LIFE CLIM'FOOT
DELIVERABLE C2.2: NATIONAL DATABASE OF EMISSION FACTORS, CROATIA

EIHP

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1. Contents

Acronyms and abbreviations

ADEME	The French Environment and Energy Management Agency
AWMS	Animal waste management system
BOD	Biochemical oxygen demand
CAEN	Croatian Agency for the Environment and Nature
CBS	Croatian Bureau of Statistics
CF DB	Clim'Foot database
CH4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COPERT	Computer Programme to Calculate Emissions from Road Transport
CRF	Common Reporting Format
DB	Database
DOC	Degradable organic carbon
DQR	Data quality rating
EF	Emission factor
EFDB	Emission factor database
EIHP	Energy Institute Hrvoje Požar
EKONERG	Energy and Environmental Protection Institute
ELCD	European Life Cycle Database
EU ETS	European Emissions Trading System
FOD	First order decay
GeR	Geographical representativeness
GHG	Greenhouse gas
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
IEF	Implied emission factor
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LULUCF	Land Use, Land Use Change and Forestry
MCF	Methane correction factor
MEE	Ministry of Environment and Energy
MSW	Municipal solid waste
N_2O	Nitrous oxide
Nex	Nitrogen excretion rate
NH_3	Ammonia
NIR	National Inventory Report
NMVOC	Non-methane volatile organic compound
NO_x	Nitrogen oxide
ODS	Ozone depleting substances
OX	Oxidation factor
SO_x	Sulphur oxide
TeR	Technological representativeness
TiR	Time representativeness
U	Uncertainty
Ym	Methane conversion factor

1. Introduction

The aim for constituting the National databases of country-specific emission factors is to provide the basis for developing the Clim'Foot Database (CF DB). Common methodology is necessary in order to:

- achieve consistency on the CF DB creation
- share data within the project
- replicate the project results

Following data set are included in the CF DB:

- metadata - provide description of the data set aimed to guaranty comprehensive information to support the end user when choosing the right dataset for the Carbon Footprint calculation;
- elementary flows - comprise all greenhouse gases (GHG) emitted in the environment by the human activities and are described in the data set with the related quantity of activities considered;
- characterized GHG in CO_2e - emitted GHGs are multiplied by their characterization factor to express different emissions caused by human activities, presented as equivalent CO_2 emission (CO_2e) in the data set.

2. Methodology

The methodology for constituting the Croatian National Database of Emission Factors to Calculate the Carbon Footprint (Croatian Carbon Footprint Database) is defined by the document Methodology for constituting the National Databases, made within the LIFE Clim'Foot project. Proposed methodological issues have been considered in the calculation of country-specific emission factors (EF) to create CF DB.

The main reference for the methodology to develop CF DB is the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) that define the methodology to calculate GHG EFs. Croatian National Inventory Report 2017, Greenhouse Gas Inventory 1990 - 2015 (Croatian NIR 2017) contains data and information on EFs for the following sectors: Energy, Industrial processes and product use, Agriculture, LULUCF and Waste. NIR contains data from the relevant National DBs, such as Energy Balances, Statistical Yearbooks, Environmental Pollution Register, Waste Management Information System as well national scientific research.

To fulfil Clim'Foot scope that comprises Life Cycle Inventory (LCI), information about EFs have been collected from other existing sources that are consistent with the Clim'Foot domain. For this purpose, data from European/International DBs have been considered whereby the issue of harmonization to national circumstances has been taken into account. The following DBs have been analysed:

- EFDB - Emission Factor Database (IPCC – International)
- Base Carbone (ADEME – France)
- ELCD - European Life Cycle Database (JRC – EU)
- Bilan Carbone® tool - version 7.4 (2015), which is adapted for the Clim'Foot project and Base Carbone Version 1.01 (2013, ADEME) have been used for EF harmonization bearing in mind coverage of sectors and categories, aggregation of data and comparability of datasets. More information is provided in Chapters 3.1 - 3.10.

Croatian Carbon Footprint Database includes the following sectors:

- Fossil and organic fuels
- Electric energy
- Heat/cool energy
- Freight transport
- Passenger transport
- Land Use, Land Use Change and Forestry (LULUCF)
- Waste
- Agriculture
- Purchasing of goods
- Refrigerants

Following GHGs are included:

- Fossil carbon dioxide (CO_2)
- Biogenic carbon dioxide (CO_2b)
- Fossil methane (CH_4f)
- Biogenic methane (CH_4b)

- Nitrous oxide (N_2O)
- Sulphur hexafluoride (SF_6)
- Hydrofluorocarbons (HFC-32, HFC-125, HFC-134a, HFC-143a).

Several categories are included within each sector, as detailed elaborated in Chapters 3.1 - 3.10. EFs have been calculated for each GHG existing in defined categories. EFs are included in the Excel document Croatian National DBs Clim'Foot DB with related information about name and unique code for each category, process name, source and collector of data, technical description and unit, data quality statement, as well as rating of time-related, technological and geographical representativeness.

Chapters 3.1. – 3.10. contain detailed information on:
- technical description
- methodology and data sources
- data quality and uncertainty analysis

Technical description presents relevant information on processes and national circumstances that are important for understanding in which way each process contribute to GHG emissions.

Description of methodology for calculation of EFs provides information on methodology level used, including the scopes that are covered. Data sources for EF calculation are also explained.

Quality rating has been performed for each criteria:
- time representativeness (TiR)
- technological representativeness (TeR)
- geographical representativeness (GeR)
- uncertainty (U)

The data quality rating (DQR) result is used to identify corresponding quality level.

3. Database analysis

3.1 Fossil and organic fuels

Technical description

The national database of emission factors covers stationary and mobile fuel combustion of fossil and organic fuels, divided in the following categories:

- Solid fossil fuels: lignite (stationary), brown coal (stationary) and hard coal (stationary)
- Solid organic fuels: wood briquettes (stationary), wood pellets (stationary), wood chips (stationary), charcoal (stationary) and firewood (stationary)
- Liquid fossil fuels: extra light fuel oil (stationary), heavy fuel oil (stationary), petroleum (stationary), LPG (stationary), gasoline (mobile), diesel fuel (mobile), jet fuel (mobile) and LPG (mobile)
- Gaseous fossil fuels: natural gas (stationary) and compressed natural gas (mobile)

The calculation of county-specific emission factors is based on National energy balances and the National inventory report (NIR). The data set represents the Croatian energy system and country-specific fuel characteristics. Calculated emission factors cover the emissions from the following anthropogenic greenhouse gases: CO_2, CH_4 and N_2O.

Lignite, brown coal and hard coal combustion

The total emission factor CO_2e per unit of consumed lignite/brown coal/hard coal, besides direct emissions of GHG, considers consumption of electricity from the power grid and diesel fuel during the production process. The emission from of diesel fuel in transportation of lignite/brown coal/hard coal from the production to the consumption location is also added.

Wood briquettes, wood pellets and wood chips combustion

Wood briquettes/pellets/chips are renewable energy source, without direct fossil emissions of CO_2 during the combustion process. The emitted CO_2 has biogenic origin. Although, the electricity is consumed during the production of briquettes/pellets/chips. The diesel fuel is combusted and greenhouse gases are emitted, because of the transport of briquettes/pellets/chips from production to consumption place. Thus, the CO_2e emission factors for wood briquettes/pellets/chips are calculated, based on the electricity and diesel fuel consumption.

Charcoal combustion

Charcoal is transformed renewable energy sources produced from firewood. Therefore, there are no direct fossil emissions of CO_2 from combustion. The emitted CO_2 has biogenic origin. 2.5 kg of wood should be consumed for production of 1 kg of charcoal. The consumed gasoline and diesel fuel for manufacturing process and transport of charcoal to the location of production has been considered in calculation. The consumption of diesel in charcoal transport to the consumption location has been also added. Thus, the CO_2e emission factor for charcoal is calculated, based on gasoline and diesel consumption.

Firewood combustion

Firewood is renewable energy sources, so there are no direct fossil emissions of CO_2 from combustion. The emitted CO_2 has biogenic origin. However, gasoline and diesel fuel are used in the manufacturing process. Diesel fuel is also consumed in the transport of firewood to the location of consumption. Thus, the CO_2e emission factor for firewood is calculated, based on fossil fuels consumption.

Diesel and gasoline combustion

In the calculation of CO_2e emission factor for the diesel/gasoline combustion, besides direct emissions from fuel combustion, the emissions which occur in the supply chain and transport to the location of consumption are also added. The losses and own consumption of fuels (fuel oil, petroleum coke, refinery gas, LPG and natural gas) during the production process of petroleum products in refineries are included in the calculation. The own consumption of natural gas as well as the electricity consumption from the power grid for the production process of crude oil and refinery production are also included. Finally, the emission from diesel which occurs in transport process from the production to the consumption place has been added.

Extra light and heavy fuel oil combustion

In the calculation of CO_2e emission factor for the extra light and heavy fuel oil combustion, besides direct emissions from fuel combustion, the emissions which occur in the supply chain and transport to the location of consumption are also added. The losses and own consumption of fuels (fuel oil, petroleum coke, refinery gas, LPG and natural gas) during the production process of petroleum products in refineries are included in the calculation. The own consumption of natural gas as well as the electricity consumption from the power grid for the production process of crude oil and refinery production are also included. Finally, the emission from diesel oil which occurs in transport process from the production to the consumption place has been added.

Petroleum (stationary) and jet fuel (mobile) combustion

In the calculation of CO_2e emission factor for the petroleum and jet fuel combustion, besides direct emissions from fuel combustion, the emissions which occur in the supply chain and transport to the location of consumption are also added. The losses and own consumption of fuels (fuel oil, petroleum coke, refinery gas, LPG and natural gas) during the production process of petroleum products in refineries are included in the calculation. The own consumption of natural gas as well as the electricity consumption from the power grid for the production process of crude oil and refinery production are also included. Finally, the emission from diesel oil which occurs in transport process from the production to the consumption place has been added.

LPG combustion (stationary and mobile)

In the calculation of CO_2e emission factor for the LPG, besides direct emissions from fuel combustion, the emissions which occur in the supply chain and transport to the location of consumption are also added. The losses and own consumption of fuels (fuel oil, petroleum coke, refinery gas, LPG and natural gas) during the production process of petroleum products in refineries are included in the calculation. The own consumption of natural gas as well as the electricity consumption from the power grid in the NGL (natural gas liquids) plant, because it is a part of the production process for the LPG. The consumption of natural gas to produce cruel oil is also included, as the consumption of electricity from the power grid to produce crude oil and refinery production, as well as the own consumption for the production of natural gas and light fractions which are used in the NGL plant for the production of LPG. Finally, the emission from diesel oil which occurs in transport process from the production to the consumption place has been added.

Natural gas (stationary) and compressed natural gas (mobile) combustion

The direct emissions of CO_2e generated during the combustion of natural gas are increased for the own consumption in production process and the losses of natural gas which occur during the transport and distribution to the consumption location. The emission from the consumption of electricity from the power grid in the production chain, as well as the required electricity for the transport and distribution of gas, are also added.

Methodological issues

The data set considers the whole supply chain from fuel exploration over the processing and transportation to the consumption by end-users (households, services or industrial facilities). The emission factors for the combustion of fossil fuels (stationary and mobile) are in accordance with national energy balances. An average value of the last 6 years (2010-2015) has been considered for the calculation of the emission factors. All elementary flows and relevant characterization factors (Global Warming Potentials) have been used in the calculation.

The results of calculation are 18 emission factors for fossil and organic fuels used in Croatia (Tables 3.1-1 and 3.1-2). The total emission factors for CO_2e is a sum of emission factors for presented greenhouse gases, expressed as kg CO_2e per MWh.

