second age class forests through the performed harvesting operations only the wood useable for firewood has been produced. These legislative acts and forest management practices related to first and second age classes forests on afforested areas, allows Croatia to report units of land harvested since the beginning of the commitment period if this occurred. Croatia uses notation key NO in CRF tables since no wood products has been produced through harvesting operations on afforested area so far.

Table 5(KP-I) A.2.1 Article 3.3 activities: Deforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)

Only forest management has been elected under Article 3.4. As Deforestation is a permanent loss of forest cover, any unit of land that has been deforested under Article 3.3 cannot also be subject to the forest management under Article 3.4.

Table 5(KP-II)1. Direct N_2O emissions from N fertilization

N fertilization of forests is not performed in Croatia, so emissions are reported as not occurring.

Table 5(KP-II)2. N_2O emissions from drainage of soils

Drainage of soils does not occur in Croatia.

Table 5(KP-II)3. N_2O emissions from disturbance associated with land use conversion to cropland.

The annual release of N_2O due to the conversion of forestland to cropland was calculated using the default value (Tier 1) and equations 11.1 and 11.2 from 2006 IPCC Guidelines:

---

[81] Ordinance on Forest management (OG 97/18)
[82] Forest Law (OG 68/18, 115/18)

$$N_2O_{net-min} - N = EF_1 \times \Delta C_{LCmineral} \times 1/(C/N \text{ ratio})$$

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)

Table 5(KP-II)4. Carbon emissions from lime application

No lime is applied to forests and perennial cropland from D activities, so emissions are reported as NO.

Controlled biomass burning

Controlled biomass burning does not occur in Croatia. All fires can be addressed as wildfires.

Omitting carbon pools

Croatia performs estimation in the aboveground and belowground biomass, dead wood, litter and soil pools for Article 3.3. The estimation of CSC in Harvested Wood Products pool in case of deforested areas are estimated using the instantaneous oxidation method and these HWPs are exempt from the CSC reported in CRF Table 4(KP-I)C.

The estimation in the HWP pool (using the First Order Decay function), aboveground and belowground biomass pools are performed for Article 3.4. As for other carbon pools in FM activity, based on the forest management practices and the legal framework within which the latter is performed, it is concluded that remaining pools are not emission sources. The background information on these issues are as follows:

ARD areas

Starting from 2019 year's submission all carbon pools regarding afforestation and deforestation activities have been reported. In case of HWP pool on afforested areas Croatia uses notation key NO while the harvested wood products still do not occur. The reasons for this are as follows:

- Afforestation works in Croatia are performed in karst region. The main reason for the afforestation is soil protection to prevent further soil and land degradation in this region and not economic benefit. Due to the climatic characteristics of this region, forest species that have pioneer characteristics are used for afforestation purposes (i.e. species that tolerate drought well, do not require deep soil and are fast growing). This is a reason that coniferous species (i.e. black pine, Aleppo pine) are mostly used for this activity.
- Thinning and cleaning works are performed in small share of areas afforested with pioneer deciduous forests. The main reason for using deciduous species for afforestation on karst region refers also to the prevention of soil and land degradation and it is not connected with economic benefit. Harvesting operations performed in second age class forests on afforested areas resulted either with the wood suitable only for energy purposes (in case of thinning in deciduous forests) or with the wood left on the forest side due to no economic value (in case of thinning in coniferous forests) and not for wood that can be used and reported under one of the HWP type categories.

FM areas

a) Omitted pools of dead wood, litter and soil in subcategory Out of yield forests (Maquies and shrub forests)

According to the national definition[83,] maquies and shrub forests are forests where besides the trees, bushes are presented in the same crown layer.

This type of forest in Croatia includes typical Sub-Mediterranean and Eu-mediterranean species such as Holly oak and Pubescent oak (and naturally associated species) as well as pines (i.e., Aleppo pine) that appear in the smaller areas or as a number of trees created through afforestation or natural means (fires) that due to its dispersion cannot be classified as coniferous culture.

According to the forest law and prescribed management plans, these forests are primarily left to the natural development supported through the specific management measures such as: fire protection measures, afforestation (using primarily pioneer tree species) and sporadic activities with the purpose of converting these forests to the form of high forests (i.e. according to the FMAP 2016-2025 conversion to high form of forests and reconstruction of maquies and shrub forests is prescribed to be executed on more than 20 000 ha in 10 year period). The main role of these forests is protection, so this is the reason that, according to the national legislation, there is no biomass harvest in maquis and shrub forests, but sporadic measures of planting to convert such forests into higher form of forests.

As one of the measures for preservation of maquies and shrub forests, ban of goat keeping in these forests was introduced by Croatian law on forest during 1950. This measure supported spreading of pioneer tree species, their role in maquies and shrub forests and helped return of native vegetation.

Additionally, given species of small dbh prevail in these forests, their exploitation for firewood consumption would require more time and resources than the exploitation of wood in the high forests, that make them unattractive for firewood extraction. At the same time, vicinity of Lika region with high quality forest species of firewood, contributes to the preservation of maquies and shrub forests.

According to the measures in energy sector adopted by the Croatian Government and Parliament[84] (i.e. completion of gas pipelines for Dalmatia (Mediterranean region) and supporting measures to the production of electricity that originates form wind farms and solar panels both of which are most suitable for this region), and increase of prices of wood for heating, lower consumption of wood for heating is expected in Mediterranean part of Croatia and in the future there will be no demand for consumption of wood that originates from maquies and shrub forests. Additionally, it is not expected that legal framework by which maquies and shrub forests are defined and managed as protective forests with no harvest, will be changed in the future.

Harvest operations have not been carried out in these forest as these operations have not been predicted by legislative framework (main role of these forests is protective). Sporadic planting measure and the pressure from animals decreased due to the depopulation of rural areas.

Croatia believes that presented arguments prove that these changes in maquies and shrub forests consequently are connected to the increase in the input of dead wood from natural mortality due to the increase in biomass. Additionally, Croatia believes that dead wood stock can only increase with time as a result of forest fires and the fact that these forests grow mainly in Mediterranean part of Croatia which is due to climate conditions frequently disturbed by forest fires. Although these forests have very good

---

[83] Ordinance on Forest management (OG 97/18), Article 13

[84] Energy Development Strategy of the Republic of Croatia (OG 130/2009); Law on Energy (OG 120/12); Tariff system for the production of electricity from renewable energy sources and cogeneration (OG 33/07); Amendments to the plan of development, construction and modernization of gas transportation system in the Republic of Croatia from 2002 to 2011 - The second investment cycle 2007 – 2011

ability to regenerate themselves after the fires, in cases of long-lasting fires when biomass is lost, all biomass burnt has to be cut when preparing forest area for restoration. In these cases, all biomass is left on the side to decay.

According to the Forest Law[85] removal of peat, litter and humus is strictly prohibited and their use, in exceptional situations, is regulated by Article 38. For the same arguments as provided for dead wood (steady increase in biomass in these forests due to the lack of harvest and planting measures and less pressure from agricultural animals), litterfall and consequently the litter pool and the soil pool under the maquies and shrub forests are not a source of emissions, but a C sink.

  b)   Omitted pools in subcategories Deciduous and Coniferous Forest

b.1) Dead wood, litter and soil pools

According to the Croatian report for FAO Forest Resources Assessment 2005 (FRA 2005)[86] carbon stock in dead wood pool for forest land has increased in Croatia within the period 1990-2005:

Table 11.3-4: Deadwood in forest land

FRA 2005	1990	2000	2005
Dead wood / Mt C	20.8	26	27

The latter clearly indicates that this pool is not an emission source.

Data on wood removal from FRA reports (for 1990 FRA 2005 and for 2000 and 2005 FRA 2010) were compared to NIR data on fellings. The comparison indicated that not all wood was removed from the forest and that certain percentage (about 10-15%) was left in the forest; thus, contributing to a C input in other carbon pools. Reporting on wood removals under the FRA fits adequately to the wood removals practices conducted in Croatia that is performed in a way that harvest residues and wood less than 7 cm in diameter are left in the forest. Within the KP Forest management reporting, total gross fellings (i.e. including branches and bark) are reported. Considering latter, there are no underestimations in regard to dead wood.

Furthermore, based on the available data on growing stocks and harvest which prove steadily increase in the standing stocks in Croatia (Table 11.3-5) while the forest management methods remain the same. Under such circumstances and because mortality is correlated with stand density, also an increase in dead wood stocks is very likely, as indicated by the FRA results.

Table 11.3-5: Growing stock, harvest, increment and forest areas in Croatia

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Growing stock (m³/ha)													
Deciduous	218.5	219.5	220.6	221.7	222.8	223.9	225.0	226.1	227.2	229.0	230.3	231.4	232.9
Coniferous	236.6	238.1	239.7	241.2	242.8	244.3	245.9	247.4	249.0	247.5	247.4	249.3	246.4

[85] Ibid
[86] FAO, Forest Resources Assessment Croatia 2005 (FRA 2005)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Out of yield forests	50.0*	50	50	50	50	50	50	50	50	50	50	50	50
Harvest (m^3/ha)													
Deciduous	2.862	2.707	2.790	3.147	3.201	3.132	3.204	3.363	3.429	3.506	3.525	3.502	3.418
Coniferous	3.674	3.475	3.283	3.810	3.827	4.286	4.673	4.510	4.674	5.006	5.890	5.461	4.817
Out of yield forests	0.003	0.002	0.001	0.007	0.013	0.0007	0.0001	0.0044	0.0045	0.03	0.0002	0.0006	0.0139
Increment (m^3/ha)													
Deciduous	5.796	5.772	5.747	5.723	5.699	5.675	5.650	5.626	5.602	5.636	5.680	5.716	5.780
Coniferous	5.250	5.258	5.266	5.275	5.283	5.291	5.300	5.308	5.316	5.335	5.283	5.340	5.273
Out of yield forests	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
FM area (kha)													
Deciduous	1,609.04	1,608.95	1,608.88	1,608.86	1,608.81	1,608.73	1,608.71	1,608.5854	1,608.5637	1,608.5572	1,608.5507	1,608.5206	1,608.5005
Coniferous	214.23	214.21	214.16	214.14	214.04	214.04	214.04	214.0321	214.0201	214.0187	214.0187	214.0186	214.0181
Out of yield forests	500.10	499.60	499.38	499.22	499.12	499.04	499.01	498.9083	498.9078	498.9078	498.9058	498.9022	498.9019

* According to the expert judgement growing stock ranges between 20 to 50 m^3/ha in these forests

Also, it should be mentioned that the forest management practices in Croatia are governed by the strict legal framework which prohibits, for example, to cut the branches or their parts (unless it is provided by the forest management plans), to collect and remove leaf litter, moss etc. (Forest Act, Article 32).

As a consequence of War, areas polluted with mines are still present in Croatia.

Although continued work has been conducted for de-mining purposes, according to the data available at Croatian Mine Action Centre (CMAC) there are still more than 201 km^2 of areas polluted with mines[87]. By 2018, Croatia reduced the hazardous area (HA, areas polluted with mines and mine suspected areas) to 411.5 km² through demining and the application of improved survey methods.

From the remaining HA, forest areas with 369 km^2 or 89% of the total HA have the largest portion in HA of the Republic of Croatia (while in 2017 forest areas made 95.3% of HA).

In March 2018 Croatia submitted to the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction second request and received the extension for the clearance task. In its request, Croatia emphasized it is capable of clearing 56 km^2 per year of HA with the currently available capacities.

Due to safety reasons, regular forest management activities have not been conducted on forest areas 2.5 times bigger than area officially proclaimed as mine polluted and they include forest area suspected to be mine-polluted. In these forest areas no forest work has been performed if they are polluted or

[87] Croatian Mine Action Centre

suspicious to be mine-polluted. De-mined forest areas are subject to official procedure prescribed by Forest Act[88] requiring a special audit to be performed and new Forest management plan for the corresponding forest unit developed. By this plan all activities that need to be conducted in ten-year period are prescribed. However, due to safety reasons activities defined by the plan on de-mined areas are usually executed slower than activities in forest areas that are not mine polluted and are connected also with the labour shortages that emerged due to depopulation in War affected areas. Delays in plans' execution additionally contributes to the deterioration of growing stocks in forests contributing to the dead wood stock increase. After the mine-polluted area becomes susceptible to complete, normal forest management practices again, a significant decline in quality in wood assortments is observed (Figure 11.3.-1) leading to the increase of DW stock in Croatia.

Figure 11.3.-1: Quality of the wood assortments derived after demining

Forest areas polluted with mines are determined by official maps available at the CMAC, overlapping them with official forest maps present at Croatian forest Ltd.

Due to above presented facts, Croatia believes dead wood stock increases and consequently carbon stock in this pool is increasing. The reason is the prevention of dead wood removal from forests and the implementation of required thinning operations on the areas polluted with mines or that are de-mined.

Before it was approved, General Forest management plan for the Republic of Croatia in period 2016-2025 (FMAP 2016-2025) was subject of official approval of other relevant institutions in Croatia. Requirements of the Ministry of Economy and Sustainable Development to ensure that a constant number (3-5 trees/ha) of old and dry, standing and fallen trees, especially trees with hollows are left on logging sites, are incorporated into the FMAP.

Additionally, according to the Article 26 of Forest Act, all forest management plans that need to be developed for forest incorporated in one of areas protected under the Law of Nature Protection (i.e., national park), must be approved by the Ministry of Economy and Sustainable Development and in order to be in line with the requirements of nature protection. Securing biodiversity through leaving certain number of dead trees on logging sites is one of constant requirement requested by the Ministry of Economy and Sustainable Development.

---

[88] OG (68/18, OG 15/18)

Since Forest Act was published in 2005 according to the Article 8, Croatian Forests Ltd. and private forest owners are obliged to manage forests by maintaining and enhancing biological and landscape diversity and promote the protection of forest ecosystems in a way that due attention must be given to other species in the ecosystem that are associated with dry and dead trees through leaving the required number of old dead wood, hollow and decayed trees, in spatial distribution and number which preserves biodiversity.

Since 2002 Croatian Forests Ltd disposes with FSC (Forest Stewardship Council) certificate for forest management which proves that forests are managed according to strict environmental, social and economic standards. Since the first certificate was gained, certificate has been renewed on regular basis every 5 years. According to the available information, FSC certificate refers to more than 2.0 million ha of Croatian forests and land under the forest management[89].

In order to secure compliance with FSC requirements and national legislation, 3-5 dead wood/ha have to be left on the logging sites since year 2002.

The area and number of protected areas in Croatia increased during the years. According to the Protected Areas Register of the Ministry of Environmental and Nature Protection, 1.7% of Croatian terrestrial area is protected in categories of strict reserve and national park[90]. In these protected categories forests make significant part. Due to the fact any economic activity and commercial use of natural resources are prohibited in these protected areas[91], it can be assumed that dead wood stock increases in forests within these protected categories. Consequently, carbon stock in dead wood pool also increases.

According to the nature protection legislation and new amendments on ordinance on conservation of targeted bird species in ecological network established in Croatia[92], it is obligatory: „*To preserve a favourable share of stands older than 80 years in oak forests; forest areas managed as un-even or even-aged forests older than 80 years (oak) must contain at least 10m³ / ha of dry wood, and during the process of tree selection for cutting it is obligatory to leave trees containing hollows for birds nesting; to leave in the forest as many fruit trees as possible for woodpeckers nesting*.“ An ordinance defining objectives and measures for the conservation of other species and habitat types for each ecological network area is expected to be developed in the near future[93]. Since the significant area of forests in Croatia falls under the ecological network it is expected that implementation of ordinances above will contribute to the increase of dead wood in forests in Croatia. Consequently, higher dead wood stock leads to the higher inputs to the litter and soil pools. Thus, it is expected that carbon stocks in dead wood, litter and soil pools will be increasing with the time.