Table 3.1-1: CO_2, CH_4 and N_2O EFs for fossil and organic fuels

Fossil and organic fuels	Breakdown of GHG emissions by type (kg CO_2e per MWh)					
	CO_2		CH_4 f		N_2O	
Type of fuel	upstream	combustion	upstream	combustion	upstream	combustion
Lignite (stationary)	5.30E+01	3.64E+02	1.30E+00	1.08E-01	4.30E-01	1.43E+00
Brown coal (stationary)	3.93E+01	3.46E+02	1.29E+00	1.08E-01	3.32E-01	1.43E+00
Hard coal (stationary)	5.84E+01	3.41E+02	1.31E+00	1.08E-01	4.69E-01	1.43E+00
Wood briquettes (stationary)	4.87E+01	0.00E+00	2.71E+00	3.24E+00	4.57E-01	3.82E+00

Wood pellets (stationary)	4.87E+01	0.00E+00	2.71E+00	3.24E+00	4.57E-01	3.82E+00
Wood chips (stationary)	4.85E+01	0.00E+00	1.91E+00	3.24E+00	4.23E-01	3.82E+00
Charcoal (stationary)	4.21E+01	0.00E+00	6.20E-02	3.24E+00	3.06E-01	3.82E+00
Firewood (stationary)	2.66E+01	0.00E+00	3.49E-02	3.24E+00	1.92E-01	3.82E+00
Extra light fuel oil (stationary)	5.10E+01	2.67E+02	1.66E-01	3.24E-01	1.05E-01	5.72E-01
Heavy fuel oil (stationary)	5.31E+01	2.79E+02	1.68E-01	3.24E-01	1.09E-01	5.72E-01
Petroleum (stationary)	5.13E+01	2.59E+02	1.66E-01	3.24E-01	1.05E-01	5.72E-01
LPG (stationary)	5.00E+01	2.27E+02	1.73E-01	1.08E-01	1.00E-01	9.54E-02
Gasoline (mobile)	4.83E+01	2.49E+02	1.64E-01	1.73E+00	1.00E-01	2.09E+00
Diesel fuel (mobile)	5.10E+01	2.67E+02	1.66E-01	2.77E-01	1.05E-01	1.91E+00
Jet fuel (mobile)	4.90E+01	2.57E+02	1.64E-01	5.40E-02	9.89E-02	1.91E+00
LPG (mobile)	5.00E+01	2.27E+02	1.73E-01	1.24E+00	1.00E-01	2.56E+00
Natural gas (stationary)	1.95E+01	2.02E+02	1.94E-01	1.08E-01	1.35E-02	9.54E-02
Compressed natural gas (mobile)	1.95E+01	2.02E+02	1.94E-01	6.07E+00	1.35E-02	1.55E-02

Table 3.1-2: Total CO_2e EFs and biomass-related CO_2 EFs for fossil and organic fuels

Fossil and organic fuels	**Total emissions**		**Biomass-related CO_2 emissions**	
	kg CO_2e per MWh		**kg CO_2 per MWh**	
Type of fuel	upstream	combustion	upstream	combustion
Lignite (stationary)	5.47E+01	3.65E+02	2.28E+00	0.00E+00
Brown coal (stationary)	4.09E+01	3.47E+02	2.28E+00	0.00E+00
Hard coal (stationary)	6.01E+01	3.42E+02	2.28E+00	0.00E+00
Wood briquettes (stationary)	5.19E+01	7.06E+00	4.87E+00	3.60E+02
Wood pellets (stationary)	5.19E+01	7.06E+00	4.87E+00	3.60E+02
Wood chips (stationary)	5.08E+01	7.06E+00	3.41E+00	4.03E+02
Charcoal (stationary)	4.25E+01	7.06E+00	0.00E+00	4.03E+02
Firewood (stationary)	2.68E+01	7.06E+00	0.00E+00	4.03E+02
Extra light fuel oil (stationary)	5.13E+01	2.68E+02	2.27E-01	0.00E+00
Heavy fuel oil (stationary)	5.34E+01	2.80E+02	2.27E-01	0.00E+00
Petroleum (stationary)	5.16E+01	2.60E+02	2.27E-01	0.00E+00
LPG (stationary)	5.02E+01	2.27E+02	2.41E-01	0.00E+00
Gasoline (mobile)	4.86E+01	2.53E+02	2.27E-01	0.00E+00
Diesel fuel (mobile)	5.13E+01	2.69E+02	2.27E-01	0.00E+00
Jet fuel (mobile)	4.93E+01	2.59E+02	2.27E-01	0.00E+00
LPG (mobile)	5.02E+01	2.31E+02	2.41E-01	0.00E+00
Natural gas (stationary)	1.97E+01	2.02E+02	1.35E-01	0.00E+00
Compressed natural gas (mobile)	1.97E+01	2.08E+02	1.35E-01	0.00E+00

Data quality and uncertainty analysis

According to the Croatian NIR, the uncertainty of emission calculations from fuel combustion is relatively small. The uncertainty associated with activity data from national energy balance is less than 5%, while the uncertainty associated with emission factors is also very low for the case of CO_2, less than 5%. 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 accuracy of data on net calorific values, which were also taken from national energy balance, is high. Consequently, the largest part of uncertainty refers to the EF applied while the fuel consumption data (national energy balance) are rather good.

Data quality rating (DQR)

Data quality rating of the EFs for time-related representativeness, geographical representativeness and uncertainty criteria (TiR, GeR and U) of each fossil and organic fuel has been determined as very good, while for technological representativeness (TeR) as good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.1-3.

Table 3.1-3: Data quality rating for fossil and organic fuels

Fossil and organic fuels	TiR	TeR	GeR	U	DQR
Solid fossil fuels	good	good	good	very good	**very good**
Solid organic fuels	good	good	good	very good	**very good**
Liquid fossil fuels	good	good	good	very good	**very good**
Gaseous fossil fuels	good	good	good	very good	**very good**

3.2 Electricity

Technical description

The starting point for calculating the emission factors for electrical energy is the structure of the electricity mix supply system. The supply system consists of renewable energy sources (hydropower plans, wind power plants and PVs), thermal power plants (hard coal, natural gas, extra light fuel oil, heavy fuel oil, landfill gas), cogeneration plants (natural gas, biogas, biomass, extra light fuel oil, heavy fuel oil), imported electricity from nuclear power plant Krško in Slovenia (under the joint ownership of the Croatian company HEP d.d. (50%) and the Slovenian company ELES GEN d.o.o. (50%)) and other imported electricity. After that, the calculation comprises transmission and distribution losses, as well as their own electricity consumption in various plants on different fuel. It also includes the efficiency of each power plant with different energy sources for electricity production. Finally, applying emission factors of primary energy for each type of fuel in electricity production will determine the total consumption of energy sources in the supply chain. The total average emission of CO_2e per unit of electricity is calculated by using emission factors of greenhouse gases (CO_2, CH_4, N_2O) for each fuel.

Methodological issues

The data set considers the average national specific electricity consumption mix, based on electricity production in Croatia, import and export. The emission factor for the combustion in electricity production is in accordance with national energy balances for the period from 2010 to 2015, because the annual differences can be significant. All elementary flows and relevant characterization factors (Global Warming Potentials) have been used in the calculation.

For each greenhouse gas, the sum of all emissions is divided by electricity consumption in MWh to achieve the average EF of national electricity mix as reported in Tables 3.2-1 and 3.2-2. Total emission factors for CO_2e are sum of emission factors for presented greenhouse gases, expressed as kg CO_2e per MWh.

Table 3.2-1: CO_2, CH_4 and N_2O EFs for electricity consumption

Electricity	Breakdown of GHG emissions by type (kg CO_2e per MWh)					
	CO_2		CH_4 f		N_2O	
	upstream	combustion	upstream	combustion	upstream	combustion
National electricity mix	5.87E+01	2.95E+02	0.00E+00	2.70E+01	0.00E+00	3.61E+01

Table 3.2-2: Total CO_2e EFs and biomass-related CO_2 EFs for electricity consumption

Electricity	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per MWh		kg CO_2 per MWh	
	upstream	combustion	upstream	combustion
National electricity mix	5.87E+01	3.25E+02	0.00E+00	4.87E+01

Data quality and uncertainty analysis

The uncertainty of emission calculation for electricity consumption is relatively small. In the calculation of GHG emission factors, besides direct emissions from fuel combustion in power plants, emissions which occur in the supply chain from extraction (domestic production and imports), processing, as well as transportation are calculated. The calculation is based on the structure of the electricity mix supply system, which consists of renewable energy sources, thermal power plants, cogeneration plants and import.

The uncertainty associated with activity data from National energy balance is less than 5%, while the uncertainty associated with CO_2 emission factors is also very low, less than 5%. 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 accuracy of data on net calorific values, which were also taken from national energy balance, is high. Consequently, the largest part of uncertainties is referring to applied EFs while the fuel consumption data (national energy balance) are rather good.

Data quality rating (DQR)

Overall quality rating of the EF for electricity consumption using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as very good. Assessments under the each of criteria and total data quality are presented in the Table 3.2-3.

Table 3.2-3: Data quality rating for electricity consumption

Electricity	**TiR**	**TeR**	**GeR**	**U**	**DQR**
National electricity mix	good	good	good	good	**very good**

3.3 Thermal energy and steam

Technical description

The heat is produced in different heating systems. In Croatia, there are autonomous district heating systems in certain cities (Zagreb, Osijek, Rijeka, Slavonski Brod, Split, Karlovac, Varaždin, Vinkovci, Vukovar and Sisak), which differ from each other. Circumstances in each city have been analysed and the appropriate CO_2e emission factors have been calculated. Furthermore, emission factors for characteristic public heat plants on natural gas, extra light fuel oil, heavy fuel oil and wood chips, as well as emission factors for combined heat and power (CHP) plants are been calculated. Additionally, solar thermal collectors and geothermal heating systems were analysed and appropriate emission factors have been determined.

District heating - public heat plants in Zagreb, Osijek, Rijeka, Slavonski Brod, Split, Karlovac, Varaždin, Vinkovci, Vukovar and Sisak

The starting point for EFs calculation in district heating is the heat quantity supplied to end users from public heat plants in 10 Croatian towns. Quantities of produced heat and consumed fuel in public heat plants have been determinate. In Croatia, district heat is produced in public heat plants from natural gas, extra light fuel oil and heavy fuel oil. The following step in the calculation was assessing distribution losses and own consumption in plants. Considering the efficiency of production in individual plants and factors of primary energy, the corresponding CO_2e emissions have been estimated. Finally, electricity consumption for pumps in the distribution system and appropriate emissions have been calculated.

District heating - public heat plants on natural gas, heavy fuel oil, extra light fuel oil and wood chips

The starting point for EFs calculation in district heating is the heat quantity of heat supplied to end users from public heat plants on natural gas, heavy fuel oil, extra light fuel oil and wood chips. Quantities of heat produced and fuel consumed in public heat plants have been determinate. The following step in the calculation was determining the scope of distribution losses and own consumption in plants. Considering the efficiency of production in plant and factor of primary energy, the corresponding CO_2e emissions have been estimated. Finally, electricity consumption for pumps in the distribution system and appropriate emissions have been calculated.

District heating - average public heat plants for Croatia

For the district heating calculation, the starting point is the quantity of heat supplied to end users from all public heat plants in Croatia. Quantities of heat produced and fuel consumed in public heat plants have been determinate. In Croatia, district heat is produced in public heat plants from natural gas, extra light fuel oil and heavy fuel oil. The following step in the calculation was determining the scope of distribution losses and own consumption in plants. Considering the efficiency of production in individual plants and factors of primary energy, the corresponding CO_2e emissions have been determinate. Finally, electricity consumption for pumps in the distribution system and appropriate emissions have been calculated. Taking into account all these calculations, average CO_2e emission factor for district heating from all public heat plants in Croatia has been calculated.

District heating - public CHP plants in Zagreb, Osijek and average for Zagreb and Osijek

For the district heating calculation, the starting point is the quantity of heat supplied to end users from CHP plants in Zagreb and Osijek. Quantities of heat produced and fuel consumed in cogeneration plants have been calculated. The following step in the calculation was determining the scope of distribution losses and own consumption in plants. Considering the efficiency of production in plants and factors of primary energy, the corresponding CO_2e emissions have been estimated. Finally, electricity consumption for pumps in the distribution system and appropriate emissions have been added.

District heating - average heat consumption in Croatia

For the district heating calculation, the starting point is the quantity of heat supplied to end users from all district heating plants. Quantities of heat produced and fuel consumed in public heat plants and cogeneration plants have been calculated. The structure of fuels origin in each of the previously mentioned sources of district heating has been analysed. In Croatia, district heat is produced in public heat plants from natural gas, extra light fuel oil and heavy fuel oil, while in cogeneration plants, biofuel and biomass are also used besides previously mentioned sources. The following step in the calculation was determining the scope of distribution losses and own consumption in plants. Considering the efficiency of production in individual plants and factors of primary energy, the corresponding CO_2e emissions have been estimated. Finally, electricity consumption for pumps in the distribution system and appropriate emissions have been added.

Solar thermal collectors

There are no CO_2e emissions for production of low temperature heat from solar energy. However, the pumps for the circulation of hot water should be installed, in order to provide functionality of solar thermal collectors. Thus, the CO_2e emission factor is calculated, based on electricity consumption for the operation of pumps in solar thermal collectors.

Geothermal heating systems

There are no CO_2e emissions from the use of geothermal energy. However, pumps for the circulation of hot water should be installed, in order to provide functionality of geothermal heating installations. The electricity consumption is relatively high because of longer transmission distances. Thus, the CO_2e emission factor is calculated, based on electricity consumption for the operation of pumps in geothermal installations.

Methodological issues

The data set represents the currently used technical standard of installed plants for heat production (residential heat and process steam) in Croatia and considers the whole supply chain from fuel exploration over the processing and transportation to the consumption by end-users (households, services or industrial facilities). The emission factors for the combustion in heat production are in accordance with national energy balances. For the calculation of the emission factor an average value of the last 6 years for period from 2010 to 2015 has been considered. All elementary flows and relevant characterization factors (Global Warming Potentials) have been used in the calculation.

In Tables 3.3-1 and 3.3-2, 21 characteristic emission factors for heat consumption in Croatia are presented. Total emission factors represent the sum of emission factors for each greenhouse gas, expressed as kg CO_2e per MWh.

Table 3.3-1: CO_2, CH_4 and N_2O EFs for heat consumption

Heat consumption	**Breakdown of GHG emissions by type (kg CO_2e per MWh)**					
	CO_2		**CH_4 f**		**N_2O**	
Type and/or location of plant	upstream	combustion	upstream	combustion	upstream	combustion
Public heat plants in Zagreb	1.06E+02	2.77E+02	3.21E-01	1.94E-01	1.02E-01	2.46E-01
Public heat plants in Osijek	9.29E+01	2.35E+02	3.04E-01	1.26E-01	6.63E-02	1.11E-01
Public heat plants in Rijeka	1.41E+02	2.64E+02	3.35E-01	1.94E-01	1.24E-01	2.58E-01
Public heat plants in Slavonski Brod	1.02E+02	2.49E+02	3.19E-01	1.77E-01	1.00E-01	2.29E-01
Public heat plants in Split	2.04E+02	3.18E+02	4.12E-01	3.72E-01	2.88E-01	6.56E-01
Public heat plants in Karlovac	1.44E+02	2.61E+02	3.49E-01	2.29E-01	1.57E-01	3.48E-01
Public heat plants in Varaždin	1.02E+02	2.57E+02	3.07E-01	1.38E-01	6.93E-02	1.22E-01
Public heat plants in Vinkovci	1.11E+02	2.83E+02	3.34E-01	2.36E-01	1.30E-01	3.46E-01
Public heat plants in Vukovar	9.89E+01	2.25E+02	3.09E-01	1.35E-01	7.78E-02	1.42E-01
Public heat plants in Sisak	2.64E+02	3.10E+02	3.45E-01	1.66E-01	1.02E-01	1.46E-01
Public heat plants on natural gas	6.63E+01	2.35E+02	2.96E-01	1.26E-01	5.92E-02	1.11E-01
Public heat plants on heavy fuel oil	1.80E+02	3.36E+02	4.03E-01	3.90E-01	2.72E-01	6.90E-01
Public heat plants on extralight fuel oil	1.69E+02	3.16E+02	4.01E-01	3.83E-01	2.68E-01	6.77E-01
Public heat plants on wood chips	8.93E+01	0.00E+00	4.02E+00	3.90E+00	4.45E+00	4.60E+00
Average for all public heat plants	1.28E+02	2.75E+02	3.29E-01	1.91E-01	1.10E-01	2.41E-01
Public CHP plants in Zagreb	1.29E+02	2.21E+02	3.18E-01	1.36E-01	8.98E-02	1.50E-01

Public CHP plant in Osijek	1.41E+02	2.28E+02	3.28E-01	1.57E-01	1.09E-01	1.96E-01
Public CHP plants in Zagreb & Osijek	1.29E+02	2.22E+02	3.19E-01	1.39E-01	9.17E-02	1.56E-01
Average for Croatia	1.30E+02	2.19E+02	3.73E-01	2.85E-01	1.57E-01	3.33E-01
Solar thermal collectors	1.06E+01	0.00E+00	8.09E-01	0.00E+00	1.08E-01	0.00E+00
Geothermal heating systems	3.53E+01	0.00E+00	2.70E+00	0.00E+00	3.61E-01	0.00E+00

Table 3.3-2: Total CO_2e EFs and biomass-related CO_2 EFs for heat consumption

Fossil and organic fuels	**Total emissions**		**Biomass-related CO_2 emissions**	
	kg CO_2e per MWh		**kg CO_2 per MWh**	
Type of fuel	upstream	combustion	upstream	combustion
Public heat plants in Zagreb	1.06E+02	2.77E+02	4.87E-01	0.00E+00
Public heat plants in Osijek	9.32E+01	2.35E+02	4.87E-01	0.00E+00
Public heat plants in Rijeka	1.41E+02	2.64E+02	4.87E-01	0.00E+00
Public heat plants in Slavonski Brod	1.02E+02	2.49E+02	4.87E-01	0.00E+00
Public heat plants in Split	2.05E+02	3.19E+02	4.87E-01	0.00E+00
Public heat plants in Karlovac	1.45E+02	2.62E+02	4.87E-01	0.00E+00
Public heat plants in Varaždin	1.02E+02	2.58E+02	4.87E-01	0.00E+00
Public heat plants in Vinkovci	1.11E+02	2.84E+02	4.87E-01	0.00E+00
Public heat plants in Vukovar	9.93E+01	2.25E+02	4.87E-01	0.00E+00
Public heat plants in Sisak	2.64E+02	3.10E+02	4.87E-01	0.00E+00
Public heat plants on natural gas	6.66E+01	2.35E+02	4.87E-01	0.00E+00
Public heat plants on heavy fuel oil	1.81E+02	3.37E+02	4.87E-01	0.00E+00
Public heat plants on extralight fuel oil	1.70E+02	3.17E+02	4.87E-01	0.00E+00
Public heat plants on wood chips	9.77E+01	8.50E+00	4.87E-01	4.86E+02
Average for all public heat plants	1.29E+02	2.75E+02	4.87E-01	0.00E+00
Public CHP plants in Zagreb	1.29E+02	2.21E+02	4.87E-01	0.00E+00
Public CHP plant in Osijek	1.41E+02	2.28E+02	4.87E-01	0.00E+00
Public CHP plants in Zagreb & Osijek	1.29E+02	2.22E+02	4.87E-01	0.00E+00
Average for Croatia	1.31E+02	2.20E+02	4.87E-01	2.13E+01
Solar thermal collectors	1.15E+01	0.00E+00	1.46E+00	0.00E+00
Geothermal heating systems	3.84E+01	0.00E+00	4.87E+00	0.00E+00

Data quality and uncertainty analysis

According to the Croatian NIR, emission uncertainties of the heat consumption from district heating, solar thermal collectors and geothermal heating systems are relatively small. The uncertainty associated with activity data from National energy balance is less than 5%, while the uncertainty associated with emission factors is also very low for the case of CO_2, less than 5%. 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 accuracy of data on net calorific values, which were also taken from national energy balance, is high. Consequently, the largest part of uncertainty refers to the EF applied while the fuel consumption data (national energy balance) are rather good.

Data quality rating (DQR)

Overall quality rating of the EF for heat consumption using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good. Assessments under the each of criteria and total data quality are presented in the Table 3.3-3.

Table 3.3-3: Data quality rating for heat consumption

Electricity	**TiR**	**TeR**	**GeR**	**U**	**DQR**
Public heat plants	good	good	good	fair	**good**
Public CHP plants	good	good	good	fair	**good**
Solar thermal collectors	good	good	good	fair	**good**
Geothermal heating systems	good	good	good	fair	**good**

3.4 Freight transport

Freight transport consists of four categories:

- Air Transport
- Road transport
- Rail transport
- Sea and waterway transport

For each of this categories EFs were created. For air transport two EFs were created, one for domestic and one for international freight transport. In road transportation category 27 EFs were created based on vehicle type, capacity and age of vehicle. Rail transport category consists of two EFs, based on fuel type, which is used (diesel or electricity). One EF was created for sea and waterway transport.

Technical description

Air Transport

Emissions from aviation come from the combustion of jet fuel (jet kerosene and jet gasoline) and aviation gasoline. Aircraft engine emissions are roughly composed of about 70% CO_2, a little less than 30% H_2O, and less than 1% each of NO_x, CO, SO_x, NMVOC, particulates, and other trace components including hazardous air pollutants. Little or no N_2O emissions occur from modern gas turbines. CH_4 may be emitted by gas turbines during idle and by older technology engines, but recent data suggest that little or no CH_4 is emitted by modern engines.

Road Transport

The mobile source category Road Transportation includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as tractor trailers and buses, and on-road motorcycles (including mopeds, scooters, and three-wheelers). These vehicles operate on many types of gaseous and liquid fuels. For emission calculation, COPERT IV model was used because EFs depend on vehicle technology, fuel and operating characteristics.

The COPERT IV model requires 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 (<1.4L, 1.4-2.0L, >2.0L)
- weight class (<3.5 t, 3.5-7.5 t, 7.5-16 t, 16-32 t, >32 t)
- age of vehicles (distribution of vehicles per ECE categories according to the EC directives)

Main activity data provider is Ministry of Interior, which is responsible for compilation of national motor vehicle database with detailed information on each registered vehicle 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.

Rail Transport

Railway locomotives generally are one of three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors. The GHG emissions from sub-sector Railways were calculated using Tier 1 approach based on fossil fuel consumption data (from national energy balance) and default IPCC EFs. Default EFs for CH_4 and N_2O were modified depending on the engine design.

Sea and Rivers Transport

This source category covers all water-borne transport from recreational craft to large ocean-going cargo ships that are driven primarily by large, slow and medium speed diesel engines and occasionally by steam or gas turbines. It includes hovercraft and hydrofoils. Water-borne navigation causes emissions of CO_2, CH_4 and N_2O. The GHG emissions from Navigation sub-sector were calculated using Tier 1 approach, based on fossil fuel consumption data (from national energy balance) and default IPCC EFs.