Additional support for Croatia's claim that the deadwood pool is not a source of emissions is provided by reports from neighbouring countries (Slovenia, Hungary) and countries with partially similar environmental conditions (Greece)[94]. These states have claimed the dead wood pool is not a source of emissions in their countries in their previous reports (i.e. NIR 2013) and have proven this in later reports (NIR 2020) through the estimation of CSC in this pool by using accurate data when these data became available.

Following the ERT request during the NIR 2020 review process, below (Figures 11.3-2. – 11.3-8.) we provide information on present and future age-class distribution of major forest species in order to

---

[89] Croatian Forests Ltd: www.hrsume.hr
[90] Ministry of environment and enrgy, www.mzoe.hr
[91] Law on Nature Protection (OG 80/13), Articles 112 and 113
[92] Ordinance on objectives of conservation and measures of conservation of target bird species in the fields of the Ecological network (OG 38/2020)
[93] Ministry of economy and sustainable development, http://www.haop.hr/hr/tematska-podrucja/odrzivo-koristenje-prirodnih-dobara-i-ekoloska-mreza/ekoloska-mreza/upravljanje
[94] UNFCCC, National Inventory Submissions 2013

additionally support claims that **DW, litter** and **soil pools** in Croatia are not source of emissions (Tier 1 application).

The age class distributions are taken out from the National Forestry Accounting Plan for the Republic of Croatia (NFAP)[95] which is developed and submitted to the European Commission as a part of Croatian obligations defined under the *Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU.* Data available in General FMAP 2016-2025 on share of tree species in total growing stock in Croatia (Table 11.3-6) were used for delivering NFAP and defining present and future age-class distribution of main forest species.

Table 11.3-6: Main tree species in Croatia and its share in total growing stock

Tree species	Share in total growing stock (%)
1. Common (pedunculate) and holm oak	12.74
2. sessile oak and pubescent oak	11.06
3. common beech and mountain maple	41.26
4. turkey oak, narrow-leafed ash and common ash	5.43
5. common hornbeam and black alder	10.91
6. black hornbeam, white hornbeam and wild cherry	0.66
7. linden	0.83
8. chestnut and birch	1.01
9. domestic poplars and willows	1.91
10. fir	8.54
11. spruce, black and Scots pine, pine	4.59
12. Aleppo and coastal pine	1.07

In order to secure that the forests will be managed on sustainable way in future, EU Member States had to develop projections of the harvest in period 2021-2025 keeping the same management practices as were implemented in period 2000-2009. Article 8 of the Regulation 2018/841 (EU) was allowing Croatia to take into consideration an influence of the War and post-War period on forest management when developing NFAP. Chapter 2 of the NFAP (pages 20-29) informs that War and consequences of the War: "*Are the reason for the lack of implementation of full management practices which can be seen in the interruption in pre-commercial tinning, thinning and harvesting operations on time and on full scale, decreasing of increment, deteriorating of age structure of the stands and declining of quality in wood products*".

Besides the provided information on present and future age-class distributions of main forest species, below listed facts need to be taken into consideration for proving the above-mentioned statement regarding the DW, litter and soil pools:

---

[95] https://mingor.gov.hr/UserDocsImages//KLIMA/SZKAIZOS//december_nfap_2019.pdf

- There has not been change in forest management practices in Croatia
- According to the Ordinance on forest management, Article 27, Point 1 (OG 97/2018) the rotation period of the main forest species must be defined based on the forest management goal and it has been defined as follows:

  1. Common (pedunculate) and holm oak - 140 years

  2. Sessile oak and pubescent oak - 120 years

  3. Common beech and mountain maple - 100 years

  4. Turkey oak, narrow-leafed ash and common ash - 80 years

  5. Common hornbeam and black alder - 70 years

  6. Black hornbeam, white hornbeam and wild cherry - 60 years

  7. Linden - 50 years

  8. Chestnut and birch - 40 years

  9. Domestic poplars and willows - 40 years

  10. Fir - 100 years

  11. Spruce, black and Scots pine, pine - 80 years

  12. Aleppo and coastal pine - 60 years.

- The same Article stipulates rotation period in case of species that are managed in ways other than even-aged forests as presented below:

  (4) The rotation period in coppice-forests that are naturally converted to high forests shall be reduced by 30% of the rotation period referred to in paragraph 1 of this Article.

  (5) Diameters of maturity in uneven-aged forests shall be determined based on forest purpose, production capacity and management objectives for individual main tree species.

  (6) The maturity of uneven-aged forests shall be determined based on the rotation period of the main tree species referred to in paragraph 1 of this Article, and the area prescribed for renewal must ensure gradual renewal of the sub-compartment.

  (7) The maturity of an individual group in uneven-aged forests corresponds to the age of rotation of the main tree species referred to in paragraph 1 of this Article, considering the purpose of the forest, stand form and management goal.

  (8) The rotation period of forest plantations and forest cultures shall be determined by the study of its establishment or the management goal.

- According to the available scientific paper[96] carbon stock in litter pool in pedunculate oak forests increases with the forest age and reaches its maximum (10.34 tC/ha) in age of 137 years.

In order to keep continuation of sustainable forest management practices as required for NFAP, Croatia had to increase harvest in period 2021-2025 due to the War influence as presented in Table 11.3-7. The increase in harvests for 18% in period 2021-2025 comparing to the realized harvest in period 2008-2020 should also secure that the adequate age class distribution in forests in Croatia destroyed due to the War and post-War circumstances are put in place again. NFAP also informs that during the period 2000-2009 the harvest was from 8% to 22% higher in forests not (fully) influenced by the War and post-War circumstances comparing to the forest areas affected by the War. At the same time decrease of increment for 4% has been recorded on the level of whole Croatia when comparing the General FMAP 2006-2015

---

[96] Ostrogović, M. Z. (2013) *Carbon stocks and carbon balance in even-aged forest of penduculate oak (Quercus robur L.) forest in river Kupa basin*, table 3.8, page 58

and General FMAP 2016-2025 (from 10.53 Mm^3/year to 10.15 Mm^3/year). In addition, an increase of increment in forest areas not (fully) influenced by the War comparing two General FMAPs has been recorded which means that the decrease in increment in War and post-War affected forest areas is much higher than 4%.

Table 11.3-7: Future harvest in Croatia

Year	2021	2022	2023	2024	2025
Harvest (million m^3)	7.31	7.34	7.56	7.48	8.00

Decrees in increment in War and post-War affected forest areas of Croatia and need to increase harvest from year to year in period 2021-2025 in order to secure adequate age class distribution in forests together with the prescribed management practices (i.e. wood less than 7 cm on diameter and stumps are left in the forests) lead to the increase in dead wood stock in Croatia.

From the Figures 11.3-2. – 11.3-8., presented in this document and the information provided on rotation period and cutting maturity of forest species in Croatia it can be seen that main species (strata in case of coniferous forests) occupy the largest areas when they are in their last or penultimate age class. Since no new forest management practices are predicted until 2055 the wood less than 7 cm on diameter will be left on the side after harvesting operations in future too. This secures carbon inflow to DW pool from these age-class forests at least as present now. In addition, the figures show that the presence of young forest trees in first and second age classes has been secured until 2055. The presence of young trees implies competition for survival and the continuous extinction of repressed trees and the inflow of carbon into the dead wood pool, at least as is it the case now.

According to the available scientific paper[97], the assessments show that biomass stocks in the Croatian Forests increased steadily in the last decades. It is evident that litterfall is higher in forests with higher biomass. In parallel, increased harvest in the last decades in the Croatian forest was associated with a higher flux of dead biomass from harvest residues (e.g. branches, stem wood parts, stumps, roots) to the soil. Also, this trend relates to an increase in litterfall to soil.

Additionally, following the above-mentioned legal framework that prohibits the removal of peat, litter and humus from the forest and herein reported data that clearly indicate increase of biomass stock and increment and harvest, it can be concluded that a decrease in the carbon stocks of the litter pool is very unlikely. In addition to this, based on the Forest act, exceptionally and under strict conditions, the use of humus can be allowed but only if it is in accordance with the forest management plans and special legal regulations. Taking the latter into account and evidence for a rise in the C input into litter/soil due to the increase in biomass standing stock and in harvest causing an increase in the input of harvest residues, it can be concluded that the litter pool of the Croatian forests is not an emission source.

Within the reporting period, there was no change in the forest management in all forest's types in Croatia. The scientific paper published in 2019 regarding the evaluation of carbon stocks, fluxes, and carbon balance in pedunculate oak forests[98] concludes:

„Under current close-to-nature forest management, Pedunculate oak forest showed to be sustainable in providing both economic and ecological ecosystem services. While assuming successful regeneration, this forest ecosystem becomes C sink very early in a development phase, between the age of 13 and 35,

---

[97] Biomass
[98] Maša Z. O. Sever , Alberti, G., Gemini, D.V., Marjanovic, H. (2019) "Temporal Evolution of Carbon Stocks, Fluxes and Carbon Balance in Pedunculate Oak Chronosequence under Close-To-Nature Forest Management", page 19

according to the pool-change and component-flux approach, respectively. For 140 years, this forest provides 604 m3 ha−1 (i.e., 187.2 Mg C ha−1) through thinning and 477 m3 ha−1 (i.e., 147.9 Mg C ha−1) in the final cut, while preserving, on average, 88.9 Mg C ha−1 in the mineral soil down to 40 cm, 18.2 Mg C ha−1 in dead wood, and 6.0 Mg C ha−1 in the forest floor. Finally, soil C stocks in our chrono sequence did not show any age-related trend, which indicated that current management practice has no negative effect on soil carbon stocks".

In a work conducted in 2017 regarding the trends in SOC stock change the analyses was performed in order to check whether there is change in carbon stock in soils in Croatia or not. Two different approaches are used for analyses in two set of soil data, from the investigation conducted in soils in Croatia in 2012 and 2016. The results gained through the first applied approach in analyses showed there is no significant change in carbon stock in soils in Croatia. The obtained result through applying the second approach in analyses suggests there is a statistically significant trend of change in carbon stocks in the sampled soils of the Republic of Croatia for the period between the two measurements. The result indicates that there is a statistically significant trend of increasing stocks in the sampled soils and that the forest land, whit the average trend of increasing soil carbon stocks of 2.6 tC ha-1 yr-1, is responsible for this increase. The results of the conducted analyse are presented in and corresponding document[99].

At this moment in Croatia there is no other expert and scientific literature or investigation the hypothesis soil pool under the Forest management is not a source of emissions.

However, based on the data and information provided above that prove carbon stock increases in biomass, dead wood and litter pool, an increase in these pools is correlated with an increase of the C input to the mineral soil and consequently with an increase of carbon stock in soil. Consequently, it can be also assumed this pool is not a source of emission.

In addition, since there is no change in forest management practices in Croatia during the reporting period, and soil carbon stock depends on the input from the dead wood and litter pools which carbon stocks will be increasing with the time. Croatia believes that above presented arguments confirms that DW, litter and soil pools are not source of the emissions in Croatia.

---

[99] Ibid, document "SOC stock changes, total nitrogen and total organic carbon trends, C:N ratio",