Methodological issues

Air Transport

EFs developed for air transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given in Croatian NIR 2017 and tone-kilometers data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. Two EFs were created, one for domestic transport (bellow 1000 km distance) and one for international transport (above 1000 km distance). For each gas, the sum of all emissions is divided by the tonne km travelled to have the EF of air freight transport for Croatia as reported in Tables 3.4-1 and 3.4-2.

For the upstream part of EFs, national database developed by EIHP was used. In Tables 3.4-1 and 3.4-2, EFs for freight air transport are given.

Table 3.4-1: CO_2, CH_4 and N_2O EFs for air freight transport

Air freight	**Breakdown of GHG emissions by type (kg CO_2e per tonne.km)**					
	CO_2		**CH_4 f**		**N_2O**	
Type of flight	upstream	combustion	upstream	combustion	upstream	combustion
Domestic, bellow 1000 km distance	6.66E-03	3.96E-02	2.23E-05	8.33E-06	1.34E-05	2.94E-04
International, above 1000 km distance	2.76E-02	1.47E-01	9.25E-05	2.55E-04	5.56E-05	3.24E-04

Table 3.4-2: Total CO_2e EFs with biomass-related CO_2 EFs for air freight transport

Air freight	**Total emissions**		**Biomass-related CO_2 emissions**	
	kg CO_2e per tonne.km		**kg CO_2e per tonne.km**	
Type of flight	upstream	combustion	upstream	combustion
Domestic, bellow 1000 km distance	6.70E-03	3.99E-02	0.00E+00	0.00E+00
International, above 1000 km distance	2.77E-02	1.48E-01	0.00E+00	0.00E+00

Road transport

EFs developed for road transportation sector consists of three parts; combustion, production and upstream part. Combustion part was calculated based on GHG emissions, kilometers travelled and number of vehicles given in Croatian NIR 2017. For GHG emissions assessment from transport sector COPERT IV model was used. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. According COPERT methodology, vehicles are distributed by categories and classes, and according to ECE regulations governing individual technological solution to reduce emissions in a given period. Freight transport vehicles are divided in two categories: Light commercial vehicles and heavy-duty vehicles. In table 3.4-3 distribution of road freight transportation is given.

Table 3.4-3: Distribution of road freight transport by COPERT IV model

Vehicle	Fuel and weight class	Technology
Light-duty vehicles	Gasoline <3,5t	Conventional
		LD Euro 1 - 93/59/EEC
		LD Euro 2 - 96/69/EEC
		LD Euro 3 - 98/69/EC Stage2000
		LD Euro 4 - 98/69/EC Stage2005
		LD Euro 5 - 2008 Standards
	Diesel <3,5 t	Conventional
		LD Euro 1 - 93/59/EEC
		LD Euro 2 - 96/69/EEC
		LD Euro 3 - 98/69/EC Stage2000
		LD Euro 4 - 98/69/EC Stage2005
		LD Euro 5 - 2008 Standards
		LD Euro 6
Heavy-duty vehicles	Gasoline >3,5 t	Conventional
	Rigid <=7,5 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 7,5 - 12 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 12 - 14 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 14 - 20 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 20 - 26 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 26 - 28 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid 28 - 32 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Rigid >32 t	Conventional
		HD Euro I - 91/542/EEC Stage I

Vehicle	Fuel and weight class	Technology
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 14 - 20 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 20 - 28 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 28 - 34 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 34 - 40 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 40 - 50 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
	Articulated 50 - 60 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards

From 84 categories that are given by COPERT model, 27 EFs were created for freight transport. Euro I and II technologies were presented together as well as Euro III and Euro IV data. Heavy-duty vehicles were summed by transport capacity in 6 classes (for Rigid below 7.5 t, 7.5-20 t, above 326 and for articulated 10-28 t, 28-40 t and 40-60 t). For each gases the sum of all emissions is divided by the number of vehicles in each category and kilometres travelled to have the EF of mobile combustion by one vehicle and one km travelled as reported in Tables 3.4-4 and 3.4-5.

For the production part of EFs, data from Bilan Carbone® tool - version 7.4 model were used and for upstream part, EFs from national database developed by EIHP were used. National EFs for road freight transport are given in Tables 3.4-4 and 3.4-5 while total EFs in CO_2e are given in table 3.4-6.

Biomass-related CO_2 emissions in Croatia arising from biodiesel combustion in heavy-duty vehicles and busses therefore EFs for that part were given as well.

Table 3.4-4: National EFs for road freight transport for CO_2 and biomass-related CO_2 emissions

	Vehicle category	Fuel and weight class	EU Norm	Production year	CO_2 emissions by type (kg CO_2 per vehicle.km)			Biomass-related CO_2 emissions kg CO_2 per vehicle.km		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
1	Light-duty vehicles	Gasoline <3,5t	Conventional	till 1992	0.0886	0.0496	0.2593	0.00E+00	0.00E+00	0.00E+00
2	Light-duty vehicles	Gasoline <3,5t	Euro I and II	1993-2000	0.0886	0.0583	0.3023	0.00E+00	0.00E+00	0.00E+00
3	Light-duty vehicles	Gasoline <3,5t	Euro III, IV and V	2001-	0.0886	0.0538	0.2790	0.00E+00	0.00E+00	0.00E+00
4	Light-duty vehicles	Diesel <3,5t	Conventional	till 1992	0.0886	0.0527	0.2743	0.00E+00	0.00E+00	0.00E+00
5	Light-duty vehicles	Diesel <3,5t	Euro I and II	1993-2000	0.0886	0.0465	0.2422	0.00E+00	0.00E+00	0.00E+00
6	Light-duty vehicles	Diesel <3,5t	Euro III, IV and V	2001-	0.0886	0.0446	0.2319	0.00E+00	0.00E+00	0.00E+00
7	Heavy-duty vehicles	Rigid <=7,5 t	Conventional	till 1992	0.0172	0.0702	0.3652	0.00E+00	0.00E+00	1.17E-04
8	Heavy-duty vehicles	Rigid <=7,5 t	Euro I and II	1993-2000	0.0172	0.0571	0.2970	0.00E+00	0.00E+00	9.49E-05
9	Heavy-duty vehicles	Rigid <=7,5 t	Euro III and IV	2001-	0.0172	0.0595	0.3095	0.00E+00	0.00E+00	9.89E-05
10	Heavy-duty vehicles	Rigid 7,5 - 20 t	Conventional	till 1992	0.0172	0.1147	0.5972	0.00E+00	0.00E+00	1.91E-04
11	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro I and II	1993-2000	0.0172	0.0974	0.5068	0.00E+00	0.00E+00	1.62E-04
12	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro III and IV	2001-	0.0172	0.0998	0.5192	0.00E+00	0.00E+00	1.66E-04
13	Heavy-duty vehicles	Rigid 20 - 32 t	Conventional	till 1992	0.0172	0.1757	0.9144	0.00E+00	0.00E+00	2.92E-04
14	Heavy-duty vehicles	Rigid 20 - 32 t	Euro I and II	1993-2000	0.0172	0.1539	0.8007	0.00E+00	0.00E+00	2.56E-04
15	Heavy-duty vehicles	Rigid 20 - 32 t	Euro III and IV	2001-	0.0172	0.1569	0.8164	0.00E+00	0.00E+00	2.61E-04
16	Heavy-duty vehicles	Rigid >32 t	Conventional	till 1992	0.0088	0.1771	0.9218	0.00E+00	0.00E+00	2.95E-04
17	Heavy-duty vehicles	Rigid >32 t	Euro I and II	1993-2000	0.0088	0.1423	0.7406	0.00E+00	0.00E+00	2.37E-04
18	Heavy-duty vehicles	Rigid >32 t	Euro III and IV	2001-	0.0088	0.1676	0.8721	0.00E+00	0.00E+00	2.79E-04
19	Heavy-duty vehicles	Articulated 14 - 28 t	Conventional	till 1992	0.0088	0.1326	0.6903	0.00E+00	0.00E+00	2.21E-04
20	Heavy-duty vehicles	Articulated 14 - 28 t	Euro I and II	1993-2000	0.0088	0.1133	0.5894	0.00E+00	0.00E+00	1.88E-04
21	Heavy-duty vehicles	Articulated 14 - 28 t	Euro III and IV	2001-	0.0088	0.1147	0.5971	0.00E+00	0.00E+00	1.91E-04
22	Heavy-duty vehicles	Articulated 28 - 40 t	Conventional	till 1992	0.0088	0.1696	0.8824	0.00E+00	0.00E+00	2.82E-04
23	Heavy-duty vehicles	Articulated 28 - 40 t	Euro I and II	1993-2000	0.0088	0.1423	0.7408	0.00E+00	0.00E+00	2.37E-04
24	Heavy-duty vehicles	Articulated 28 - 40 t	Euro III and IV	2001-	0.0088	0.1549	0.8061	0.00E+00	0.00E+00	2.58E-04
25	Heavy-duty vehicles	Articulated 40 - 60 t	Conventional	till 1992	0.0088	0.2203	1.1464	0.00E+00	0.00E+00	3.66E-04
26	Heavy-duty vehicles	Articulated 40 - 60 t	Euro I and II	1993-2000	0.0088	0.1766	0.9189	0.00E+00	0.00E+00	2.94E-04
27	Heavy-duty vehicles	Articulated 40 - 60 t	Euro III and IV	2001-	0.0088	0.2087	1.0863	0.00E+00	0.00E+00	3.47E-04

Table 3.4-5: National EFs for road freight transport for CH_4 and N_2O

	Vehicle category	Fuel and weight class	EU Norm	Production year	CH_4 emissions by type (kg CH_4 per vehicle.km)			N_2O emissions by type (kg N_2O per vehicle.km)		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
1	Light-duty vehicles	Gasoline <3,5t	Conventional	till 1992	0.00E+00	5.60E-06	1.09E-04	0.00E+00	3.89E-07	7.56E-06
2	Light-duty vehicles	Gasoline <3,5t	Euro I and II	1993-2000	0.00E+00	6.58E-06	3.02E-05	0.00E+00	4.57E-07	2.81E-05
3	Light-duty vehicles	Gasoline <3,5t	Euro III, IV and V	2001-	0.00E+00	6.07E-06	1.83E-05	0.00E+00	4.22E-07	3.73E-06
4	Light-duty vehicles	Diesel <3,5t	Conventional	till 1992	0.00E+00	5.71E-06	1.48E-05	0.00E+00	4.09E-07	0.00E+00
5	Light-duty vehicles	Diesel <3,5t	Euro I and II	1993-2000	0.00E+00	5.04E-06	5.87E-06	0.00E+00	3.62E-07	4.45E-06
6	Light-duty vehicles	Diesel <3,5t	Euro III, IV and V	2001-	0.00E+00	4.83E-06	4.35E-07	0.00E+00	3.46E-07	6.82E-06
7	Heavy-duty vehicles	Rigid <=7,5 t	Conventional	till 1992	0.00E+00	7.61E-06	4.00E-05	0.00E+00	5.45E-07	2.92E-05
8	Heavy-duty vehicles	Rigid <=7,5 t	Euro I and II	1993-2000	0.00E+00	6.19E-06	3.26E-05	0.00E+00	4.43E-07	4.78E-06
9	Heavy-duty vehicles	Rigid <=7,5 t	Euro III and IV	2001-	0.00E+00	6.45E-06	7.91E-06	0.00E+00	4.62E-07	5.26E-06
10	Heavy-duty vehicles	Rigid 7,5 - 20 t	Conventional	till 1992	0.00E+00	1.24E-05	6.16E-05	0.00E+00	8.91E-07	2.89E-05
11	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro I and II	1993-2000	0.00E+00	1.06E-05	4.93E-05	0.00E+00	7.57E-07	7.66E-06
12	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro III and IV	2001-	0.00E+00	1.08E-05	1.06E-05	0.00E+00	7.75E-07	8.68E-06
13	Heavy-duty vehicles	Rigid 20 - 32 t	Conventional	till 1992	0.00E+00	1.90E-05	1.02E-04	0.00E+00	1.36E-06	2.86E-05
14	Heavy-duty vehicles	Rigid 20 - 32 t	Euro I and II	1993-2000	0.00E+00	1.67E-05	8.03E-05	0.00E+00	1.20E-06	1.07E-05
15	Heavy-duty vehicles	Rigid 20 - 32 t	Euro III and IV	2001-	0.00E+00	1.70E-05	1.84E-05	0.00E+00	1.22E-06	1.17E-05
16	Heavy-duty vehicles	Rigid >32 t	Conventional	till 1992	0.00E+00	1.92E-05	9.36E-05	0.00E+00	1.38E-06	2.62E-05
17	Heavy-duty vehicles	Rigid >32 t	Euro I and II	1993-2000	0.00E+00	1.54E-05	7.14E-05	0.00E+00	1.11E-06	1.16E-05
18	Heavy-duty vehicles	Rigid >32 t	Euro III and IV	2001-	0.00E+00	1.82E-05	2.89E-05	0.00E+00	1.30E-06	1.11E-05
19	Heavy-duty vehicles	Articulated 14 - 28 t	Conventional	till 1992	0.00E+00	1.44E-05	1.03E-04	0.00E+00	1.03E-06	2.88E-05
20	Heavy-duty vehicles	Articulated 14 - 28 t	Euro I and II	1993-2000	0.00E+00	1.23E-05	8.19E-05	0.00E+00	8.80E-07	9.06E-06
21	Heavy-duty vehicles	Articulated 14 - 28 t	Euro III and IV	2001-	0.00E+00	1.24E-05	1.74E-05	0.00E+00	8.91E-07	1.02E-05
22	Heavy-duty vehicles	Articulated 28 - 40 t	Conventional	till 1992	0.00E+00	1.84E-05	9.93E-05	0.00E+00	1.32E-06	2.79E-05
23	Heavy-duty vehicles	Articulated 28 - 40 t	Euro I and II	1993-2000	0.00E+00	1.54E-05	7.56E-05	0.00E+00	1.11E-06	1.32E-05
24	Heavy-duty vehicles	Articulated 28 - 40 t	Euro III and IV	2001-	0.00E+00	1.68E-05	1.90E-05	0.00E+00	1.20E-06	1.52E-05
25	Heavy-duty vehicles	Articulated 40 - 60 t	Conventional	till 1992	0.00E+00	2.39E-05	9.36E-05	0.00E+00	1.71E-06	2.62E-05
26	Heavy-duty vehicles	Articulated 40 - 60 t	Euro I and II	1993-2000	0.00E+00	1.91E-05	7.14E-05	0.00E+00	1.37E-06	1.23E-05
27	Heavy-duty vehicles	Articulated 40 - 60 t	Euro III and IV	2001-	0.00E+00	2.26E-05	2.89E-05	0.00E+00	1.62E-06	1.24E-05

Table 3.4-6: National EFs for road freight transport in kg CO_2e per vehicle km

	Vehicle category	Fuel and weight class	EU Norm	Production year	Total EF by gasses (kg CO_2e per vehicle.km)			
					CO_2	CH_4	N_2O	CO_2e
1	Light-duty vehicles	Gasoline <3,5t	Conventional	till 1992	0.39750	3.45E-03	2.11E-03	0.4031
2	Light-duty vehicles	Gasoline <3,5t	Euro I and II	1993-2000	0.44918	1.10E-03	7.58E-03	0.4579
3	Light-duty vehicles	Gasoline <3,5t	Euro III, IV and V	2001-	0.42139	7.32E-04	1.10E-03	0.4232
4	Light-duty vehicles	Diesel <3,5t	Conventional	till 1992	0.41556	6.15E-04	1.08E-04	0.4163
5	Light-duty vehicles	Diesel <3,5t	Euro I and II	1993-2000	0.37734	3.27E-04	1.27E-03	0.3789
6	Light-duty vehicles	Diesel <3,5t	Euro III, IV and V	2001-	0.36504	1.58E-04	1.90E-03	0.3671
7	Heavy-duty vehicles	Rigid <=7,5 t	Conventional	till 1992	0.45261	1.43E-03	7.88E-03	0.4619
8	Heavy-duty vehicles	Rigid <=7,5 t	Euro I and II	1993-2000	0.37132	1.16E-03	1.38E-03	0.3739
9	Heavy-duty vehicles	Rigid <=7,5 t	Euro III and IV	2001-	0.38611	4.31E-04	1.52E-03	0.3881
10	Heavy-duty vehicles	Rigid 7,5 - 20 t	Conventional	till 1992	0.72913	2.22E-03	7.89E-03	0.7392
11	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro I and II	1993-2000	0.62141	1.80E-03	2.23E-03	0.6254
12	Heavy-duty vehicles	Rigid 7,5 - 20 t	Euro III and IV	2001-	0.63613	6.43E-04	2.51E-03	0.6393
13	Heavy-duty vehicles	Rigid 20 - 32 t	Conventional	till 1992	1.10724	3.64E-03	7.95E-03	1.1188
14	Heavy-duty vehicles	Rigid 20 - 32 t	Euro I and II	1993-2000	0.97175	2.91E-03	3.16E-03	0.9778
15	Heavy-duty vehicles	Rigid 20 - 32 t	Euro III and IV	2001-	0.99042	1.06E-03	3.43E-03	0.9949
16	Heavy-duty vehicles	Rigid >32 t	Conventional	till 1992	1.10766	3.38E-03	7.32E-03	1.1184
17	Heavy-duty vehicles	Rigid >32 t	Euro I and II	1993-2000	0.89169	2.61E-03	3.37E-03	0.8977
18	Heavy-duty vehicles	Rigid >32 t	Euro III and IV	2001-	1.04843	1.41E-03	3.30E-03	1.0531
19	Heavy-duty vehicles	Articulated 14 - 28 t	Conventional	till 1992	0.83168	3.52E-03	7.92E-03	0.8431
20	Heavy-duty vehicles	Articulated 14 - 28 t	Euro I and II	1993-2000	0.71151	2.82E-03	2.63E-03	0.7170
21	Heavy-duty vehicles	Articulated 14 - 28 t	Euro III and IV	2001-	0.72069	8.95E-04	2.94E-03	0.7245
22	Heavy-duty vehicles	Articulated 28 - 40 t	Conventional	till 1992	1.06077	3.53E-03	7.73E-03	1.0720
23	Heavy-duty vehicles	Articulated 28 - 40 t	Euro I and II	1993-2000	0.89191	2.73E-03	3.79E-03	0.8984
24	Heavy-duty vehicles	Articulated 28 - 40 t	Euro III and IV	2001-	0.96978	1.07E-03	4.34E-03	0.9752
25	Heavy-duty vehicles	Articulated 40 - 60 t	Conventional	till 1992	1.37545	3.52E-03	7.41E-03	1.3864
26	Heavy-duty vehicles	Articulated 40 - 60 t	Euro I and II	1993-2000	1.10432	2.72E-03	3.63E-03	1.1107
27	Heavy-duty vehicles	Articulated 40 - 60 t	Euro III and IV	2001-	1.30386	1.55E-03	3.71E-03	1.3091

Rail transport

EFs developed for rail transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given in Croatian NIR 2017 and tone-kilometres data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. Two EFs were created, one for diesel-powered locomotive and one for electricity power locomotive. For each gas, the sum of all emissions is divided by the tonne kilometres travelled to have the EF of rail freight by kilometres travelled as reported in Tables 3.4-7 and 3.4-8. To calculate CO_2 EF from electricity consumption, conversion factor in g CO_2/kWh was used. This conversion factor was taken from national database developed by EIHP. For the upstream part of EFs national database developed by EIHP was used. EFs created for rail transport category are given in Tables 3.4-7 and 3.4-8.

Table 3.4-7: CO_2, CH_4 and N_2O EFs for fright rail transport

Rail freight	Breakdown of GHG emissions by type (kg CO_2e per tonne.km)					
	CO_2		CH_4 f		N_2O	
Type of train	upstream	combustion	upstream	combustion	upstream	combustion
Diesel powered	6.15E-03	3.21E-02	2.00E-05	4.31E-05	1.27E-05	6.87E-03
Electricity powered	2.63E-05	2.07E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 3.4-8: Total CO_2e EFs with biomass-related CO_2 EFs for freight rail transport

Rail freight	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per tonne.km		kg CO_2e per tonne.km	
Type of train	upstream	combustion	upstream	combustion
Diesel powered	6.18E-03	3.90E-02	0.00E+00	0.00E+00
Electricity powered	2.63E-05	2.07E-02	0.00E+00	0.00E+00

Sea and waterway transport

EF developed for water borne transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given Croatian NIR 2017 and tone-kilometres data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. For each gas, the sum of all emissions is divided by the tonne kilometres travelled to have the EF of sea and waterway freight by kilometres travelled as reported in Tables 3.4-9 and 3.4-10. EF was created only for domestic transportation. For now, it is not possible to estimate the international transportation because available data on fuel include only the part of the fuel in Croatia that is sold to international transportation. For the upstream part of EFs, national database developed by EIHP was used.

EFs created for Sea and waterway transport category are given in Tables 3.4-9 and 3.4-10.

Table 3.4-9: CO_2, CH_4 and N_2O EFs for freight sea and waterway transport

Sea and waterway freight	Breakdown of GHG emissions by type (kg CO_2e per tonne.km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
	upstream	combustion	upstream	combustion	upstream	combustion
Domestic	1.80E-04	1.16E-03	1.95E-08	1.12E-07	1.40E-09	2.79E-08

Table 3.4-10: Total CO_2e EFs with biomass-related CO_2 EFs for freight sea and waterway transport

Sea and waterway freight	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per tonne.km		kg CO_2e per tonne.km	
	upstream	combustion	upstream	combustion
Domestic	1.80E-04	1.16E-03	0.00E+00	0.00E+00

Data quality and uncertainty analysis

For all freight transport sectors, good overall data quality was estimated. National energy balance was used for all fuel consumption data. Statistical Yearbook for 2016 was used for tonne kilometres travelled data. The estimated uncertainty of data from energy balance is below 5%. Data from statistical yearbook are generally well determined too. The accuracy of data on net calorific values, which were also taken from national energy balance, is high. CO_2 EFs for fuels are generally well determined within 5%, as they primarily depend on the carbon content of the fuel. 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 EF applied while the fuel consumption data (national energy balance) are rather good. Implementation of COPERT IV model for estimation of CH_4 and N_2O emissions from Road transport lead to certain uncertainty reduction.

Data quality rating (DQR)

Overall quality rating of the EFs for each freight transport sector using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good, except road freight transport that is very good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.4-11.

Table 3.4-11: Data quality rating

Freight transport sector	TiR	TeR	GeR	U	DQR
Air freight transport	good	very good	good	poor	**good**
Road freight transport	good	very good	good	very good	**very good**
Rail freight transport	good	very good	good	poor	**good**
Sea and waterway freight transport	good	very good	good	poor	**good**

3.5 Passenger transport

People transport consists of four categories:

- Air Transport
- Road transport
- Rail transport
- Sea and waterway transport

For each of this category EFs were created. For air transport two EFs were created, one for domestic and one for international travel. In road transportation category 64 EFs were created based on vehicle type, capacity and age of vehicle. Rail transport category consists of two EFs, based on fuel type, which is used (diesel or electricity). One EF was created for sea and waterway transport.

Technical description

Air Transport

Emissions from aviation come from the combustion of jet fuel (jet kerosene and jet gasoline) and aviation gasoline. Aircraft engine emissions are roughly composed of about 70% CO_2, a little less than 30% H_2O, and less than 1% each of NO_x, CO, SO_x, NMVOC, particulates, and other trace components including hazardous air pollutants. Little or no N_2O emissions occur from modern gas turbines. CH_4 may be emitted by gas turbines during idle and by older technology engines, but recent data suggest that little or no CH_4 is emitted by modern engines.