Figure 11.3-2: Common (pedunculate) oak age class distribution
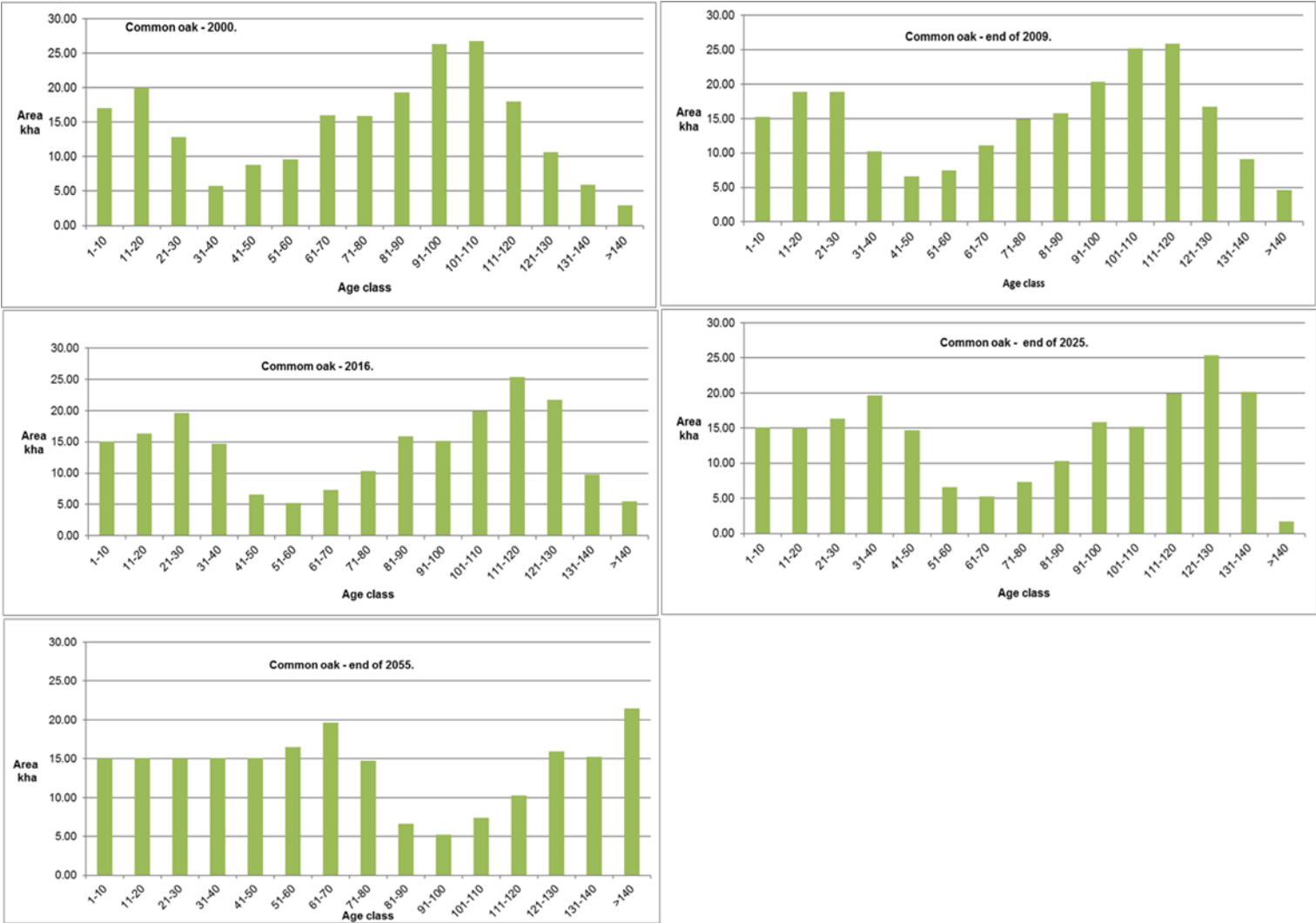
Figure 11.3-3: Sessile oak age class distribution
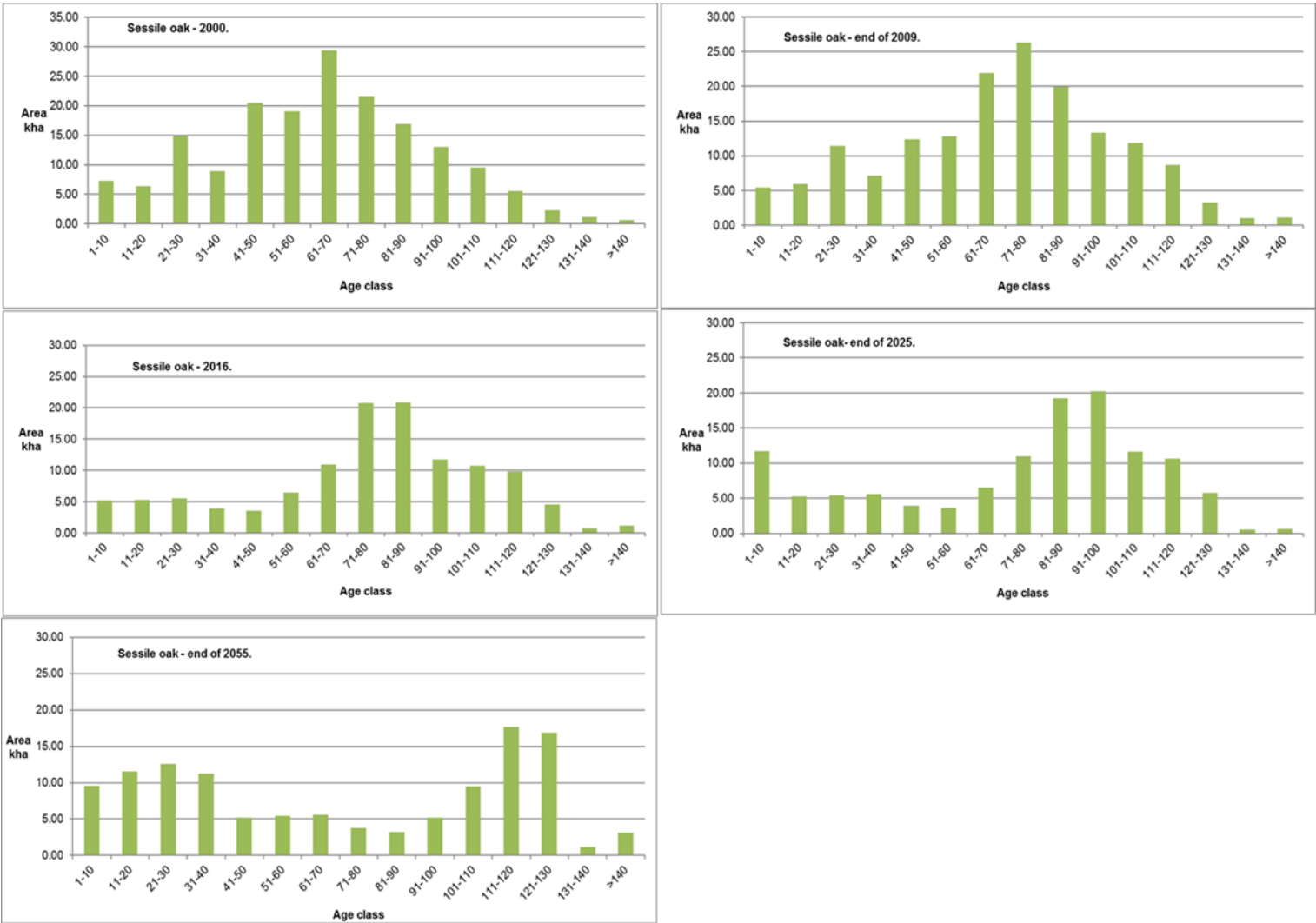
Figure 11.3-4: Beech age class distribution
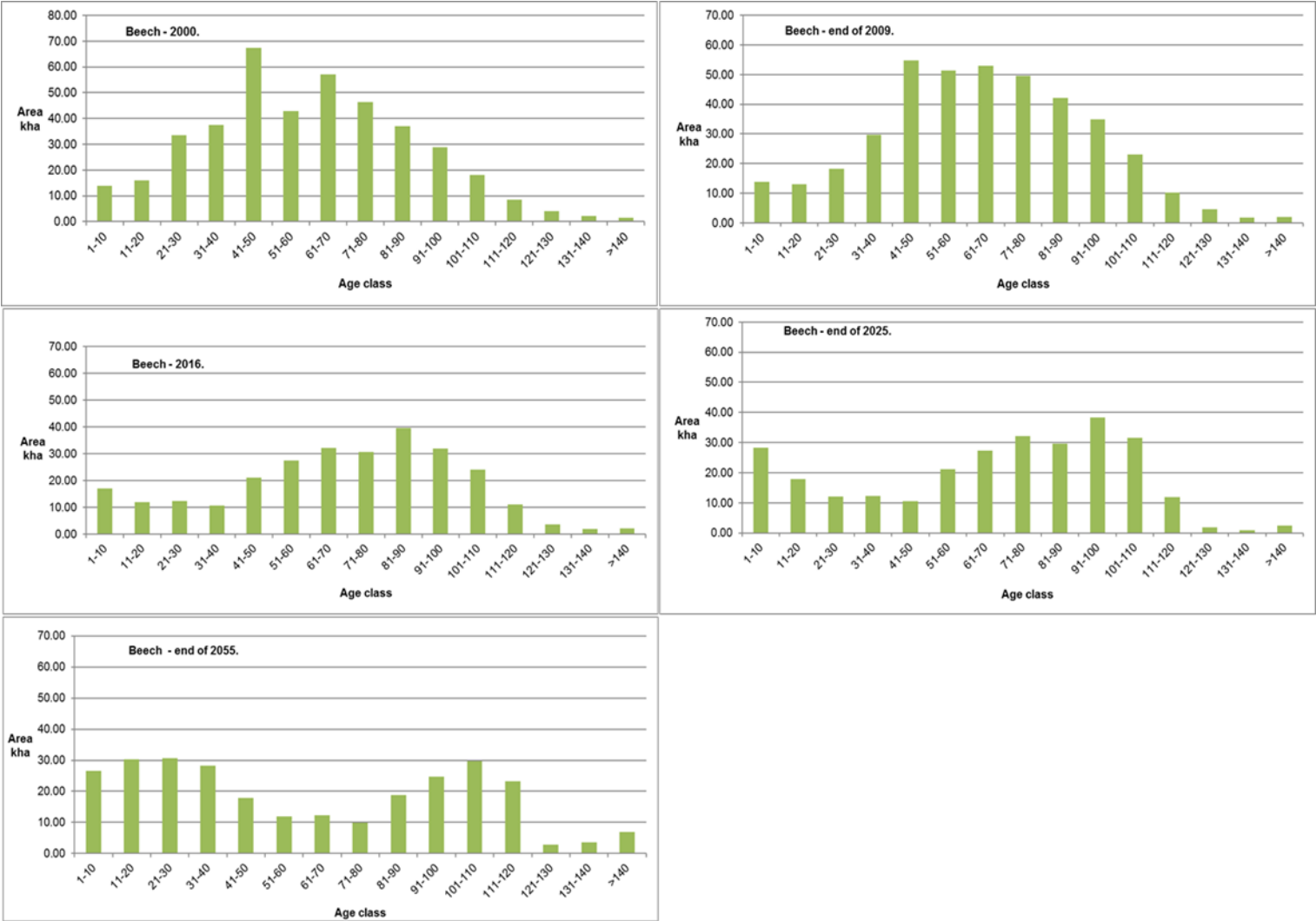
Figure 11.3-5: Age class distribution of stratum Other deciduous
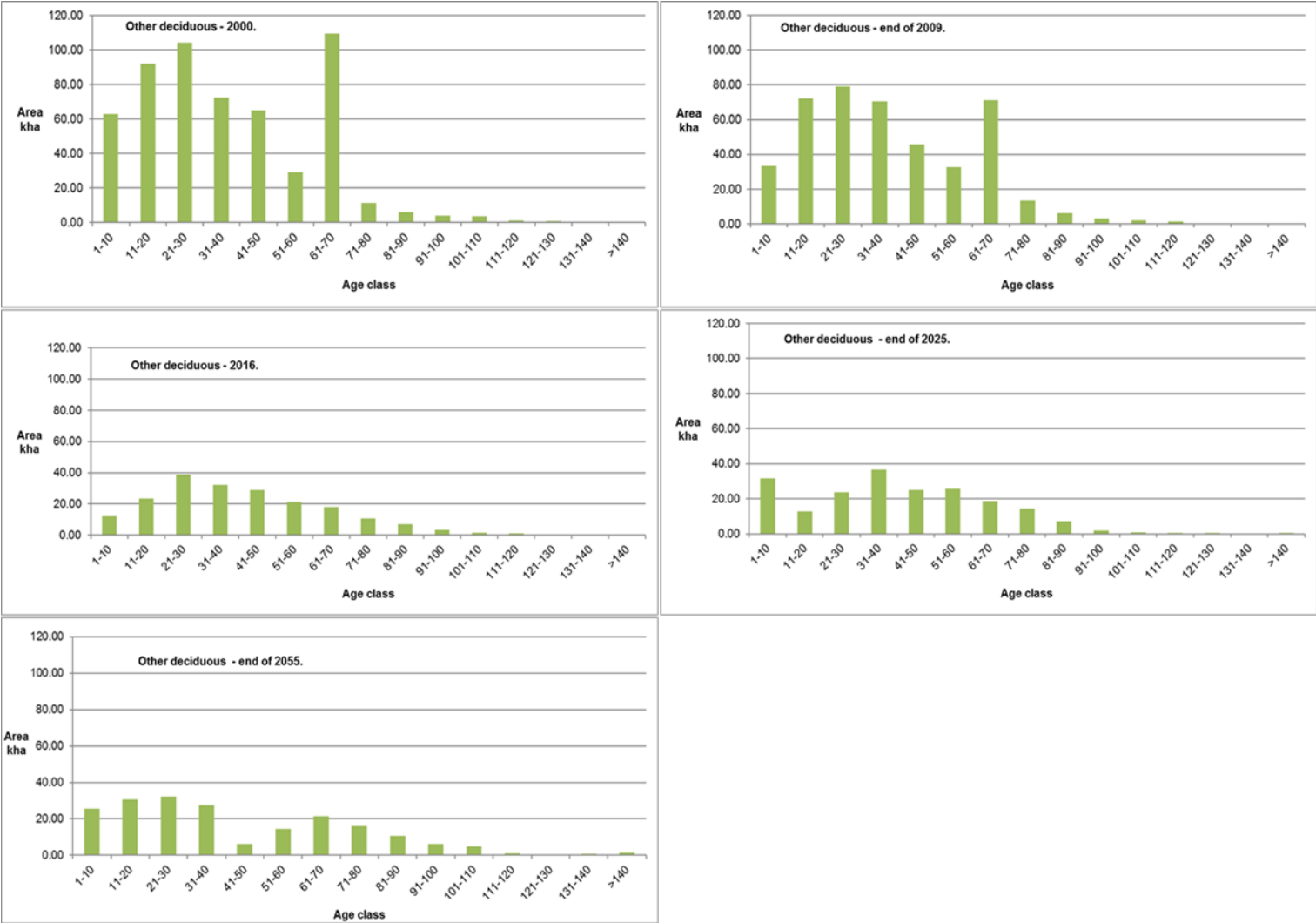
Figure 11.3-6: Age class distribution for all deciduous species
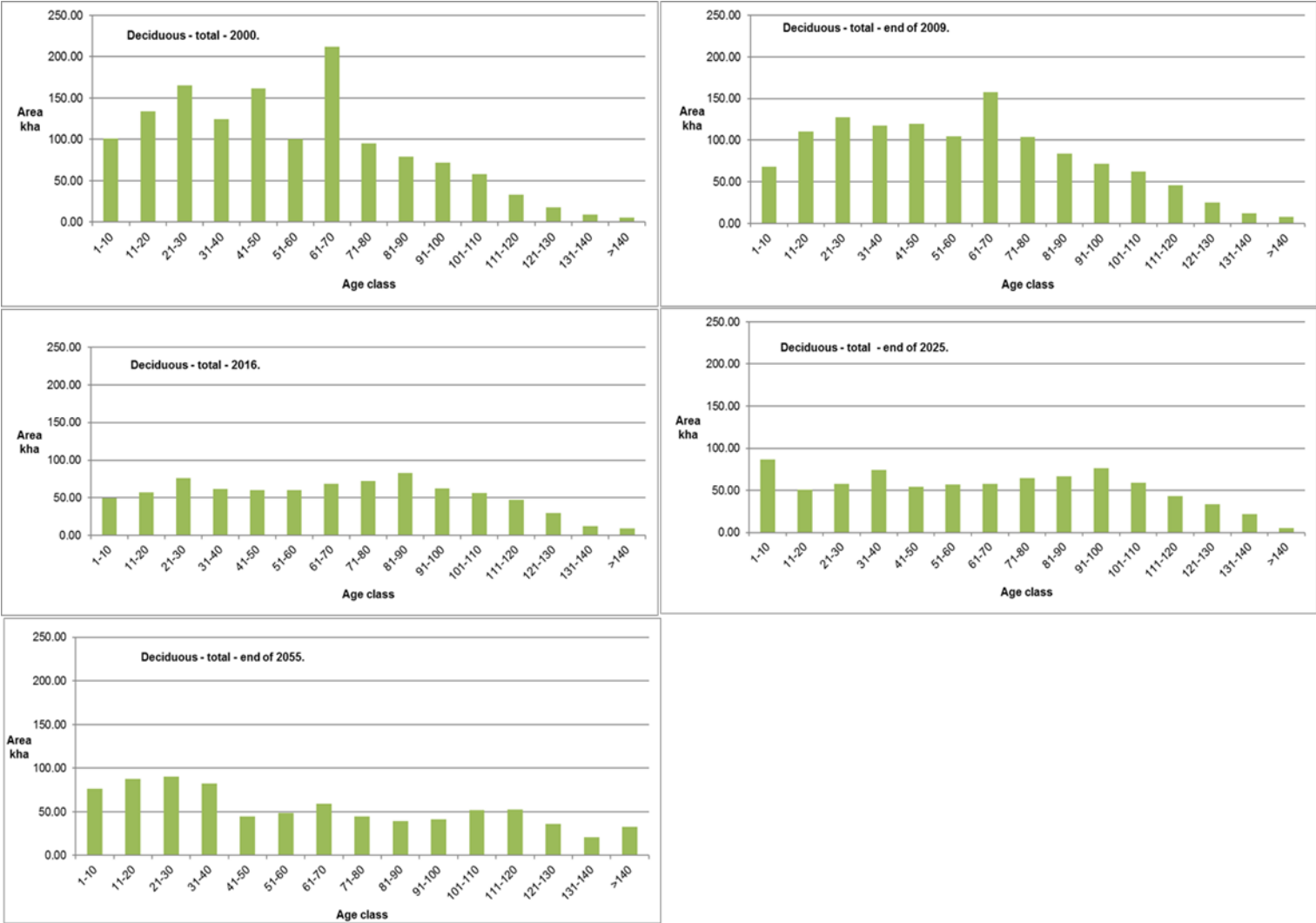
Figure 11.3-7: Age class distribution for stratum Other coniferous
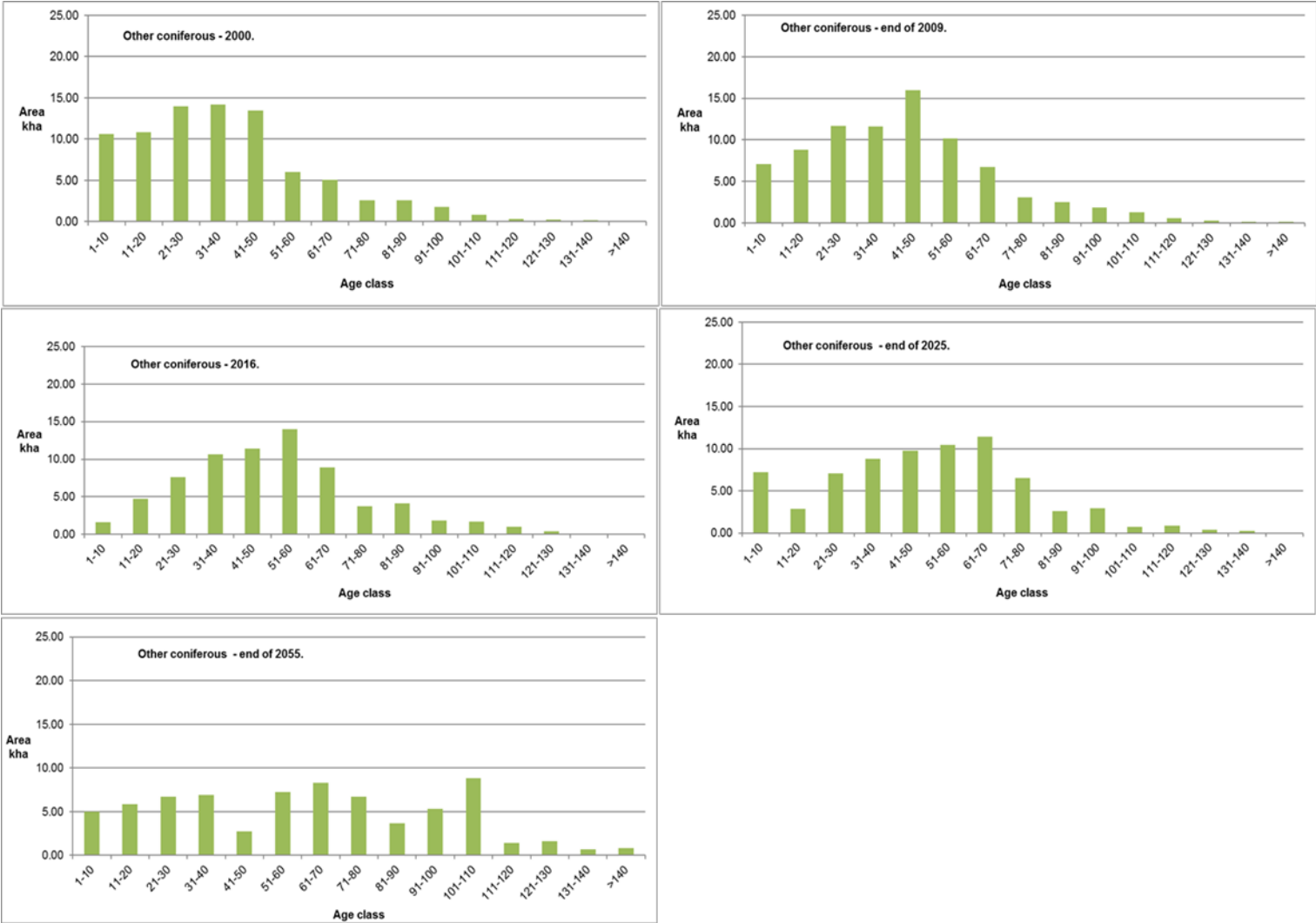
Figure 11.3-8: Age class distribution of even aged forests (aggregated level)
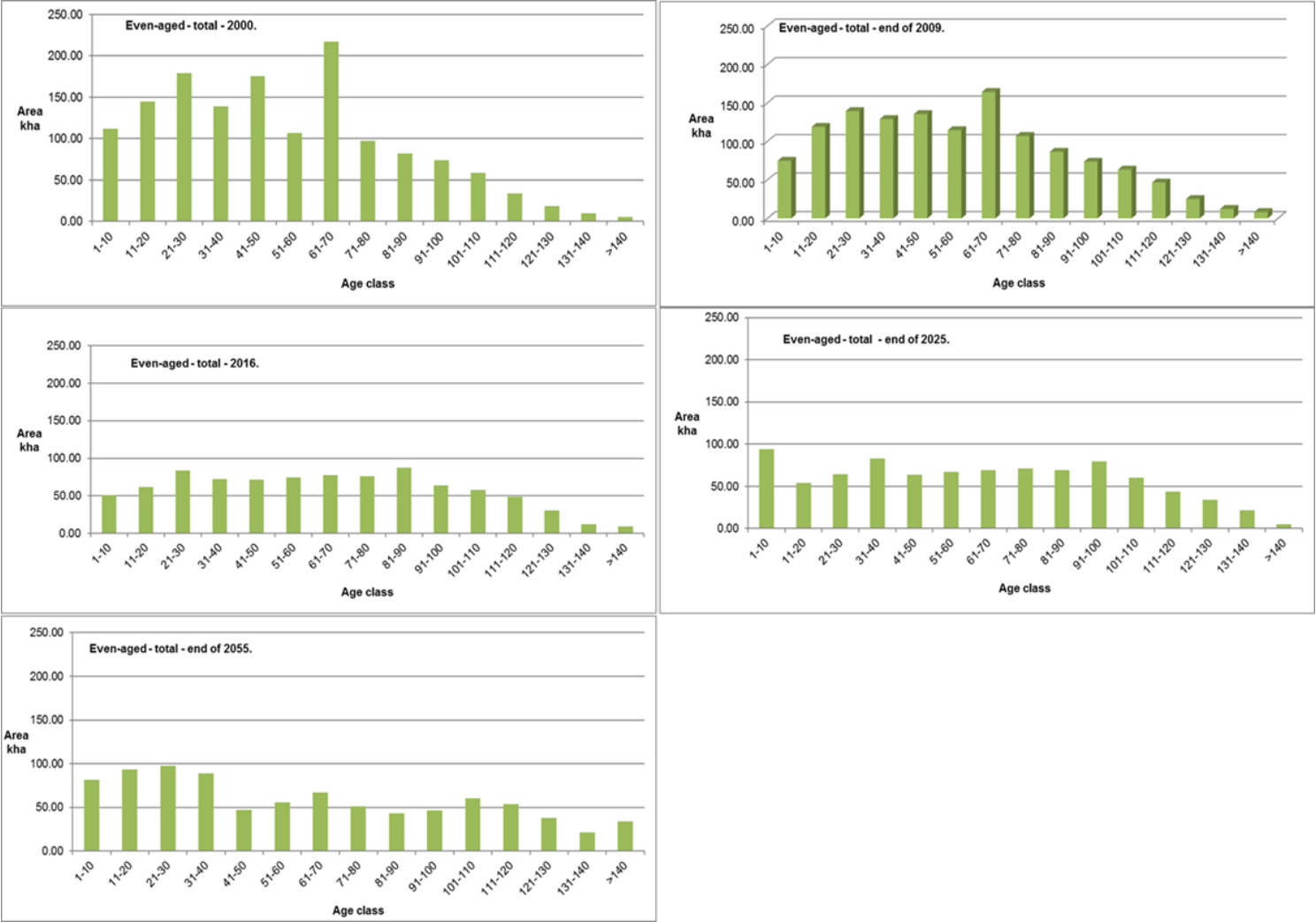
11.3.1.3. Improvements planned for FM activity:

Not applicable since the KP reporting terminates with this submission.

11.3.1.4. Information relating to exclusion/inclusion of emissions from natural disturbances

Regarding the explicit indication for which of the activities of afforestation and reforestation (AR) under Article 3, paragraph 3, of the Kyoto Protocol and/or forest management (FM) under Article 3, paragraph 4, of the Kyoto Protocol intends to apply the ND provision Croatia reports that intends to apply ND provisions as follows:

1. For the activity of afforestation under the Article 3, paragraph 3 of the Kyoto protocol

2. For the forest management activity under the Article 3, paragraph 4 of the Kyoto protocol.

Regarding the Country-specific information on the background level of emissions associated with annual natural disturbances that have been included in its forest management reference level, Croatia reports that the FMRL of Croatia is based on a projection without consideration of biomass losses due to ND events. Therefore, there is no Technical Correction of the FMRL needed due to Croatia's use of the ND provision, net credits due to the use of the ND provision will not occur

In nest lines, Croatia reports how the background level(s) for afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol and/or forest management under Article 3, paragraph 4, of the Kyoto Protocol have been estimated, and information on how it avoids the expectation of net credits or net debits during the commitment period, including information on how a margin is established, if a margin is needed:

A) ND provisions for Afforestation area under Article 3, paragraph 3 of the KP

The background level of emissions associated with annual natural disturbances has been estimated following an iterative process described in detail below, in accordance with footnotes 7 and 9 of annex Decision 2/CMP.7 and the guidance provided by the KP Supplement. For the necessity of determining the background and margin level of emissions in afforestation areas due to natural disturbances, forest fires were selected as the only type of ND that Croatia intends to exclude and consequently to report about. This type of ND was selected based on the first analyses conducted in Croatia regarding the ND types in period 1990-2009 and its occurrence. There has been not found other types of ND that significantly occurred in these areas during the calibration period. Therefore, it was assumed that other types of ND will be unlikely significant at these areas in future. Since forests on these areas mostly belong to the first age class at the moment (the oldest forest is 24 years old), first analyses showed that in case of forest fires all biomass is fully burnt. Because of that the estimation of emissions for ND provision purposes is performed by using the complete afforestation area and biomass affected with forest fires during the calibration period.

The background level was determined in line with the provisions given in Annex E to decision 2/CMP.7 for the emissions due to ND on AR areas. The background level and the margin have been determined by applying the IPCC default method, as follows:

i. A consistent and complete time series containing area specific annual emissions from wildfires for the calibration period 1990 - 2009 was set.
ii. The arithmetical mean and standard deviation of the emissions from wildfires were calculated.

iii. Any emissions that were larger than the arithmetic mean plus twice the standard deviation (outlier) were removed from the time series.

iv. The process mentioned in points 2. and 3. above was iterated until no further outliers were identified.

v. The arithmetic mean and twice the standard deviation estimated in the last step of this process (no outliers remain) define the background level and the margin, respectively.

vi. Both the area-specific background level and the margin were multiplied by the average afforested annual area estimated for the commitment period. For the projection of the area under afforestation for the commitment period, constant increase of afforested areas of 1.8 kha per year was assumed for years 2015-2020. For the remaining two years of the commitment period (2013 and 2014), exact data were available and used in estimation.

The total and the area-specific emissions associated with disturbances for the calibration period for AR lands are presented in Table 11.3-8. and Figure 11.3-9.

Table 11.3-8: Emissions from natural disturbances for AR

Total and area specific emissions from disturbances for the calibration period for AR																				
Disturbance type*	Inventory year during the calibration period																			
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Total annual emission [Gg CO_2 eq.]																			
Wildfires				0.04		0.35	0.54	3.88	0.91		2.73	0.21	0.01	1.94		0.61	0.91	5.04	2.49	1.80
Insect attacks, disease infestations																				
extreme weather events																				
geological disturbances																				
other																				
SUM				0.04		0.35	0.54	3.88	0.91		2.73	0.21	0.01	1.94		0.61	0.91	5.04	2.49	1.80
For all land under AR	Total area [kha]																			
		0.21	0.38	0.67	0,93	1.16	1.45	1.65	1.91	2.24	2.48	2.74	3.04	3.32	3.97	7.02	9.89	13.85	15.69	20.14
	Area-specific emissions (Emissions per unit of land area under AR, Mg CO_2 eq. ha^{-1}) **																			
				0.057		0.298	0.373	2.353	0.477		1.099	0.076	0.005	0.584		0.087	0.092	0.364	0.159	0.089
* Sub-division of types can be added as needed																				
** In any year, emissions per unit of land area are calculated as the Sum divided by the total area under AR																				

Figure 11.3-9: Emissions from natural disturbances for AR
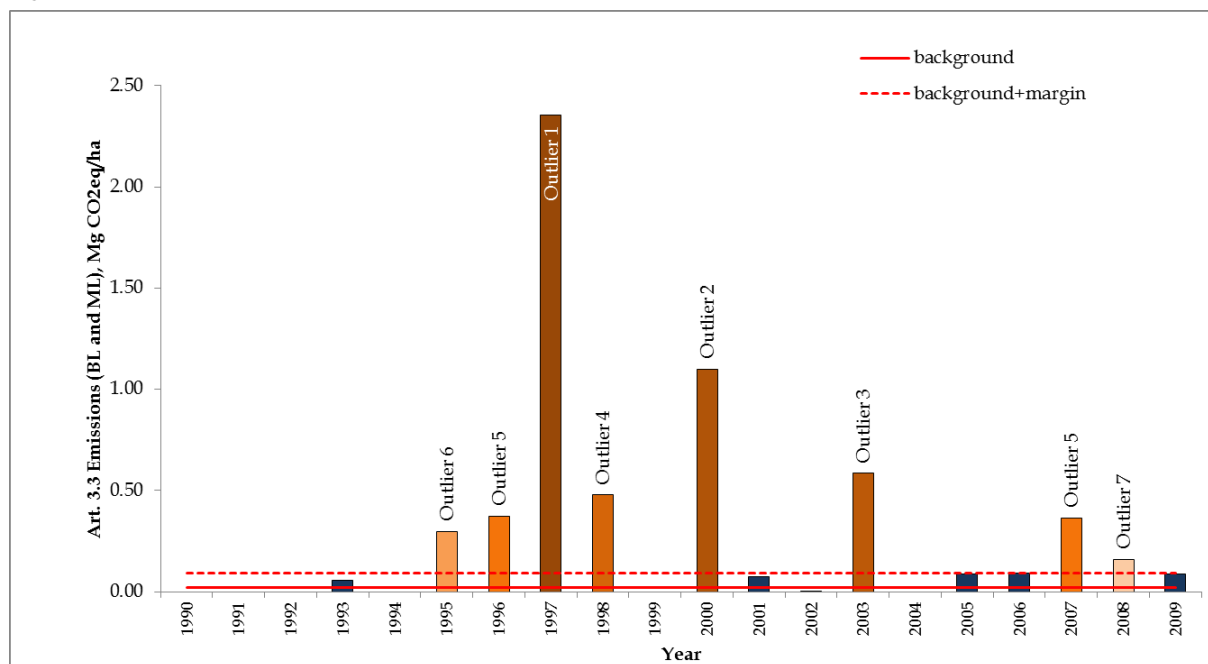
The results of the whole process as described above are:

1. Background level: 1.12 Gg CO_2eq

2. Margin: 3.98 Gg CO_2eq

3. Background level plus margin: 5.10 Gg CO_2eq

4. Total number of years with fires: 14

5. Number of excluded years: 8

6. Years excluded: 1997, 2000, 2003, 1998, 1996, 2007, 1995, 2008.

By applying the KP Supplement in the way just described for the development of the background level and the associated margin, Croatia believes that the expectation of net credits or net debits has been avoided.

Croatia intends to apply the ND provisions for Afforestation area under Article 3, paragraph 3 of the KP in respect to forest fires.

B) ND provisions for Forest management area under Article 3, paragraph 4 of KP

The background level of emissions associated with annual natural disturbances has been estimated following an iterative process described in detail below, in accordance with footnotes 7 and 9 of annex Decision 2/CMP.7 and the guidance provided by the KP Supplement. For the necessity of determining the background and margin level of emissions in FM areas due to natural disturbances, forest fires were selected as the first type of ND that Croatia decided to report about. This type of ND was selected based on the first analyses conducted in Croatia regarding the ND types in period 1990-2009 and its occurrence. Based on the ERT request the emissions corresponding to the 100% of the forest fire area was used instead of previously used 60% of forest fire areas when calculating emissions due to the natural disturbances.

The estimation of forest fires emissions are performed using the equation 2.27 from the 2006 IPCC Guidelines and Tier 1 method. For this estimation Croatia uses only data about areas affected by forest fires that are determined on national level.