Road Transport

The mobile source category Road Transportation includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as tractor trailers and buses, and on-road motorcycles (including mopeds, scooters, and three-wheelers). These vehicles operate on many types of gaseous and liquid fuels. For emission calculation, COPERT IV model was used because EFs depend on vehicle technology, fuel and operating characteristics.

The COPERT IV model requires 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 (<1.4L, 1.4-2.0L, >2.0L)
- weight class (<3.5 t, 3.5-7.5 t, 7.5-16 t, 16-32 t, >32 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 compilation of national motor vehicle database with detailed information on each registered vehicle 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.

Rail Transport

Railway locomotives generally are one of three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors. The GHG emissions from sub-sector Railways were calculated using Tier 1 approach based on fossil fuel consumption data (from national energy balance) and default IPCC EFs. Default EFs for CH_4 and N_2O were modified depending on the engine design.

Sea and Rivers Transport

This source category covers all water-borne transport from recreational craft to large ocean-going cargo ships that are driven primarily by large, slow and medium speed diesel engines and occasionally by steam or gas turbines. It includes hovercraft and hydrofoils. Water-borne navigation causes emissions of CO_2, CH_4 and N_2O. The GHG emissions from Navigation sub-sector were calculated using Tier 1 approach, based on fossil fuel consumption data (from national energy balance) and default IPCC EFs.

Methodological issues

Air Transport

EFs developed for air transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given in Croatian NIR 2017 and passenger-kilometres data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. Two EFs were created, one for domestic travel (bellow 1000 km distance) and one for international travel (above 1000 km distance). For each gas, the sum of all emissions is divided by the passenger km travelled to have the EFs of air passenger transport for Croatia as reported in Tables 3.5-1 and 3.5-2.

For the upstream part of EFs, national database developed by EIHP was used. In Tables 3.5-1 and 3.5-2 EFs for air travel are given.

Table 3.5-1: CO_2, CH_4 and N_2O EFs for air travel

Air travel	Breakdown of GHG emissions by type (kg CO_2e per passenger.km)					
	CO_2		CH_4 f		N_2O	
Type of flight	upstream	combustion	upstream	combustion	upstream	combustion
Domestic, bellow 1000 km distance	4.09E-02	2.93E-01	1.37E-04	6.16E-05	8.25E-05	2.18E-03
International, above 1000 km distance	5.02E-02	2.67E-01	1.68E-04	4.62E-04	1.01E-04	5.89E-04

Table 3.5-2: Total CO_2e EFs with biomass-related CO_2 EFs for air travel

Air travel	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per passenger.km		kg CO_2e per passenger.km	
Type of flight	upstream	combustion	upstream	combustion
Domestic, bellow 1000 km distance	4.11E-02	2.95E-01	0.00E+00	0.00E+00
International, above 1000 km distance	5.04E-02	2.68E-01	0.00E+00	0.00E+00

Road transport

EFs developed for road transportation sector consists of three parts; combustion, production and upstream part. Combustion part is calculated on the basis of GHG emissions, kilometres travelled and number of vehicles given in Croatian NIR 2017. For GHG emissions assessment from transport sector COPERT IV model was used. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. According COPERT methodology vehicles are distributed by categories and classes, and according to ECE regulations governing individual technological solution to reduce emissions in a given period. Passenger transport vehicles are divided in four categories; passenger cars, mopeds, motorcycles and busses. In table 3.5-3 distribution of road passenger transportation is given.

Table 3.5-3: Distribution of road freight transport by COPERT IV model

Vehicle	Fuel and engine capacity	Technology
Passenger Cars	Gasoline 0 - 1,4 l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	Gasoline 1,4 - 2,0 l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	Gasoline >2,0 l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03

Vehicle	Fuel and engine capacity	Technology
		ECE 15/04
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	Diesel 0 - 2,0 l	Conventional
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
		Conventional
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	LPG	Conventional
		PC Euro 1 - 91/441/EEC
		PC Euro 2 - 94/12/EEC
		PC Euro 3 - 98/69/EC Stage2000
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	CNG	PC Euro 4 - 98/69/EC Stage2005
		PC Euro 5 - EC 715/2007
		PC Euro 6 - EC 715/2007
	2-Stroke	Conventional
	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005
		PC Euro 4 - 98/69/EC Stage2005
		PC Euro 4 - 98/69/EC Stage2005
Mopeds	2-stroke <50 cm³	Conventional
		Mop - Euro I
		Mop - Euro II
		Mop - Euro III
	4-stroke <50 cm³	Conventional
		Mop - Euro I
		Mop - Euro II
		Mop - Euro III
Motorcycles	2-stroke >50 cm³	Conventional
		Mot - Euro I
		Mot - Euro II
		Mot - Euro III
	4-stroke <250 cm³	Conventional
		Mot - Euro I

Vehicle	Fuel and engine capacity	Technology
		Mot - Euro II
		Mot - Euro III
	4-stroke 250 - 750 cm³	Conventional
		Mot - Euro I
		Mot - Euro II
		Mot - Euro III
	4-stroke >750 cm³	Conventional
		Mot - Euro I
		Mot - Euro II
		Mot - Euro III
Buses	Urban Buses Midi <=15 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
		HD Euro V - 2008 Standards
		HD Euro VI
	Urban Buses Standard 15 - 18 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
		HD Euro V - 2008 Standards
		HD Euro VI
	Urban Buses Articulated >18 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
		HD Euro V - 2008 Standards
		HD Euro VI
	Coaches Standard <=18 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
		HD Euro V - 2008 Standards
		HD Euro VI
	Coaches Articulated >18 t	Conventional
		HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards
		HD Euro IV - 2005 Standards
		HD Euro V - 2008 Standards
		HD Euro VI
	Urban CNG Buses	HD Euro I - 91/542/EEC Stage I
		HD Euro II - 91/542/EEC Stage II
		HD Euro III - 2000 Standards

From 123 categories that are given by COPERT model 64 EFs were created for road travel. For passenger cars category, all vehicles with PRE ECE technology were summed together while Euro I to Euro VI technologies were given separately. Euro I, II and III technologies were summed together for Mopeds and Motorcycles categories. Buses were divided in two main categories; urban and coaches with summed Euro norms in one technology type. For each gas the sum of all emissions is divided by the number of vehicles in each category and kilometres travelled to have the EFs of mobile combustion by one vehicle and one km travelled as reported in Tables 3.5-4 and 3.5-5.

For the production part of CO_2 EFs, data from Bilan Carbone® tool - version 7.4 model were used and for upstream part of EFs, national database developed by EIHP was used. Production EFs for CH_4 and N2O were not available in Bilan Carbone® tool - version 7.4 model. National EFs for road travel are given in Tables 3.5-4 and 3.5-5 while total EFs in CO_2e are given in Table 3.5-6.

Biomass-related CO_2 emissions in Croatia arising from biodiesel combustion in busses therefore EFs for that part were given as well.

Table 3.5-4: National EFs for road travel for CO_2 and biomass-related CO_2 emissions

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	CO_2 emissions by type (kg CO_2 per vehicle.km)			Biomass-related CO_2 emissions kg CO_2 per vehicle.km		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
1	Passenger Cars	Gasoline 0 - 1,4 l	PRE ECE and ECE	till 1992	3.30E-02	3.47E-02	0.1811	0.00E+00	0.00E+00	0.00E+00
2	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 1 - 91/441/EEC	1993-1996	3.30E-02	3.21E-02	0.1666	0.00E+00	0.00E+00	0.00E+00
3	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 2 - 94/12/EEC	1997-2000	3.30E-02	3.15E-02	0.1635	0.00E+00	0.00E+00	0.00E+00
4	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	3.30E-02	3.24E-02	0.1682	0.00E+00	0.00E+00	0.00E+00
5	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	3.30E-02	3.36E-02	0.1745	0.00E+00	0.00E+00	0.00E+00
6	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 5 - EC 715/2007	2010-2014	3.30E-02	3.35E-02	0.1738	0.00E+00	0.00E+00	0.00E+00
7	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 6 - EC 715/2007	2015-…	3.30E-02	3.36E-02	0.1745	0.00E+00	0.00E+00	0.00E+00
8	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE and ECE	till 1992	4.03E-02	4.04E-02	0.2110	0.00E+00	0.00E+00	0.00E+00
9	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	4.03E-02	3.83E-02	0.1986	0.00E+00	0.00E+00	0.00E+00
10	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	4.03E-02	3.71E-02	0.1922	0.00E+00	0.00E+00	0.00E+00
11	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	4.03E-02	3.87E-02	0.2007	0.00E+00	0.00E+00	0.00E+00
12	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	4.03E-02	3.99E-02	0.2068	0.00E+00	0.00E+00	0.00E+00
13	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	4.03E-02	3.97E-02	0.2059	0.00E+00	0.00E+00	0.00E+00
14	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	4.03E-02	3.99E-02	0.2067	0.00E+00	0.00E+00	0.00E+00
15	Passenger Cars	Gasoline >2,0 l	PRE ECE	till 1992	4.68E-02	4.99E-02	0.2608	0.00E+00	0.00E+00	0.00E+00
16	Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	4.68E-02	4.92E-02	0.2551	0.00E+00	0.00E+00	0.00E+00
17	Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	4.68E-02	5.05E-02	0.2617	0.00E+00	0.00E+00	0.00E+00
18	Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	4.68E-02	4.57E-02	0.2372	0.00E+00	0.00E+00	0.00E+00
19	Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	4.68E-02	5.39E-02	0.2796	0.00E+00	0.00E+00	0.00E+00
20	Passenger Cars	Gasoline >2,0 l	PC Euro 5 - EC 715/2007	2010-2014	4.68E-02	5.35E-02	0.2775	0.00E+00	0.00E+00	0.00E+00
21	Passenger Cars	Gasoline >2,0 l	PC Euro 6 - EC 715/2007	2015-…	4.68E-02	5.39E-02	0.2794	0.00E+00	0.00E+00	0.00E+00
22	Passenger Cars	Diesel 0 - 2,0 l	Conventional	till 1992	2.48E-02	3.75E-02	0.1951	0.00E+00	0.00E+00	0.00E+00
23	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	2.48E-02	3.21E-02	0.1669	0.00E+00	0.00E+00	0.00E+00
24	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	2.48E-02	3.34E-02	0.1738	0.00E+00	0.00E+00	0.00E+00
25	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	2.48E-02	3.18E-02	0.1653	0.00E+00	0.00E+00	0.00E+00
26	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	2.48E-02	3.18E-02	0.1653	0.00E+00	0.00E+00	0.00E+00
27	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	2.48E-02	3.16E-02	0.1645	0.00E+00	0.00E+00	0.00E+00
28	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	2.48E-02	3.18E-02	0.1654	0.00E+00	0.00E+00	0.00E+00
29	Passenger Cars	Diesel >2,0 l	Conventional	till 1992	3.74E-02	3.74E-02	0.1945	0.00E+00	0.00E+00	0.00E+00
30	Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	till 1992	3.74E-02	4.32E-02	0.2246	0.00E+00	0.00E+00	0.00E+00
31	Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	1993-1996	3.74E-02	4.33E-02	0.2254	0.00E+00	0.00E+00	0.00E+00
32	Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	1997-2000	3.74E-02	4.33E-02	0.2253	0.00E+00	0.00E+00	0.00E+00

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	CO_2 emissions by type (kg CO_2 per vehicle.km)			Biomass-related CO_2 emissions kg CO_2 per vehicle.km		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
33	Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2001-2004	3.74E-02	4.33E-02	0.2253	0.00E+00	0.00E+00	0.00E+00
34	Passenger Cars	Diesel >2,0 l	PC Euro 5 - EC 715/2007	2005-2009	3.74E-02	4.31E-02	0.2242	0.00E+00	0.00E+00	0.00E+00
35	Passenger Cars	Diesel >2,0 l	PC Euro 6 - EC 715/2007	2010-2014	3.74E-02	2.18E-02	0.1135	0.00E+00	0.00E+00	0.00E+00
36	Passenger Cars	LPG	Conventional	till 1992	3.30E-02	3.77E-02	0.1751	0.00E+00	0.00E+00	0.00E+00
37	Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	1993-1996	3.30E-02	3.71E-02	0.1723	0.00E+00	0.00E+00	0.00E+00
38	Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	1997-2000	3.30E-02	3.72E-02	0.1729	0.00E+00	0.00E+00	0.00E+00
39	Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	2001-2004	3.30E-02	3.73E-02	0.1734	0.00E+00	0.00E+00	0.00E+00
40	Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	2005-2009	3.30E-02	3.73E-02	0.1735	0.00E+00	0.00E+00	0.00E+00
41	Passenger Cars	LPG	PC Euro 5 - EC 715/2007	2010-2014	3.30E-02	3.80E-02	0.1767	0.00E+00	0.00E+00	0.00E+00
42	Passenger Cars	LPG	PC Euro 6 - EC 715/2007	2015-…	3.30E-02	3.71E-02	0.1726	0.00E+00	0.00E+00	0.00E+00
43	Passenger Cars	CNG	PC Euro 4 - 98/69/EC Stage2005	till 2009	3.30E-02	1.82E-02	0.1606	0.00E+00	0.00E+00	0.00E+00
44	Passenger Cars	CNG	PC Euro 5 - EC 715/2007	2010-2014	3.30E-02	1.90E-02	0.1675	0.00E+00	0.00E+00	0.00E+00
45	Passenger Cars	CNG	PC Euro 6 - EC 715/2007	2015-…	3.30E-02	9.60E-03	0.0845	0.00E+00	0.00E+00	0.00E+00
46	Passenger Cars	2-Stroke	Conventional	all years	3.30E-02	2.94E-02	0.1530	0.00E+00	0.00E+00	0.00E+00
47	Passenger Cars	Hybrid Gasoline	PC Euro 4 - 98/69/EC Stage2005	all years	3.30E-02	2.04E-02	0.1057	0.00E+00	0.00E+00	0.00E+00
48	Mopeds	2-stroke <50 cm³	Conventional	till 1998	3.67E-02	1.50E-02	0.0783	0.00E+00	0.00E+00	0.00E+00
49	Mopeds	2-stroke <50 cm³	Euro I+II+III	1999-…	3.67E-02	1.50E-02	0.0784	0.00E+00	0.00E+00	0.00E+00
50	Mopeds	4-stroke <50 cm³	Conventional	till 1998	3.67E-02	1.50E-02	0.0783	0.00E+00	0.00E+00	0.00E+00
51	Mopeds	4-stroke <50 cm³	Euro I+II+III	1999-…	3.67E-02	1.20E-02	0.0627	0.00E+00	0.00E+00	0.00E+00
52	Motorcycles	2-stroke >50 cm³	Conventional	till 1998	3.67E-02	1.73E-02	0.0903	0.00E+00	0.00E+00	0.00E+00
53	Motorcycles	2-stroke >50 cm³	Euro I+II+III	1999-…	3.67E-02	1.60E-02	0.0834	0.00E+00	0.00E+00	0.00E+00
54	Motorcycles	4-stroke <250 cm³	Conventional	till 1998	3.67E-02	1.68E-02	0.0876	0.00E+00	0.00E+00	0.00E+00
55	Motorcycles	4-stroke <250 cm³	Euro I+II+III	1999-…	3.67E-02	1.21E-02	0.0631	0.00E+00	0.00E+00	0.00E+00
56	Motorcycles	4-stroke 250 - 750 cm³	Conventional	till 1998	3.67E-02	2.31E-02	0.1206	0.00E+00	0.00E+00	0.00E+00
57	Motorcycles	4-stroke 250 - 750 cm³	Euro I+II+III	1999-…	3.67E-02	1.94E-02	0.1018	0.00E+00	0.00E+00	0.00E+00
58	Motorcycles	4-stroke >750 cm³	Conventional	till 1998	3.67E-02	2.63E-02	0.1374	0.00E+00	0.00E+00	0.00E+00
59	Motorcycles	4-stroke >750 cm³	Euro I+II+III	1999-…	3.67E-02	2.47E-02	0.1295	0.00E+00	0.00E+00	0.00E+00
60	Urban Buses	Diesel	Conventional	till-1992	0.00E+00	3.53E-03	0.0184	0.00E+00	0.00E+00	0.00E+00
61	Urban Buses	Diesel and biodiesel (3%)	Euro I,II,III and IV	1993-…	0.00E+00	2.94E-03	0.0153	0.00E+00	0.00E+00	8.74E-06
62	Coaches Buses	Diesel	Conventional	till-1992	0.00E+00	3.19E-03	0.0166	0.00E+00	0.00E+00	0.00E+00
63	Coaches Buses	Diesel	Euro I,II,III and IV	1993-…	0.00E+00	2.89E-03	0.0150	0.00E+00	0.00E+00	0.00E+00
64	Urban Buses	CNG	Euro	all years	0.00E+00	1.37E-03	0.0145	0.00E+00	0.00E+00	0.00E+00

Table 3.5-5: National EFs for road travel for CH_4 and N_2O

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	CH_4 emissions by type (kg CH_4 per vehicle.km)			N_2O emissions by type (kg N_2O per vehicle.km)		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
1	Passenger Cars	Gasoline 0 - 1,4 l	PRE ECE and ECE	till 1992	0.00E+00	3.92E-06	1.11E-04	0.00E+00	2.72E-07	7.88E-06
2	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 1 - 91/441/EEC	1993-1996	0.00E+00	3.63E-06	2.46E-05	0.00E+00	2.52E-07	1.29E-05
3	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 2 - 94/12/EEC	1997-2000	0.00E+00	3.56E-06	3.48E-05	0.00E+00	2.47E-07	6.98E-06
4	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.00E+00	3.66E-06	2.43E-05	0.00E+00	2.54E-07	2.43E-06
5	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.00E+00	3.80E-06	1.79E-05	0.00E+00	2.64E-07	1.77E-06
6	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	3.78E-06	1.78E-05	0.00E+00	2.63E-07	9.99E-07
7	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	3.80E-06	1.78E-05	0.00E+00	2.64E-07	1.00E-06
8	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE and ECE	till 1992	0.00E+00	4.56E-06	1.12E-04	0.00E+00	3.17E-07	7.94E-06
9	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.00E+00	4.32E-06	2.47E-05	0.00E+00	3.00E-07	1.30E-05
10	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.00E+00	4.18E-06	3.48E-05	0.00E+00	2.91E-07	6.99E-06
11	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.00E+00	4.37E-06	2.44E-05	0.00E+00	3.03E-07	2.43E-06
12	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.00E+00	4.50E-06	1.79E-05	0.00E+00	3.13E-07	1.77E-06
13	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	4.48E-06	1.78E-05	0.00E+00	3.11E-07	1.00E-06
14	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	4.50E-06	1.78E-05	0.00E+00	3.13E-07	1.00E-06
15	Passenger Cars	Gasoline >2,0 l	PRE ECE	till 1992	0.00E+00	5.64E-06	1.12E-04	0.00E+00	3.92E-07	7.94E-06
16	Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.00E+00	5.55E-06	2.47E-05	0.00E+00	3.86E-07	1.30E-05
17	Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.00E+00	5.70E-06	3.48E-05	0.00E+00	3.96E-07	6.99E-06
18	Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.00E+00	5.16E-06	2.44E-05	0.00E+00	3.59E-07	2.43E-06
19	Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.00E+00	6.09E-06	1.79E-05	0.00E+00	4.23E-07	1.77E-06
20	Passenger Cars	Gasoline >2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	6.04E-06	1.77E-05	0.00E+00	4.20E-07	9.97E-07
21	Passenger Cars	Gasoline >2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	6.08E-06	1.78E-05	0.00E+00	4.23E-07	1.00E-06
22	Passenger Cars	Diesel 0 - 2,0 l	Conventional	till 1992	0.00E+00	4.06E-06	1.58E-05	0.00E+00	2.91E-07	0.00E+00
23	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.00E+00	3.48E-06	1.02E-05	0.00E+00	2.49E-07	2.66E-06
24	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.00E+00	3.62E-06	4.08E-06	0.00E+00	2.60E-07	4.93E-06
25	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.00E+00	3.44E-06	1.20E-06	0.00E+00	2.47E-07	7.60E-06
26	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.00E+00	3.44E-06	4.40E-07	0.00E+00	2.47E-07	7.60E-06
27	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	3.43E-06	4.37E-07	0.00E+00	2.45E-07	7.56E-06
28	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	3.45E-06	4.40E-07	0.00E+00	2.47E-07	6.26E-06
29	Passenger Cars	Diesel >2,0 l	Conventional	till 1992	0.00E+00	4.05E-06	1.58E-05	0.00E+00	2.90E-07	0.00E+00
30	Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	till 1992	0.00E+00	4.68E-06	1.01E-05	0.00E+00	3.35E-07	2.65E-06
31	Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	1993-1996	0.00E+00	4.70E-06	4.08E-06	0.00E+00	3.37E-07	4.92E-06