In order to use natural disturbances provision as defined in Annex I to decision 2/CMP.8 natural disturbances areas on which wood have been left on site needed to be determined. Taking into consideration provisions of national legislation regarding the natural disturbances in forests (remediation prescribed and requested), it was concluded that damaged wood has been left on site after the natural disturbances only in special circumstances, and that this can happen only in case of:

a) Forest areas that are strictly protected on which any kind of forest practices are forbidden (i.e. strict forest reserves)
b) Areas with forest which diameter breast height (dbh) is under the measurement limit (i.e. first age class forests)
c) High mountains forest areas without access by forest roads
d) Areas still under the mines as a consequence of War in Croatia in 1990's

The additional analyses performed in Croatia showed that other types of ND (except the forest fires) also occurred on above listed areas during the calibration period, and it is reasonable to expect these ND types will repeat in the future also. This is a reason that Croatia decided to report emissions from extreme weather events as part of its ND provisions under the Decision 2/CMP.8. This ND type (extreme weather events) has been additionally presented as: (i) Windbreaks; (ii) Snow-breaks and ice-breaks (presented together).

In order to perform the emission estimation due to extreme weather events and presenting the data in the Initial report, a proxy was used. The emission estimation arising from the above listed ND (sub)types are calculated for FM areas using the Gain-Loss method from the IPCC 2006 Guidelines and Tier 2.

However, since then Croatia initiated a separate project in order to determine emissions due to natural disturbances selected in the Initial report and defining BL and ML in FM areas. Basic information about the project's tasks are presented in Annex 3.2. Within the project a specially designed Questionnaire was sent out to all forest units in Croatia (169) with the request to check areas affected by natural disturbances in period 1990 -2015. and deliver data on forest types (deciduous, coniferous maquies and shrub), volume and areas affected. The questionnaire referred to all forests in Croatia, regardless the forest ownerships. Detailed results of the project and conducted survey are presented in a separate, official document[100].

The basis for determining wood volume left on the site after the disturbance made data on the so-called salvage logging (refers to volume cut due to natural disturbance, and which is removed from the site) on FM areas and shares between FM and the ND areas without salvage logging. Through this project Croatia collected detailed data on natural disturbances by type, year of its occurrence and species (deciduous, coniferous, maquies and shrub) affected by it. The data collected refers to areas listed in point B of this paper (forest areas that are strictly protected on which any kind of forest practices are forbidden, areas with forest which dbh is under the measurement limit, high mountains forest areas that are not adequately accessible by forest roads, areas still under the mines) and to the following types of natural disturbances:

- Windbreaks
- Snow-breaks and ice-breaks (presented together)

---

[100] Janeš, D., Kovač, G. i Grubišić, I. (2017): Assessment of the effects of natural disturbances - windbreaks, snowbreaks and icebreaks - for the needs of the project: Calculation of greenhouse gas emissions due to natural disturbaces under the provisions of Decision 2/CMP.7

Since Croatia already disposes with the data about forest fire emissions that are recently revised (through the LULUCF 1 project implemented in period 2014-2015) there was no need for additional check about data on this type of natural disturbance.

After the relevant new data were collected through the project, and using the already existing data on forest fire emissions, Croatia performed a new estimation of emissions from listed (sub)types of NDs (windbreaks, snow-breaks and ice-breaks) on defined areas (forest areas that are strictly protected, areas with forest which dbh is under the measurement limit, high mountains forest areas without access by forest roads, areas still under the mines as a consequence of War in Croatia in 1990s). After that, the corresponding background and margin level were defined in accordance with footnotes 7 and 9 of annex Decision 2/CMP.7 and the guidance provided by the KP Supplement, as follows:

i.   A consistent and complete time series containing annual emissions from selected ND types (Table 2) for the calibration period 1990 - 2009 was set.
ii. The arithmetical mean and standard deviation of the emissions were calculated.
iii. Any emissions that were larger than the arithmetic mean plus twice the standard deviation (outlier) were removed from the time series.
iv. The process mentioned in points 2. and 3. above was iterated until no further outliers were identified.
v.   The arithmetic mean and twice the standard deviation estimated in the last step of this process (no outliers remain) define the background level and the margin, respectively.

The total emissions associated with the disturbances for the calibration period for FM lands are presented in Table 11.3-9 while defined BL and ML on these areas are presented in Figure 11.3-10.

Table 11.3- 9: Emissions from natural disturbances for FM

Total and area specific emissions from disturbances for the calibration period for FM																				
Distrubance type*	Inventory year during the calibration period																			
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Total annual emission [Gg CO$_2$ eq.]																			
Wildfires	16.840	45.106	204.803	492.534	160.361	105.157	226.805	240.456	596.998	63.906	1,304.998	240.291	84.299	537.714	29.304	31.871	81.100	439.193	127.224	71.376
Insect attacks, disease infestations																				
extreme weather events (total)	0.94	0.14	1.14	2.02	8.04	1.23	3.82	9.77	4.84	23.74	11.61	5.63	3.45	2.90	4.24	3.70	1.34	3.69	2.18	6.36
1. windbreaks	0.76	0.07	0.09	1.48	0.45	0.34	0.42	3.50	2.72	22.12	11.16	5.01	3.37	2.82	3.90	3.70	1.27	3.68	2.18	6.15
2.snowbreaks and ice breaks	0.17	0.06	1.04	0.53	7.59	0.88	3.40	6.27	2.12	1.62	0.44	0.61	0.07	0.07	0.33	0	0.07	0.01	0	0.21
geological disturbances																				
other																				
SUM	11.78	29.20	133.08	319.32	111.35	68.97	149.94	164.67	389.44	64.91	852.30	160.43	57.76	349.30	23.12	24.23	53.59	286.63	84.14	52.34
For all land under FM	Total area [kha]																			
	2,326.19	2,326.19	2,326.19	2,326.19	2,326.13	2,326.13	2,326.13	2,326.05	2,325.95	2,325.91	2,325.75	2,325.39	2,325.16	2,325.07	2,324.72	2,324.36	2,324.00	2,323.78	2,323.37	2,322.76
	Area-specific emissions (Emissions per unit of land area under FM, Mg CO$_2$ eq. ha^{-1})** (= t CO2eq/ha)																			
	0.008	0.019	0.089	0.213	0.072	0.046	0.099	0.108	0.259	0.038	0.566	0.106	0.038	0.233	0.014	0.015	0.035	0.191	0.056	0.033
* Sub-division of types can be added as needed																				
** In any year, emissions per unit of land area are calculated as the Sum divided by the total area under FM																				

Figure 11.3-10: Emissions from natural disturbances for FM
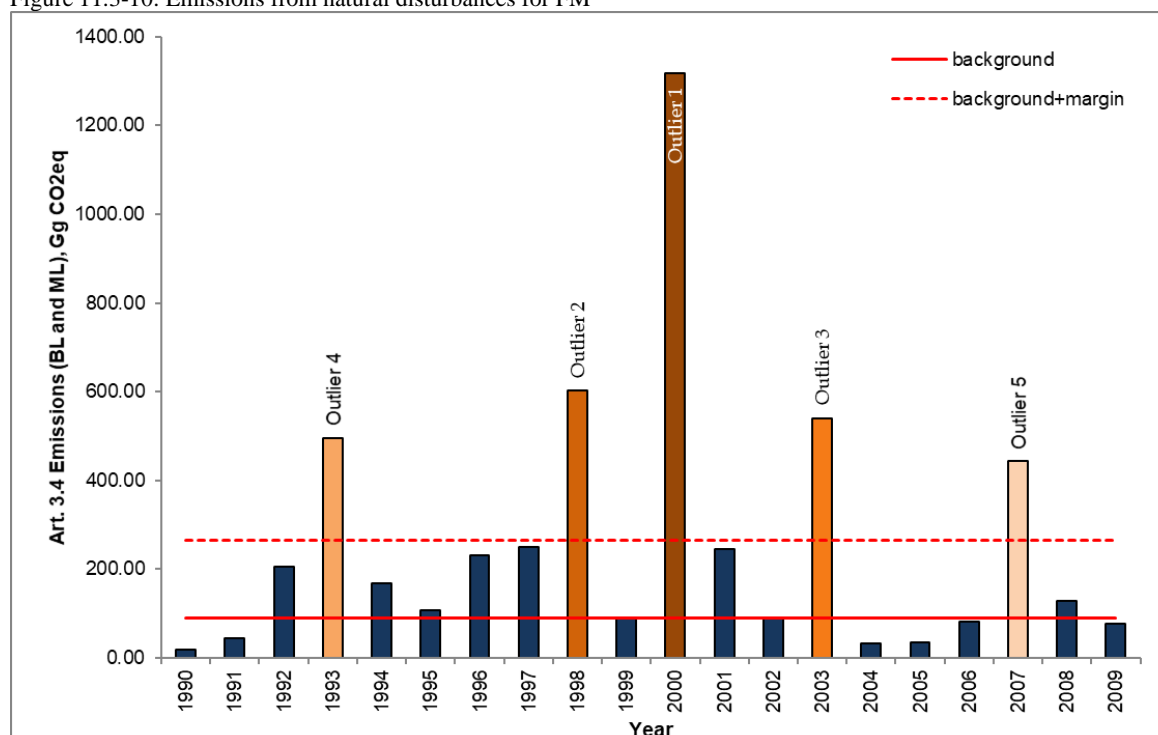
The results of the whole process as described above are:

1. Background level: 90.23 Gg CO_2eq.

2. Margin: 174.88 Gg CO_2eq.

3. Background level plus margin: **265.11** Gg CO_2eq.

4. Total number of years: 20

5. Number of excluded years: 5

6. Years excluded: 2000, 1998, 2003, 1993, 2007.

By applying the KP Supplement in the way just described for the development of the background level and the associated margin, Croatia believes that the expectation of net credits or net debits has been avoided.

As it can be seen from the information reported above, in case of FM areas, Croatia intends to apply the ND provisions in respect to: (i) forest fires; (ii) extreme weather events (additionally presented as: 1) windbreaks; 2) snow-breaks and ice-breaks (presented together)).

In respect to specific provisions of decision 2/CMP.8, Croatia reports as follows:

- Identification of lands subject to the exclusion due to natural disturbances
- Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (i), no lands was subject to exclusion in years 2013-2020.
- Annual emissions and subsequent removals areas excluded from the accounting

- Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (ii), no lands was subject to exclusion in years 2013-2020.
- Land-use change occurring on lands for which the Natural disturbances provision apply
- Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iii), no lands was subject to exclusion in years 2013-2020.
- Demonstration that the events or circumstances related to excluded emissions from Natural disturbances were beyond the control of the Party
- Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (iv), no lands was subject to exclusion in years 2013-2020.
- Efforts taken to rehabilitate, where practicable, the land for which the natural disturbances provisions are applied
- Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (v), no lands was subject to exclusion in years 2013-2020.
- Salvage logging

Referring to decision 2/CMP.8, Annex II, paragraph 2 (f) (vi), emissions associated with salvage logging - no lands was subject to exclusion in years 2013-2020.

11.3.1.5. Information relating emissions and removals from the harvest wood products

For the estimation of emissions/removals from Harvested wood products (HWPs) in areas that are subject of Forest management activity, Croatia applied Tier 2 and production approach (approach B) as it is described in Chapter 6.10. According to the official data the harvest operations performed on afforested areas in Croatia so far did not result with HWPs since afforestation in Croatia has been performed mainly with coniferous, pioneer species of less economic value. Areas that are subject of reforestation activity do not occur in Croatia.

Harvested wood products resulting from the deforestation are accounted on the basis of instantaneous oxidation as it is defined in Annex to the Decision 2/CMP.7. Estimation performed for this purpose is in line with the Croatian estimation applied for Forest land converted to Cropland and Forest land converted to Settlement categories of land (NIR 2022, Chapters 6.5.2.2.1 and 6.8.2.1.1) by using the same parameters in the estimation for HWP originating from the deforested areas as in mentioned NIR Chapter. Emissions are calculated for each type of forest land (deciduous, coniferous and maquies and shrub forests) that are converted to perennial Cropland (conversion from FL-aCL does not exists) or settlement category of land.

For the purpose of NIR 2022 the HWP activity data from the Central Bureau of Statistics (CBS) were used for the period 1990-2020. The same data are delivered to the UNECE/FAO international database.

1. For a start, from the total amount of wood harvested in Croatia in period 1990-2020 the amount of harvested wood that comes from deforested areas were exempt defining the ratio which presents % of harvest that comes from FM areas

Based on the Ordinance on forest management amount of wood that is harvested due to the deforestation purposes must be well recorded in Croatia. Thus, since 1990 these data are well known. Performed analyse showed that from the total amount of harvest recorded in Croatia in period 1990-2020, more than 99% is realized on FM areas. The remaining quantity of wood produced for both types of forests belong to the harvest realized on deforested areas.

In Croatia in period 1990-2020 there are no HWP types that are coming from the afforested areas.

After subtracting HWP amount harvested on deforested areas from total HWP amount the UNECE/FAO HWP data on total industrial roundwood (IRW) in period 1990-2020 were analysed and a share of IRW from domestic harvest was determined using the equations 2.8.1 from KP Supplement:

IRW share from domestic harvest = $(IRW_{Production} - IRW_{Export}) / (IRW_{Production} + IRW_{Import} - IRW_{Export})$

2. IRW data related to domestic harvest on each HWP types were corrected using the percentages defined under the point 1 to secure that these IRW data corresponds to harvest on FM areas only (securing the subtraction of IRW originating from the deforested land from the total IRW data)
3. 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 $(f_{PULP}) = (Pulp_{Production} - Pulp_{Export}) / (Pulp_{Production} + Pulp_{Import} - Pulp_{Export})$

4. HWP data related to domestic harvest as corrected in points 2 and 3 are are recalculated to Gg of carbon using the methodology and parameters prescribed by the KP Supplement (Equation 2.8.5)
5. HWP data presented as Gg of carbon according to the specific types (i.e. veneer sheets, plywood etc) were aggregated under the corresponding HWP types - saw wood, wood panels and paper and paperboard

Information on Harvested Wood Products under article 3.4 (Decision 2/CMP.8, paragraph g)

(i) Information on activity data for the HWP categories

The HWP estimates for the KP activities follow the same approach as those for the HWP estimates under the UNFCCC. Detailed information on the activity data is provided in 6.10.

(ii) Information on half-lives, information on methodologies used

The HWP estimates for the KP activities follow the same approach as those for the HWP estimates under the UNFCCC (production approach from domestic harvest). Detailed information on the half-lives and methodology is provided in chapter 6.10.

(iii) If FMRL is based on a projection, information on whether emissions from HWP originating

from forests prior to the start of the second CP have been included in the accounting

The estimates of the HWP share in the FMRL and those of the HWP emissions and removals under FM are fully consistent. The projections of the HWP emissions and removals also include those from the forests prior to the start of the 2nd CP.

(iv) Information on how emissions from HWP pool that have been accounted for during the first CP based on instantaneous oxidation have been excluded from the accounting of the 2nd CP

As defined in Annex of Decision 2/CMP.7, paragraph 16. and IPCC 2013 KP supplement, in case when FMRL are defined based on a projection which represents "Business as usual scenario", Croatia excludes inherited emissions from before the start of the 2nd CP in its estimates.

(v) Demonstrate that HWP from D have been accounted as instantaneous oxidation

The HWP removals and emissions are estimated and reported separately for three activities (A, D, FM), which ensures that HWP from D have been accounted as instantaneous oxidation. Details for the separate estimation for all activities are provided in chapters 6.10.

(vi) Showing that CO_2 emissions from SWDS are separately accounted, and wood for energy

purposes accounted on the basis of instantaneous oxidation

Croatia uses Tier 2 (first order decay function) and the production approach for the estimation of carbon stock changes in HWP pool. Emissions from HWP in SWDS are not separately accounted and they make a part of emissions in SWDS that are reported under the Waste sector.

(vii) Information showing that emissions/removals from HWPs which are accounted do not

include imported HWP

In NIR Chapter 6.10 the methodological details and the used IPCC approach are presented. The description proves that the applied approach has been implemented to separate the HWP production originating from domestic harvest in Croatia from the total HWP production.

Croatia has not factored out removals from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of age structure resulting from activities prior to 1 January 1990, considering also that GPG gives no methods for factoring out.

11.3.1.7. Changes in data and methods since the previous submission (recalculations)

Since NIR 2021 following changes are made in Croatian KP Chapter:

1) Since the NIR 2014 and start of applying the Approach 3 in identification of ARD areas and determining the FM areas, 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 FM areas in NIR 2021 and NIR 2022 too. For this year reporting, recalculation of FM areas data was performed harmonizing them with the General FMAP 2016-2025 data. This process resulted in changes in following data for:

    a. Total forest areas recorded at the beginning and at the end of each year in period 2008-2019 for each type of forests. Together with the other reported area corrections (presented in points b. to f. below) this resulted in changes in areas reported in NIR 2021 and NIR 2022 for each forest types as presented in Table 11.3-10:

Table 11.3-10: Difference between forest areas in NIR 2021 and NIR 2022 according to the forest type

	Forest type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NIR 2021 areas (kha)	Coniferous	200.65	200.63	200.57	200.55	200.46	200.45	200.45	208.56	209.14	210.28	207.26	211.71
	Deciduous	1,681.30	1,681.21	1,681.14	1,681.12	1,681.08	1,681.00	1,680.98	1,625.16	1,624.44	1,630.97	1,635.15	1,630.31
	Out of yield	440.28	439.78	439.56	439.40	439.30	439.22	439.19	486.66	486.77	479.09	477.92	478.27
NIR 2022 areas (kha)	Coniferous	214.23	214.21	214.16	214.14	214.04	214.04	214.04	214.03	214.02	214.02	214.02	214.02
	Deciduous	1,609.04	1,608.95	1,608.88	1,608.86	1,608.81	1,608.73	1,608.71	1,608.59	1,608.56	1,608.56	1,608.55	1,608.52
	Out of yield	500.10	499.60	499.38	499.22	499.12	499.04	499.01	498.91	498.91	498.91	498.91	498.90

    b. Afforested areas in deciduous forest type (due to the seedling and planting) for years 2003 and years 2012-2016

    c. Afforested areas in deciduous forest type (due to the human induced promotion of natural spreading of forests after 1989) for year 2013

    d. Afforested areas in coniferous forest type (due to the seedling and planting) in 2012

    e. Afforested areas in maquies and shrub (Out of yield) forests (due to the human induced promotion of natural spreading of forests after 1989) for year 2013

    f. Traced and reported areas as the result of natural spreading of forests before 1990 (due to the human induced promotion of natural spreading of forests) in 2018 and 2019. This led to the change in reported increase of the total areas due natural spreading of forests before

1990 from 271,707.00 ha reported in NIR 2021 to 270,509.74 ha in NIR 2022.The total area traced as the result of natural spreading of forests before 1990 was assigned to the forest area in 1990.

g. New input data for harvest (m3/ha) and increment (m3/ha) in Deciduous and Coniferous forest types in period 1990-2020 as the result of General FMAP 2016-2025 data application

The emission/removal estimation performed using the new area data led to the small difference of 1.5% between the removals for total FM activity between NIR 2021 and NIR 2022 in period 2008-2019. There is a major change in the areas of a particular type of forest between two consecutive reports, which is not reflected in total estimation for FM activity. This is a result of the fact that biomass losses in Out of yield forests are estimated using the data on biomass losses due to the forest fires since only this type of biomass loss appears in these forests (harvest in these forests are not predicted by Croatian legislation).

Identification of forest areas in new forest plans/programs that are result of human induced afforestation before 1990 is continuous process and will last for the next couple of years. It is expected that there will be less and less difference between areas reported in two consecutive NIRs for FL-FL category of land in the next couple of years.

2) For estimating biomass carbon stock in NIR 2021, mean value of harvested volume for each forest type in period 1990-2019 was used. In NIR 2022 mean value of volume harvested in period 1990-2020 was used. The difference in harvested value for all three categories is less than 1.5%.

3) Wood densities (WD) for coniferous and deciduous forests were recalculated based on the General FMAP 2016-2025 data on shares of main forest species in total growing stock. The difference between WDs used in NIR 2021 and NIR 2022 is less than 0.5% in case of both forest types. There has not been changes in WD in Maquies and shrub (Out of yield) forests.

4) For this year submission equation 2.8.2 from KP Supplement was applied using the nationally available data on Wood pulp production. Shares of the domestically produced wood pulp for years 2017 and 2018 were corrected using the average share from period 2018-2019

5) When estimating CS and annual CS changes in HWP pool inherited emissions from before the start of the 2nd CP are excluded

11.3.1.8.   Uncertainty estimates

For the purpose of defining uncertainties in LULUCF sector in Croatia, special questionnaire was developed 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)".

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 Table 6.4-6.

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.

The same approach and methodology were applied for both the UNFCCC and the KP reporting frame as already presented in Chapter 6.4.3.

11.3.1.9.   Information on other methodological issues

Additional information regarding the Forest Management Reference Level (FMRL)

As a Party to the UNFCCC and the Kyoto Protocol, the Republic of Croatia submitted its Forest Management Reference Level (FMRL) for the forest management activity during the Second Commitment period (2nd CP) in October 2011. For this purpose, Croatia developed projections of the parameters relevant for calculating emissions/removals in KP forest management activity by using the so-called business-as-usual scenario and considering the measures that were defined in the national legislation and in force until the end of 2009.

The basis for defining FMRL was the calculation of emissions/removals in FM activity performed in 2011 and it presented the state in Croatia's reporting for the UNFCCC and KP at the time of FMRL submission. Considering that at the time of defining the FMRL, Croatia did not have sufficient quality data and information needed to perform necessary estimation in the part of Maquis and shrub forests (Out of yield forests), and in the part of calculations related to harvested wood products, FMRL for Croatia was defined without considering removals in these forests and applying Tier 2 for CSC estimation in HWP pool. In order to be in line with the provisions of Decision 2/CMP.7 the FMRL technical correction has been performed to secure methodological consistency between the reference level and reporting for forest management during the 2nd CP, triggered by the below listed improvements introduced in Croatian estimation:

- Changes in total FM area in historic period because of the FMAP 2016-2025 application (Table 11.3-11)
- Changes in harvest values for coniferous forests because of the FMAP 2016-2025 application (Table 11.3-12.)
- Introducing the Maquis and shrub (Out of yield) forest into the FM estimation
- Application of 2006 IPCC Guidelines specifically equation 2.12 that addresses annual carbon loss in biomass due to wood removal in a way that includes R/S factor which differs comparing to the equation 3.2.7 from the previously used GPG
- Application of Tier 2 method in HWP pool carbon stock change estimation

However, no changes in domestic policies adopted and implemented after December 2009 were considered during the implementation of the technical correction of the FMRL, leaving the projected harvest at the same level (8.0 million m^3 in 2020) but addressing the changes in average harvest value recorded for coniferous forests in period 2005-2009 between the harvest value in 2011 and NIR 2022. Since the Maquis and shrub (Out of yield) forests prevail in karst, Mediterranean part of Croatia and have primarily protective function, Croatian legislative acts do not predict any harvest in these forests. Nevertheless, biomass losses occur on these forests areas as a result of the forests fires. To estimate losses in these forests when predicting harvest in period 2013-2020 for technical correction, the NIR 2022 data were used considering that the biomass losses due to the fires are highly difficult to predict.

Table 11.3-11: A comparison of activity data used for the FMRL submission, NIR 2022 Submission and technical correction

Year	2/CMP.6 Submission	2022 Submission	2022 Submission - FM technical correction
	FM areas (kha)		
1990	2,053.34	2,326.19	2,326.19
1991	2,054.14	2,326.19	2,326.19
1992	2,054.95	2,326.19	2,326.19
1993	2,055.76	2,326.19	2,326.19
1994	2,056.57	2,326.13	2,326.13
1995	2,057.38	2,326.13	2,326.13

Year	2/CMP.6 Submission	2022 Submission	2022 Submission - FM technical correction
		FM areas (kha)	
1996	2,058.19	2,326.13	2,326.13
1997	2,082.74	2,326.05	2,326.05
1998	2,107.30	2,325.95	2,325.95
1999	2,131.86	2,325.91	2,325.91
2000	2,156.41	2,325.75	2,325.75
2001	2,180.97	2,325.39	2,325.39
2002	2,205.52	2,325.16	2,325.16
2003	2,230.08	2,325.07	2,325.07
2004	2,254.64	2,324.72	2,324.72
2005	2,279.19	2,324.36	2,324.36
2006	2,303.75	2,324.00	2,324.00
2007	2,305.12	2,323.78	2,323.78
2008	2,310.72	2,323.37	2,323.37
2009	2,315.16	2,322.76	2,322.76
2010	2,316.10	2,322.41	2,322.41
2011	2,316.58	2,322.22	2,322.22
2012	2,317.06	2,321.98	2,321.98
2013	2,317.54	2,321.81	2,309.78
2014	2,318.02	2,321.77	2,309.46
2015	2,318.50	2,321.53	2,309.15
2016	2,318.98	2,321.49	2,308.84
2017	2,319.46	2,321.48	2,308.52
2018	2,319.94	2,321.48	2,308.21
2019	2,320.42	2,321.44	2,307.89
2020	2,320.90	2,321.42	2,307.58

Table 11.3-12: Harvest in coniferous forests used for the FMRL submission, NIR 2022 Submission and technical correction (m3)

Year	2/CMP.6 Submission	2022 Submission	2022 Submission - FM technical correction
		Coniferous forests harvest (m³)	
1990	621,281.20	643,087.39	643,087.39
1991	460,123.60	475,439.19	475,439.19
1992	459,441.00	465,748.25	465,748.25
1993	471,328.40	484,973.58	484,973.58

Year	2/CMP.6 Submission	2022 Submission	2022 Submission - FM technical correction
		Coniferous forests harvest (m³)	
1994	487,711.40	502,512.40	502,512.40
1995	440,720.00	446,510.00	446,510.00
1996	494,959.20	500,452.08	500,452.08
1997	506,976.20	513,023.04	513,023.04
1998	522,195.00	528,824.69	528,824.69
1999	472,137.40	480,286.36	480,286.36
2000	502,460.40	512,860.60	512,860.60
2001	534,058.00	545,613.92	545,613.92
2002	574,263.20	585,170.52	585,170.52
2003	614,936.60	624,833.59	624,833.59
2004	693,530.05	708,065.91	708,065.91
2005	663,003.00	665,058.54	665,058.54
2006	772,426.60	776,797.87	776,797.87
2007	777,941.16	788,780.01	788,780.01
2008	936,614.04	787,152.73	787,152.73
2009	912,329.44	744,470.84	744,470.84
2010	757,307.11	702,996.59	702,996.59
2011	799,951.59	815,818.04	815,818.04
2012	842,596.07	819,171.40	819,171.40
2013	885,240.54	917,352.44	819,854.12
2014	927,885.02	1,000,158.55	859,348.75
2015	970,529.50	965,304.01	898,843.39
2016	1,011,703.48	1,000,328.48	936,976.14
2017	1,052,877.46	1,071,290.41	975,108.89
2018	1,094,051.44	1,260,669.51	1,013,241.64
2019	1,135,225.41	1,168,691.17	1,051,374.39
2020	1,176,399.39	1,030,852.75	1,089,507.14

Table 11.3-13: Methodological Improvements in FM input data, FM estimates and FM figures of historic years

Factor subject to the change	Old Period 2005 – 2009 at the time of FMRL submission	New Period 2005 – 2009 at the time of 2022 Submission	Difference (%)
Average annual FM increment, high forests (mil. m³)	10.04	10.56	4.92
Average annual FM harvest, high forests (mil. m³)	5.19	5.14	-1.37

Factor subject to the change	Old Period 2005 – 2009 at the time of FMRL submission	New Period 2005 – 2009 at the time of 2022 Submission	Difference (%)
Maquies and shrub (Out of yield) forests	Not considered	Estimated	
Wood density deciduous	0.588	0.558	-5.38
Wood density coniferous	0.4	0.398	-0.50
Wood density Maquies and shrub (Out of yield) forests	Not considered	0.683	
Root/shoot ratio for increment - deciduous	0.24	0.23	-4.35
Root/shoot ratio for increment - coniferous	0.23	0.29	20.69
Root/shoot ratio for increment - Maquis and shrub (Out of yield) forests	Not considered	0.46	
Biomass expansion factor for increment - Maquis and shrub (Out of yield) forests	Not considered	1.1	
Biomass expansion factor for harvest - deciduous	1.4	1.197	-16.96
Biomass expansion factor for harvest - coniferous	1.3	1.0387	-25.16
Biomass expansion factor for harvest - Maquis and shrub (Out of yield) forests	Not considered	1.15	
Carbon fraction - deciduous	0.5	0.48	-4.17
Carbon fraction - coniferous	0.5	0.51	1.96
Carbon fraction - Maquis and shrub (Out of yield) forests	0.5	0.47	-6.38
Harvested Wood Products	Instantaneous oxidation (HWP carbon stock change not estimated)	Estimated	

As a consequence of the methodological improvements (except the estimates of root biomass losses due to harvest which is an improvement in the 2006 IPCC GL and HWP which are new for the 2nd CP, respectively), the average annual net removals for the 1st CP changed from -8,158.15 Gg CO_2 at the time of FMRL submission (2011) to -7,216.93 Gg CO_2 accounted in NIR 2022.

The methodological improvements in the table above requested the following average changes in the FMRL input data as presented in Table 11.3-14:

Table 11.3-14: Changes in FMRL input data

Parameter	Period 2005 – 2009 at the time of FMRL submission	Period 2005 – 2009 at the time of 2022 Submission	Difference (%)
Increment, high forests 2020 (1000 m³)	10676	10563	-6.04
Harvest, high forests 2020 (1000 m³)	8000	7916	-1.06
Increment, Maquies and shrub forests (Out of yield) 2020 (1000 m³)	0	88.81	

Parameter	Period 2005 – 2009 at the time of FMRL submission	Period 2005 – 2009 at the time of 2022 Submission	Difference (%)
Harvest, Maquies and shrub forests (Out of yield) 2020 (1000 m³)	0	6.17	
Wood density - deciduous	0.588	0.558	-5.38
Wood density -coniferous	0.4	0.398	-0.50
Root/shoot ratio for increment deciduous	0.24	0.23	-4.35
Root/shoot ratio for harvest (deciduous)	0	0.23	23.00
Root/shoot ratio for harvest (coniferous)	0	0.29	29.00
Root/shoot ratio for harvest (Out of yield)	0	0.46	46.00
HWP stock change (Gg CO_2)	0	296.46	

The changes in FMRL input are not a result of a change in prediction due to a change in forest measures and policies. As the result of methodological improvement, they are needed in order to secure consistency with the GHG inventory.

The introduction of the CSC in maquis and shrub forests (Out of yield) and root biomass losses due to harvest into the estimation for the 2nd CP has significantly increased the lost harvest biomass in the 2nd CP and consequently also in the FMRL correction estimates by approximately 24%. Since FMRL for Croatia is defined based on projections the technical procedure defined in IPCC 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol was applied to exclude inherited emissions from before the start of the 2nd CP.

As a consequence of all above listed methodological improvements in Croatian FM estimation and the exclusion of inherited emissions from before the start of the 2nd CP, the FMRL changed from -6,288.98592 Gg CO_2 net removals to FMRL -4,809.67964Gg CO_2 net removals without HWP (instantaneous oxidation) and to **FMRL -6,192.41222 Gg CO_2** net removals with the HWP, leading to the FMRL technical correction of 96.57 GgCO_2 (-1.54%).

11.3.1.10. The year of the onset of an activity, if after 2013

During the Second commitment period, Croatia reports afforestation, deforestation, and Forest management activities. Reforestation activity has not been performed in Croatia during the reporting period.

11.4. Article 3.3

In the period 1990-2020, afforestation activities resulted in net removals while deforestation presented a net source. The data are presented in Table 11.4-1.

Table 11.4-1: Emissions/removals of Article 3.3 activities [Gg CO2]

Year		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total		24.85	43.94	10.45	-9.61	-46.20	-53.55	-83.76	-100.41	-225.96	-206.20	-246.73	-261.57	-271.55
Afforestation														
Biomass*	AGB	-44.62	-21.39	-42.52	-41.51	-93.56	-94.87	-106.45	-152.73	-248.36	-223.45	-263.28	-283.89	-289.97
	BGB	-36.87	-29.32	-44.85	-48.55	-80.26	-87.99	-99.45	-123.69	-177.20	-168.40	-188.67	-199.04	-202.68
Dead wood		-0.74	-7.75	7.93	2.34	7.04	-13.30	-6.89	-7.00	-29.04	-71.16	-55.04	-74.61	-84.85
Litter		-13.14	-0.77	-1.02	-1.40	-1.61	-2.19	-2.65	-3.12	-3.33	-3.55	-3.74	-3.80	-3.81
Soil		15.67	-13.14	-16.87	-20.90	-25.79	-29.86	-35.59	-42.37	-47.52	-48.48	-51.61	-52.84	-53.01
Deforestation														
Biomass*	AGB	34.39	26.24	16.73	-1.13	11.21	6.41	-8.54	16.28	-8.56	-12.92	-13.00	-8.08	-10.21
	BGB	27.36	19.44	12.29	-1.97	7.78	4.28	-7.64	11.99	-7.84	-11.33	-11.40	-7.40	-9.10
Dead wood		3.22	8.34	8.28	5.99	2.49	5.10	3.89	0.91	6.11	1.15	0.29	0.27	1.20
Litter		6.86	3.23	2.56	2.21	0.79	2.16	1.47	0.33	2.37	0.50	0.12	0.11	0.49
Soil		23.25	6.86	10.15	5.85	3.21	4.10	2.79	0.75	4.04	0.57	0.13	0.14	0.56

*AGB=aboveground biomass; BGB=belowground biomass

In period 2008-2020 mentioned activities altogether resulted in removals by sink.

11.4.1 Information demonstrating that activities under Article 3.3 began on or after 1st January 1990 and before 31st December 2020 and are directly human induced

All data regarding the Article 3.3 activities were attained from HS database related to FMAPs. As mentioned previously, there are three main FMAPs. The first FMAP in this sense is the FMAP encompassing the period from 1986-1995 thus including 1990.

As stated earlier, afforestation in national circumstances is the activity within the biological forest renewal and it refers to afforestation of non-forest land and establishing plantations of fast-growing species. This activity mentioned is laid down in forest management plans with a clear indication of the time when it is carried out; thus, is human induced and not a result of natural succession. As stated before, survey performed under the LULUCF 1 project proved that no afforestation by seeding and planting was performed on areas of state-owned forests managed by other legal bodies and private forests. Afforestation by seeding and planting in Croatia has been performed only in state owned forests managed by Croatian forests Ltd. in period 2008-2012 based on forest management plans. This is also valid for years 2013-2020.

Regarding the afforestation due to natural spreading of forests on new areas, Croatia claims this afforestation is result of human induced promotion of natural seed sources in its entire territory. According to the conducted survey in all Croatian forests regardless the ownership and forest types within the framework of LULUCF 1 project, this type of afforestation does not occur in state owned forests that are managed by other legal bodies. This was expected outcome because forests belonging to this type of ownership are under strict or protection under the provisions of Law on nature protection, and their area is well known, fixed and cannot be changed without very complex legal procedure which implies involvement of many institutions in Croatia.

Conducted survey on state owned forests managed by Croatian forests Ltd. regarding the afforestation due to natural spreading of forests on new areas showed that this increase of forest areas happens only from Grassland category of land. As it is presented in Figure 6.16-1 area under the Forest Management plans of Croatian Forest Ltd. encompasses not only area covered by forests but also land without tree cover. The part of area without tree cover which is defined as productive forest land according to national legislation belongs to the grassland category according to the IPCC definitions of land categories.

Basic principle of silviculture in Croatia is implemented in a way that growth of new young forests is encouraged primarily through natural spreading of forests seeds coming from older trees that grow on the area. This principle is considered to be the most important part of forest management practices in Croatia securing by sustainability of all aspects in forest management as well as sustainability of forests ecosystems. According to the Article 36 of the Forest Act even aged forests in Croatia must be grown naturally using the shelterwood compartment system while uneven aged forest has to be grown naturally using the group selection method of cutting with rotation period that cannot be shorter than 5 years. When performing this work in even aged and uneven aged forests due attention must be given to the seed crop of the main species. Felling of forest trees needs to be performed after the year with a full and good seed crop securing natural spreading of seed on forest areas as a first precondition of natural regeneration of forests in Croatia.

Consequently, natural spreading of forests by promoting seed spreading on grassland without tree cover (that are under the forest management plans and under supervision of Croatian forests Ltd.) makes integral part of practices of growing forests in Croatian and can be considered as human decision to promote natural spreading of forests and as such these areas should be reported as afforested.

In privately owned forests, the total observed natural spreading of forest is recorded on categories of grassland (82.1%), annual Cropland (16.3%) and perennial Cropland (1.6%). As a part of officially prescribed procedure required under the FSC rules, foresters are obliged to get permission of private owners to record their forest area in official forest management programs if the forest is identified as a new forest during the development of forest management program. Only the areas that are officially agreed by the land owners to stay as forests are recorded in the forest management programs and are consequently direct human induced AR areas. Once the area has been recorded as forests it falls under the provisions of Forest Act and cannot be changed to other land use categories without strict legal procedures.

For other area of private forests that are so far not covered by official management programs (around 50% of private forests) Croatia claims that increase of forest area in these forests is also result of human decision to land use changes based on the information provided below.

According to the official data[101,] total 105 Settlements in Croatia had no inhabitants in 2001 which makes 1.55% of total settlement area in Croatia. In the same year 2489 Settlements (2.44%) had less than 100 inhabitants. These figures increased in 2011 when Croatia had 150 Settlements (2.22%) without inhabitants and 2653 Settlements (2.66%) with less than 100 inhabitants[102.] According to the same

---

[101] Statistical Yearbook (2011), page 57
[102] Statistical Yearbook (2012), page 57

sources of information in same period number of inhabitants increased in area of main town from 25.42% to 26.19% although the total number of inhabitants in Croatia decreased for more than 3%. Based on these arguments and fact that in year 2012 total agricultural plant production decreased for 12.3% comparing to production in 2011 and that employment in agriculture sector decreased for 3.1% comparing to the same year[103], Croatia believes that depopulation of rural areas and abandonment of agricultural practises on agricultural land is a result of human decision caused with economical situation in the country. Additionally, as a consequence of increased demand for use of woody biomass and its prices (total revenues from exports of wood products (excluding furniture) increased from 3.0% in 2011 to 3.4% in 2014), Croatia is sure that all private owners on whose land new forests grow will decide to claim them as forest during the official registration of forest areas in the development process of forest management programs.

Since depopulation of rural areas started from late 1940 in last century (Figure 11.4-1) the fact is that in many cases abounded agricultural land is covered by several decades old forests which are still register as agricultural land in cadastral due to its tardiness[104].

Figure 11.4-1: Total and number of inhabitants in rural areas in Croatia in period 1948-2011
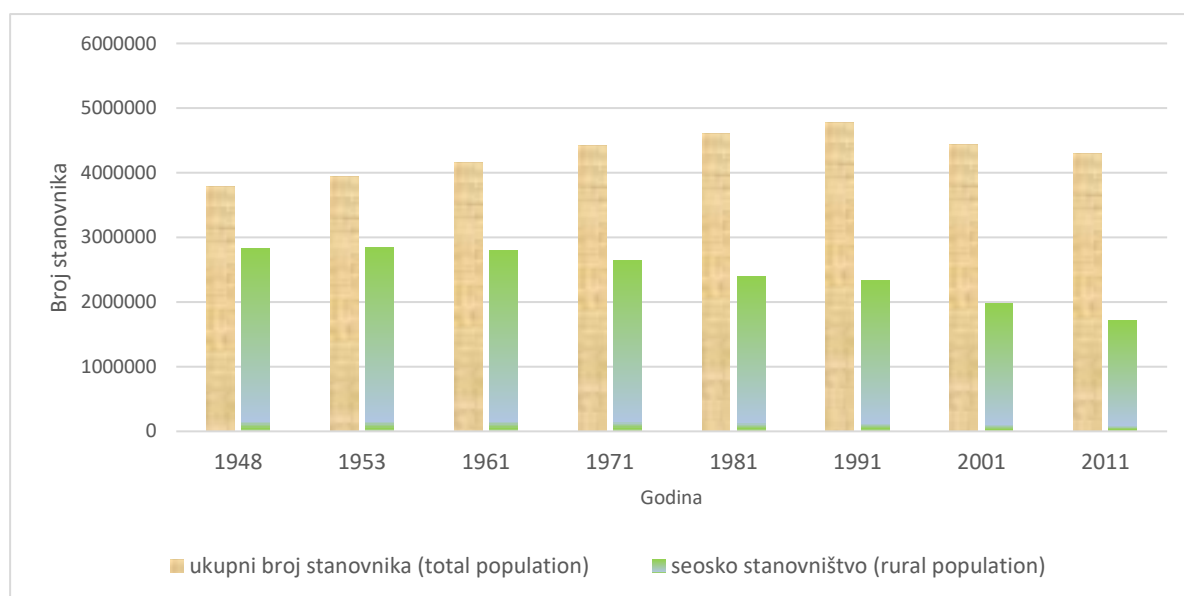
Based on the experiences gained so far in development of programs for private forests when all private owners on whose land new forests appeared because of natural spreading of forests decided to register this land as forest land, it is expected this trend will continue in case of remaining new private forest areas.

Additionally, since conversion of abounded agricultural land that is already covered with forests again to agricultural purposes is very demanding and financially expensive (especially in cases of several decades old forests) it is much easier to register these areas as new forests.

---

[103] Ministry of Agriculture (2013), Annual report on the state of agriculture in 2012, http://www.mps.hr/default.aspx?id=9567, pages 4-5

[104] Janeš et all (2014) Separation of areas under the Article 3.3 and 3.4 of the Kyoto Protocol, page 15

According to the Forest Act[105], Article[62] all private and physical persons conducting business activity in Croatia are obliged to pay 0.0265% of their yearly profit (so called green tax) to the state budget for managing the forests (state and private owned). This financial means have to be shared among private forest owners, Croatian forests Ltd. and other legal bodies that manage forests according to their share of areas in total forest area in Croatia.[106] This financial means must be used in private forests for activities that are prescribed by Forest Act such as pre-commercial thinning and thinning. Since private owners can benefit from these activities by selling wood gained through these activities, Croatia believes that this green tax also contributes that private owner decide to register their abounded agricultural land covered with forests as forests.

Croatia believes that above presented expectation is realistic also since new policy of the EU concerning rural development required special measures for forestry sector to be defined under programs for rural development in period 2014-2020. Under rural development program[107], Croatia also defined many measures for forestry sector that are of interest for private forest owners.

It is believed that activities of Croatian union of Private Forest Owners[108] (in which 35 Private Forest associations from whole Croatia are joined) will contribute to rising the awareness of relevance of forestry sector and possibilities that are available to private forest owners at EU and national level so that private owners on whose areas forests are naturally spread will decide to keep them as forests.

Therefore, all increases of forest areas in private forests that occur from Cropland and Grassland categories of land due to natural spreading of forests on new areas should be and are reported as afforestation activity under the Article 3.3 of the Kyoto protocol.

Deforestation requires land use change and relies on a strict legal frame as mentioned before. It is mainly performed due to large infrastructure projects.

Therefore, all activities reported under Article 3.3 (afforestation and deforestation) started on or after 1 January 1990 and were human induced.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

The main criteria for distinguishing the harvesting or forest disturbance followed by the re-establishment of forest from deforestation is whether the land use has changed, which is strictly regulated by the legal framework. More detailed information is provided below.

While comparing and interpreting definitions within the IPCC framework and within national legislation, it was concluded that deforestation in national circumstances referred to clear cutting intended for land use change of forest land in accordance with the spatial planning documents. However, this activity is forbidden except in very specific cases which are regulated by Articles 35 and 51 of the Low on Forests. Since all forest land in Croatia can be considered managed, if a certain forest land area is permanently removed from the forest management area (in specific circumstances, e.g., for road construction), then this event should be reported as deforestation.

The re-establishment of forest on harvested areas or areas affected by forest disturbance is also regulated by the Articles 10 and 28 of the Low on Forests and the Ordinance on Forest Management (OG 111/06, 141/08).

---

[105] OG 94/14

[106] 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), Article 3

[107] Ministry of Agriculture (2014), Program of rural development of the Republic Croatia 2014-2020 (draft).

[108] http://www.hsups.hr/udruge.html

The FMAPs make a clear distinction between areas that are deforested and areas that are cleared for forest management purposes, all consistent with the provisions of the Forest Act. By that, both activities can be easily distinguished.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover, but which have not yet been classified as deforested

Generally, forest cover can be lost through harvesting or forest disturbance which represent a temporary loss. Permanent loss of forest cover includes land use change. Therefore, there are no forest areas that have permanently lost forest cover, but which have not yet been classified as deforested.

11.5. Article 3.4

11.5.1 Information demonstrating that activities under Article 3.4 have occurred since 1 January 1990 and are human induced

Croatia has a very long forest management tradition. As stated before, all data have been obtained from FMAPs, the first covering the period from 1986-1995 (thus including 1990). Since forest management area under the KP is all managed based on the FMAPs, if human induced is assumed equivalent with the managed, then it is demonstrated that the forest management as an activity under Article 3.4 of the KP is human induced. Croatia has stock and harvest data in an annual resolution. Therefore, an easy assessment of the year of activity is possible.

11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

Not applicable. Croatia did not elect these activities for the First and Second commitment period.

11.5.3 Conversion of natural forest to planted forest

In Croatia, conversion from natural forests to plantations do not occur. According to the Forest Act and as it has been reported by Croatia, all forests in Croatia are managed. Emissions and removals in lands that are subject of forest management activity cover the emissions and removals of whole Croatian forests decreased by those emissions and removals resulting from Afforestation and Deforestation activities which are accounted under Art. 3.3.

11.5.4 Information related to the Forest Management

As stated before, all forest management area within the national frame is managed based on the FMAP and is even wider than the forest management area under the KP because it includes, for example, afforested area and also "forest land" (in Croatian sense) that is covered with vegetation which does not reach the selected thresholds for the KP definition of forest (all land under FMAPs, see Figure 6.16-1).

Forest management resulted in net removals in all years within the reporting period. Carbon stock changes in living biomass resulted in removals presented in Table 6.16-13.

Table 11.5-1: Emissions/removals of Article 3.4 activity

Activity	Emissions/removals (Gg CO$_2$)												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	-7,760.33	-7,933.42	-7,686.39	-6,766.99	-6,593.99	-6,683.43	-6,344.86	-5,676.04	-5,654.31	-5,438.19	-5,332.39	-5,558.11	-5,920.99

11.5.5 Information on the extent to which GHG removals by sinks offset the debit incurred under Article 3.3.

According to the estimation performed for activities subject of Article 3.3 of the Kyoto protocol, removals by sink achieved through afforestation activities are higher than emissions incurred due to deforestation activities during the period 2008-2019. Consequently, there are no debits that should be offset from the GHG removals by sink in this period.

11.6.Other information

There is no other information.

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

The IPCC 2006 Guidelines state that "Whenever a category is identify as key in LULUCF inventor, it is good practice that the associated activity under the KP also be treated a Key category". According to this approach, FM, afforestation and deforestation activities can be considered as key categories in Croatia (Table 11.6.-1).

The conducted significance analyses shows that above-ground biomass is significant pool under the FM activity, while in case of ARD activities, above-ground biomass and soil are significant pools.

Table 11.6-1: Summary overview of key categories for LULUCF activities under the Kyoto Protocol (CRF – NIR 2021 table NIR-3)

TABLE NIR 3. SUMMARY OVERVIEW FOR KEY CATEGORIES FOR LAND USE, LAND-USE CHANGE AND FORESTRY ACTIVITIES UNDER THE KYOTO PROTOCOL

KEY CATEGORIES OF EMISSIONS AND REMOVALS	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments[4]
		Associated category in UNFCCC inventory[1] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory[2] (including LULUCF)	Other[3]	
Specify key categories according to the national level of disaggregation used[1]					
Afforestation and Reforestation					
CO2	CO2	Land converted to forest land	Yes		Level 1, Level 2, Trend 1, Trend 2
Deforestation					
CO2	CO2	Land converted to settlements	Yes		Level 1, Level 2, Trend 1, Trend 2
Forest Management					
CO2	CO2	Forest land remaining forest land	Yes		Level 1, Level 2, Trend 1, Trend 2

[1] See section 2.3.6 of the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.
[2] If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO.
[3] This should include qualitative assessment as per section 4.3.3 of the 2006 IPCC Guidelines or any other criteria.
[4] Indicate the criteria (level, trend of both) identifying the category as key.

11.7. Information relating to article 6

Croatia does not participate in any project under Article 6.

References

Energy sector

1.   Central Bureau of Statistics (2021) Statistical Yearbook, Zagreb

2.   Ministry of Economy and Sustainable Dvelopement (2020) Republic of Croatia Informative Inventory Report for 2020, under Convention on Long-range Transboundary Air Pollution (CLRTAP), EKONERG Ltd., Zagreb

3.   FCCC/IRR/2008/HRV Report of the review of the initial report of Croatia, 26 August 2009

4.   FCCC/ARR/2008/HRV Report of the initial review of the greenhouse gas inventories of Croatia submitted in 2007 and 2008, 5 November 2009 (advance version)

5.   FCCC/ARR/2009/HRV Report of the individual review of the greenhouse gas inventory of Croatia submitted in 2009 Centralized Review Report

6.   FCCC/ARR/2010/HRV Report of the individual review of the annual submission of Croatia submitted in 2010, 20 January 2011

7.   FCCC/ARR/2012/HRV Report of the individual review of the annual submission of Croatia submitted in 2012, 8 February 2013

8.   FCCC/ARR/2012/HRV Report of the individual review of the annual submission of Croatia submitted in 2014, 7 May 2015

9.   EEA (2000) COPERT IV Computer Programme to Calculate Emissions from Road Transport, Denmark

10.   INA (2012) Data about natural gas scrubbing in Central Gas Station MOLVE and sulphur content in liquid fossil fuels, INA – Oil and Gas Company, data sent by fax or by mail

11.   INA (2013) Data about number of active wells, INA – Oil and Gas Company, data sent by mail

12.   IPCC/UNEP/WMO (2006) IPCC Guidelines for National Greenhouse Inventories, Volume 2, Energy, Japan

13.   IPCC (2000) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Japan

14.   IPCC/UNEP/OECD/IEA (1997) Greenhouse Gas Inventory – Workbook, Revised 1996 IPCC Guidelines for National Greenhouse Inventories, Volume 2, United Kingdom

15.   IPCC/UNEP/OECD/IEA (1997) Greenhouse Gas Inventory – Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Inventories, Volume 3, United Kingdom

16.   Ministry of Economy, Labour and Entrepreneurship (2012) Energy in Croatia 2012, Annual Energy Report, Energy Institute "Hrvoje Požar", Zagreb

17.   Ministry of Environmental and Nature Protection (2015) National Inventory Report 2015, Croatian greenhouse gas inventory for the period 1990 – 2013, EKONERG, Zagreb

18.   Ministry of Environmental and Nature Protection (2010) Fifth National Communication of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC), Zagreb

19.   Ministry of Environmental and Nature Protection (2006) Second, Third and Fourth National Communication of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC), Zagreb

20.   Ministry of Interior (2029) Motor Vehicle Databases for 1990-2019, data on CD

21. Vuk B. National Energy Balances–for the period from 1990 till 2019, Energy Institute Hrvoje Požar, Zagreb

22. Vuk B. Industry analysis balance–for period from 2001 till 2019, Energy Institute Hrvoje Požar, Zagreb

23. EUROSTAT energy balance for Croatia for the period 1990 till 2019

Industrial processes and product use

24. Central Bureau of Statistics, Industry, Energy and Information Society Department, Annual PRODCOM results (1990 - 2020), Zagreb

25. Central Bureau of Statistics, Statistical Yearbooks (1990 - 2020), Zagreb

26. CROATIA CEMENT g.i.u (2007) Report: Activity data for CO2 emission calculations from Portland cement production, in the framework of study Croatian Cement Industry and Climate Change, EKONERG Ltd., Zagreb

27. Croatian Environment Agency (2016) Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2014 Submission to the Convention on Long-range Transboundary Air Pollution, EKONERG Ltd., Zagreb

28. FCCC/ARR/2014/HRV Report on the individual review of the annual submission of Croatia submitted in 2014, 15 June 2015

29. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.). Published: IGES, Japan., Volume 2: Energy

30. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.). Published: IGES, Japan., Volume 3: Industrial Processes and Product Use

31. ISTRA CEMENT Ltd. (2008) Report: Activity data for CO2 emission calculations from Portland and Aluminate cement production, in the framework of survey Programme of Reduction of CO2 Emission in Istra Cement Ltd., EKONERG Ltd., Zagreb

32. Ministry of Environmental and Nature Protection (2015) National Inventory Report 2015, Croatian greenhouse gas inventory for the period 1990 – 2013, EKONERG, Zagreb

33. Ministry of Environmental and Nature Protection (2014) Sixth National Communication and First Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC), Zagreb

34. Ministry of Environmental and Nature Protection (2015) Second Biennial Report of the Republic of Croatia under the UN Framework Convention on Climate Change, Zagreb

35. PROMINS g.i.u (2008) Report: Activity data for CO2 emission calculations from lime production, in the framework of study Croatian Lime Industry and Climate Change, EKONERG Ltd., Zagreb

Agriculture

36. Bašić, F., O. Nestroy, I. Kisić, A. Butorac, M. Mesić (1988) Protection from erosion – the key role of soil cultivation in present and changed climate conditions, Croatian Academy of Sciences and

Arts – Scientific conference with international participation "The adjustment of agriculture and forestry to climate and its changes", pages 115-125, Zagreb

37. Butorac, A., (1963) Thermal condition of soil and the most characteristic temperature thresholds for certain sites in main agricultural regions of Croatia, Agricultural Gazette 12/63

38. Central Bureau of Statistics, Statistical Yearbooks (1990-2016), Zagreb

39. Croatian Environment Agency (2018) Republic of Croatia Informative Inventory Report for LRTAP Convention for the Year 2016 Submission to the Convention on Long-range Transboundary Air Pollution, EKONERG Ltd., Zagreb

40. EMEP/CORINAIR Atmospheric Emission Inventory Guidebook 2007

41. IPCC/UNEP/OECD/IEA (1997) Greenhouse Gas Inventory Workbook, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, United Kingdom

42. IPCC/UNEP/OECD/IEA (1997) Greenhouse Gas Inventory Reference Manual, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, United Kingdom

43. FAO database www.fao.org

44. Ministry of Environmental and Nature Protection (2013) National Inventory Report 2013, Croatian greenhouse gas inventory for the period 1990 – 2011, EKONERG Ltd., Zagreb

45. Ministry of Environmental and Nature Protection (2010) Fifth National Communication of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC), Zagreb

46. Response of Croatia to Potential Problems and Further Questions from the ERT formulated in the course of the 2012 review of the greenhouse gas inventories of Croatia submitted in 2012

47. FCCC/ARR/2011/HRV Report of the individual review of the annual submission of Croatia submitted in 2012

48. Znaor, D. and Karoglan Todorović, S.,(2005) Analysis of yields, nitrogen content and N-fixation of Croatian agricultural production in 2002-2003, University of Essex, Colchester. Unpublished

LULUCF and KP LULUCF

49. Badjun, S. (1965) Physical and mechanical properties of Oakwood from forest district "Lubardenik" Lipovljani, Drvna industrija 16: 2-8.

50. Badjun, S. (1977) Comparative Wood Quality Appreciation, Drvna industrija 28: 125-131.

51. Croatian Bureau of Statistics (1999) Statistical Yearbook of the Republic of Croatia, Croatian Bureau of Statistics: 228

52. Croatian Bureau of Statistics (2011-2012) Statistical Yearbooks of the Republic of Croatia, Croatian Bureau of Statistics

53. Croatian Environment Agency (2013), http://www,azo,hr/CORINELandCover: 2-5

54. Croatian Forests (2006) Forest Management Area Plan of the Republic of Croatia 2006-2015 (FMAP 20016-2015), Public company "Croatian Forests"

55. Croatian Geological Institute (2012) Total nitrogen and organic carbon in soils of the Republic of Croatia, Croatian Environment Agency

56. Croatian Parliament (1993) Law on amendments to the Law on Forests Official Gazette No 76

57. Croatian Parliament (2006), Ordinance on Forest Management, Official Gazette No. 111

58. Croatian Parliament (2009) Energy Development Strategy of the Republic of Croatia, Official Gazette No 130

59. Croatian Parliament (2012) Law on Energy, Official Gazette No 120

60. Croatian Parliament (2017), Regulation on monitoring of greenhouse gas emissions, policies and measures for their reduction in the Republic of Croatia, Official Gazette No. 5

61. Croatian Parliament (2018), Ordinance on Forest Management, Official Gazette No. 97

62. Decision 2/CMP.7 Land use, land-use change and forestry

63. Decision 24/CP.19 Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention

64. 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

65. Environment Agency Austria (2012), National inventory report 2012, Submission under the UNFCCC and the Kyoto Protocol, http://unfccc,int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598,php

66. Food and Agriculture Organization of the United Nations (FAO, 2016), Forest Products Classification and Definitions, Global Strategy Working Papers.

67. Food and Agriculture Organization of the United Nations (FAO, 2017), Joint FAO/ECE/EUROSTAT/ITTO Questionnaire - Joint Forest Sector Questionnaire Definitions.

68. Government of the Republic of Croatia (1993) The Regulation on amendments to the Law on Forests, Official Gazette No 14.

69. Government of the Republic of Croatia (2007) Tariff system for the production of electricity from renewable energy sources and cogeneration, Official Gazette No 33

70. Government of the Republic of Croatia (2013) Draft strategy for management and disposal of property of the Republic of Croatia 2013-2017, http://www.duudi.hr/wp-content/uploads/2013/04/nacrt-Strategije.pdf : 43,

71. Govorčin S., T. Sinković, J. Trajković, B. Šefc (2011) Structural, technical and usable properties of some commercial wood species, Academy of Forestry Sciences: 647.

72. Horvat, I. (1957) Investigations on technical properties of Slavonian Oakwood, Šumarski list 81: 321-360.

73. Horvat, I. (1958) Investigations on technical properties of fir-wood (Abies Alba Mill,) from Gorski kotar, Drvna industrija 9: 2-10.

74. Horvat, I. (1969) Some physical and mechanical properties of beechwood from Gorski kotar Žumberak, Petrova gora, Senjsko bilo and Velebit, Drvna industrija 20: 183-194.

75. 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

76. Ministry of Agrculture, Forest Management Area Plan for the Republic of Croatia for the period 2016-2025 (FMAP 2016-2025)

77. Ministry of Economy (2006) Amendments to the plan of development, construction and modernization of gas transportation system in the Republic of Croatia from 2002 to 2011 - The second investment cycle 2007 – 2011, http://www.plinacro.hr/default.aspx?id=44

78. Ministry of Regional Development, Forestry and Water management (2006) Regulations on the procedure for granting funds from fees for the use of beneficial functions of forests for work performed in private forests, Official Gazette No 66

79. Ministry of Regional Development, Forestry and Water management (2008) Ordinance on amendments to the Ordinance on the Register of forest owners, Official Gazette No 84

80. Ministry of Regional Development, Forestry and Water management (2010) Forest Resources Assessment Croatia 2010 (FRA 2010)

81. Republic of Bulgaria, Ministry of Environment and Water, Executive Environment Agency (2012), National inventory report 2012, Submission under the UNFCCC and the Kyoto Protocol, http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php

82. Section of Forestry and Wood Industry Association of Engineers and Technicians People's Republic of Croatia (1949), Small Forestry-technical Manual: 215

83. Sinković, T. (1991) Some physical properties of fir-wood from Gorski kotar, Drvna industrija 42: 17-21.

84. Sinković, T., S. Govorčin, T. Sedlar (2011) Comparison of Physical Properties of Untreated and Heat treated Beech and Hornbeam, Drvna industrija 62: 283-290.

85. Štajduhar, F. (1972) A contribution to Physical and mechanical properties investigation of Beechwood in Croatia, Drvna industrija 23: 43-59.

86. The Intergovernmental Panel on Climate Change (IPCC, 2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

87. Intergovernmental Panel on Climate Change (IPCC, 2013), IPCC 2014 - Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds) Published: IPCC, Switzerland.

Waste
88. Croatian Bureau of Statistics, Statistical Yearbooks (1990 - 2020)

89. Croatian Bureau of Statistics, First Releases (2013, 2016, 2019, 2020)

90. Croatian Environment Agency (2012) Environment Report of the Republic of Croatia 2005 – 2008, Zagreb

91. Decision on the adoption of theWaste Management Plan of the Republic of Croatia for the period 2017 - 2022 (OG 3/2017, 1/2022)

92. Government of the Republic of Croatia (2005) Waste Management Strategy of the Republic of Croatia, Zagreb

93. FAOSTAT: Statistical Database, http://www.fao.org

94. FCCC/ARR/2020/HRV Report on the individual review of the annual submission of Croatia submitted in 2020, 21 June 2021

95. Fundurulja, D., Mužinić, M. (2000) Estimation of the Quantities of Municipal Solid Waste in the Republic of Croatia in the period 1990 – 1998, Zagreb (part of the Background data for the 1st NC of Croatia)

96. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.). Published: IGES, Japan., Volume 2: Energy

97. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.). Published: IGES, Japan., Volume 5: Waste

98. Ministry of Economy and Sustainable Development (2021) Annual data collection plan NIR 2022 – Waste, Zagreb

99. Ministry of Economy and Sustainable Development (2021) National Inventory Report 2021, Croatian greenhouse gas inventory for the period 1990 – 2019, EKONERG Ltd., Zagreb

100. Ministry of Economy and Sustainable Development (2021) Republic of Croatia 2021 Informative Inventory Report (1990 – 2019) Submission to the Convention on Long-range Transboundary Air Pollution (CLRTAP) and National Emission Ceilings Directive (NECD 2016/2284/EU), EKONERG Ltd., Zagreb

101. Ministry of Economy and Sustainable Development (2021) The 2020 Municipal Waste Report, Zagreb

102. Ministry of Environment and Energy (2018) Seventh National Communication and Third Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change (UNFCCC), Zagreb

103. Ministry of Environmental and Nature Protection (2006) Guidelines Development for starting implementation of Waste Management Plan in the Republic of Croatia, LIFE04 TCY/CRO/000028, EKONERG Ltd., Zagreb

104. Potočnik, V. (2000) Report: The basis for methane emission estimation in Croatia 1990-1998, B. Data on Municipal Solid Waste in Croatia 1990-1998, Zagreb (part of the Background data for the 1st NC of Croatia))

105. Waste Management Act (OG 84/2021)

List of tables and figures

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
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