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	CH_4 emissions by type (kg CH_4 per vehicle.km)			N_2O emissions by type (kg N_2O per vehicle.km)		
					manufacturing	upstream	combustion	manufacturing	upstream	combustion
32	Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	1997-2000	0.00E+00	4.69E-06	1.20E-06	0.00E+00	3.36E-07	7.59E-06
33	Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2001-2004	0.00E+00	4.69E-06	4.39E-07	0.00E+00	3.36E-07	7.59E-06
34	Passenger Cars	Diesel >2,0 l	PC Euro 5 - EC 715/2007	2005-2009	0.00E+00	4.67E-06	4.37E-07	0.00E+00	3.35E-07	7.55E-06
35	Passenger Cars	Diesel >2,0 l	PC Euro 6 - EC 715/2007	2010-2014	0.00E+00	2.36E-06	2.21E-07	0.00E+00	1.69E-07	3.15E-06
36	Passenger Cars	LPG	Conventional	till 1992	0.00E+00	4.35E-06	5.01E-05	0.00E+00	2.86E-07	0.00E+00
37	Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	1993-1996	0.00E+00	4.28E-06	5.04E-05	0.00E+00	2.81E-07	1.95E-05
38	Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	1997-2000	0.00E+00	4.30E-06	2.85E-05	0.00E+00	2.82E-07	9.45E-06
39	Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.00E+00	4.31E-06	2.37E-05	0.00E+00	2.83E-07	4.04E-06
40	Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.00E+00	4.31E-06	2.25E-05	0.00E+00	2.83E-07	4.04E-06
41	Passenger Cars	LPG	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	4.39E-06	2.29E-05	0.00E+00	2.88E-07	1.01E-06
42	Passenger Cars	LPG	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	4.29E-06	2.24E-05	0.00E+00	2.82E-07	9.73E-07
43	Passenger Cars	CNG	PC Euro 4 - 98/69/EC Stage2005	till 2009	0.00E+00	8.85E-06	5.85E-05	0.00E+00	0.00E+00	1.65E-06
44	Passenger Cars	CNG	PC Euro 5 - EC 715/2007	2010-2014	0.00E+00	9.24E-06	6.12E-05	0.00E+00	0.00E+00	9.63E-07
45	Passenger Cars	CNG	PC Euro 6 - EC 715/2007	2015-…	0.00E+00	4.66E-06	3.08E-05	0.00E+00	0.00E+00	4.86E-07
46	Passenger Cars	2-Stroke	Conventional	all years	0.00E+00	3.32E-06	3.45E-05	0.00E+00	2.31E-07	3.13E-06
47	Passenger Cars	Hybrid Gasoline	PC Euro 4 - 98/69/EC Stage2005	all years	0.00E+00	2.30E-06	0.00E+00	0.00E+00	1.60E-07	3.51E-07
48	Mopeds	2-stroke <50 cm³	Conventional	till 1998	0.00E+00	1.69E-06	2.19E-04	0.00E+00	1.17E-07	1.00E-06
49	Mopeds	2-stroke <50 cm³	Euro I+II+III	1999-…	0.00E+00	1.69E-06	3.47E-05	0.00E+00	1.17E-07	1.25E-06
50	Mopeds	4-stroke <50 cm³	Conventional	till 1998	0.00E+00	1.69E-06	2.19E-04	0.00E+00	1.17E-07	1.00E-06
51	Mopeds	4-stroke <50 cm³	Euro I+II+III	1999-…	0.00E+00	1.35E-06	2.58E-05	0.00E+00	9.39E-08	1.00E-06
52	Motorcycles	2-stroke >50 cm³	Conventional	till 1998	0.00E+00	1.95E-06	1.50E-04	0.00E+00	1.36E-07	2.00E-06
53	Motorcycles	2-stroke >50 cm³	Euro I+II+III	1999-…	0.00E+00	1.80E-06	3.91E-05	0.00E+00	1.25E-07	2.00E-06
54	Motorcycles	4-stroke <250 cm³	Conventional	till 1998	0.00E+00	1.89E-06	2.00E-04	0.00E+00	1.31E-07	2.00E-06
55	Motorcycles	4-stroke <250 cm³	Euro I+II+III	1999-…	0.00E+00	1.36E-06	7.45E-05	0.00E+00	9.46E-08	2.00E-06
56	Motorcycles	4-stroke 250 - 750 cm³	Conventional	till 1998	0.00E+00	2.60E-06	2.00E-04	0.00E+00	1.81E-07	2.00E-06
57	Motorcycles	4-stroke 250 - 750 cm³	Euro I+II+III	1999-…	0.00E+00	2.19E-06	9.31E-05	0.00E+00	1.52E-07	2.00E-06
58	Motorcycles	4-stroke >750 cm³	Conventional	till 1998	0.00E+00	2.97E-06	2.00E-04	0.00E+00	2.06E-07	2.00E-06
59	Motorcycles	4-stroke >750 cm³	Euro I+II+III	1999-…	0.00E+00	2.79E-06	5.37E-05	0.00E+00	1.94E-07	2.00E-06
60	Urban Buses	Diesel	Conventional	till-1992	0.00E+00	3.83E-07	2.74E-06	0.00E+00	2.74E-08	4.70E-07
61	Urban Buses	Diesel	Euro I,II,III and IV	1993-…	0.00E+00	3.19E-07	1.15E-06	0.00E+00	2.29E-08	1.70E-07
62	Coaches Buses	Diesel	Conventional	till-1992	0.00E+00	3.46E-07	1.85E-06	0.00E+00	2.48E-08	5.39E-07
63	Coaches Buses	Diesel	Euro I,II,III and IV	1993-…	0.00E+00	3.13E-07	7.74E-07	0.00E+00	2.24E-08	1.74E-07
64	Urban Buses	CNG	Euro	all years	0.00E+00	4.53E-07	1.48E-05	0.00E+00	3.58E-09	0.00E+00

Table 3.5-6: National EFs for road travel in kg CO_2e per vehicle km

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	Total EF by gasses (kg CO_2e per vehicle.km)			
					CO_2	CH_4	N_2O	CO_2e
1	Passenger Cars	Gasoline 0 - 1,4 l	PRE ECE and ECE	till 1992	0.24882	3.46E-03	2.16E-03	0.25444
2	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 1 - 91/441/EEC	1993-1996	0.23174	8.47E-04	3.50E-03	0.23609
3	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 2 - 94/12/EEC	1997-2000	0.22801	1.15E-03	1.92E-03	0.23107
4	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.23362	8.40E-04	7.11E-04	0.23517
5	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.24110	6.50E-04	5.38E-04	0.24229
6	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 5 - EC 715/2007	2010-2014	0.24031	6.47E-04	3.34E-04	0.24129
7	Passenger Cars	Gasoline 0 - 1,4 l	PC Euro 6 - EC 715/2007	2015-…	0.24117	6.49E-04	3.36E-04	0.24216
8	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE and ECE	till 1992	0.29173	3.50E-03	2.19E-03	0.29742
9	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.27717	8.70E-04	3.52E-03	0.28156
10	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.26959	1.17E-03	1.93E-03	0.27269
11	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.27968	8.62E-04	7.25E-04	0.28126
12	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.28706	6.72E-04	5.51E-04	0.28828
13	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.28595	6.69E-04	3.47E-04	0.28697
14	Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.28689	6.70E-04	3.49E-04	0.28791
15	Passenger Cars	Gasoline >2,0 l	PRE ECE	till 1992	0.35743	3.53E-03	2.21E-03	0.36317
16	Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.35101	9.07E-04	3.54E-03	0.35545
17	Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.35888	1.21E-03	1.96E-03	0.36205
18	Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.32967	8.86E-04	7.40E-04	0.33129
19	Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.38029	7.19E-04	5.81E-04	0.38158
20	Passenger Cars	Gasoline >2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.37777	7.14E-04	3.75E-04	0.37886
21	Passenger Cars	Gasoline >2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.37999	7.18E-04	3.78E-04	0.38109
22	Passenger Cars	Diesel 0 - 2,0 l	Conventional	till 1992	0.25728	5.97E-04	7.72E-05	0.25796
23	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 1 - 91/441/EEC	1993-1996	0.22375	4.09E-04	7.71E-04	0.22493
24	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 2 - 94/12/EEC	1997-2000	0.23200	2.31E-04	1.38E-03	0.23361
25	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.22185	1.39E-04	2.08E-03	0.22407
26	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.22183	1.16E-04	2.08E-03	0.22402
27	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 5 - EC 715/2007	2010-2014	0.22081	1.16E-04	2.07E-03	0.22299
28	Passenger Cars	Diesel 0 - 2,0 l	PC Euro 6 - EC 715/2007	2015-…	0.22198	1.17E-04	1.73E-03	0.22383
29	Passenger Cars	Diesel >2,0 l	Conventional	till 1992	0.26926	5.95E-04	7.69E-05	0.26993
30	Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	till 1992	0.30520	4.44E-04	7.91E-04	0.30643
31	Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	1993-1996	0.30617	2.63E-04	1.39E-03	0.30783
32	Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	1997-2000	0.30593	1.77E-04	2.10E-03	0.30821

	Vehicle category	Fuel and engine capacity	EU Norm	Production year	Total EF by gasses (kg CO_2e per vehicle.km)			
					CO_2	CH_4	N_2O	CO_2e
33	Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	2001-2004	0.30604	1.54E-04	2.10E-03	0.30829
34	Passenger Cars	Diesel >2,0 l	PC Euro 5 - EC 715/2007	2005-2009	0.30462	1.53E-04	2.09E-03	0.30687
35	Passenger Cars	Diesel >2,0 l	PC Euro 6 - EC 715/2007	2010-2014	0.17276	7.76E-05	8.80E-04	0.17372
36	Passenger Cars	LPG	Conventional	till 1992	0.24573	1.63E-03	7.57E-05	0.24744
37	Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	1993-1996	0.24239	1.64E-03	5.23E-03	0.24926
38	Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	1997-2000	0.24314	9.83E-04	2.58E-03	0.24670
39	Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	2001-2004	0.24373	8.39E-04	1.15E-03	0.24571
40	Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	2005-2009	0.24380	8.05E-04	1.15E-03	0.24575
41	Passenger Cars	LPG	PC Euro 5 - EC 715/2007	2010-2014	0.24779	8.19E-04	3.45E-04	0.24895
42	Passenger Cars	LPG	PC Euro 6 - EC 715/2007	2015-…	0.24273	8.00E-04	3.32E-04	0.24386
43	Passenger Cars	CNG	PC Euro 4 - 98/69/EC Stage2005	till 2009	0.21179	2.02E-03	4.37E-04	0.21424
44	Passenger Cars	CNG	PC Euro 5 - EC 715/2007	2010-2014	0.21950	2.11E-03	2.55E-04	0.22187
45	Passenger Cars	CNG	PC Euro 6 - EC 715/2007	2015-…	0.12713	1.06E-03	1.29E-04	0.12832
46	Passenger Cars	2-Stroke	Conventional	all years	0.21542	1.14E-03	8.90E-04	0.21745
47	Passenger Cars	Hybrid Gasoline	PC Euro 4 - 98/69/EC Stage2005	all years	0.15910	6.90E-05	1.35E-04	0.15930
48	Mopeds	2-stroke <50 cm³	Conventional	till 1998	0.12998	6.62E-03	2.96E-04	0.13690
49	Mopeds	2-stroke <50 cm³	Euro I+II+III	1999-…	0.13008	1.09E-03	3.62E-04	0.13154
50	Mopeds	4-stroke <50 cm³	Conventional	till 1998	0.12998	6.62E-03	2.96E-04	0.13690
51	Mopeds	4-stroke <50 cm³	Euro I+II+III	1999-…	0.11140	8.16E-04	2.90E-04	0.11250
52	Motorcycles	2-stroke >50 cm³	Conventional	till 1998	0.14430	4.56E-03	5.66E-04	0.14942
53	Motorcycles	2-stroke >50 cm³	Euro I+II+III	1999-…	0.13606	1.23E-03	5.63E-04	0.13785
54	Motorcycles	4-stroke <250 cm³	Conventional	till 1998	0.14105	6.06E-03	5.65E-04	0.14767
55	Motorcycles	4-stroke <250 cm³	Euro I+II+III	1999-…	0.11184	2.28E-03	5.55E-04	0.11467
56	Motorcycles	4-stroke 250 - 750 cm³	Conventional	till 1998	0.18041	6.08E-03	5.78E-04	0.18707
57	Motorcycles	4-stroke 250 - 750 cm³	Euro I+II+III	1999-…	0.15790	2.86E-03	5.70E-04	0.16132
58	Motorcycles	4-stroke >750 cm³	Conventional	till 1998	0.20035	6.09E-03	5.85E-04	0.20702
59	Motorcycles	4-stroke >750 cm³	Euro I+II+III	1999-…	0.19099	1.70E-03	5.81E-04	0.19327
60	Urban Buses	Diesel	Conventional	till-1992	0.02191	9.37E-05	1.32E-04	0.02214
61	Urban Buses	Diesel	Euro I,II,III and IV	1993-…	0.01825	4.41E-05	5.11E-05	0.01835
62	Coaches Buses	Diesel	Conventional	till-1992	0.01978	6.58E-05	1.49E-04	0.02000
63	Coaches Buses	Diesel	Euro I,II,III and IV	1993-…	0.01792	3.26E-05	5.19E-05	0.01800
64	Urban Buses	CNG	Euro	all years	0.02191	9.37E-05	1.32E-04	0.02214

Rail transport

EFs developed for rail transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given in Croatian NIR 2017 and passenger kilometres data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. Two EFs were created, one for diesel-powered locomotive and one for electricity power locomotive. For each gas, the sum of all emissions is divided by the passenger kilometres travelled to have the EFs of rail travel by kilometres travelled as reported in Tables 3.5-7 and 3.5-8. To calculate CO_2 EF from electricity consumption, conversion factor in g CO_2/kWh was used. This conversion factor was taken from national database developed by EIHP. For the upstream part of EFs, national database developed by EIHP was used. EFs created for rail transport category are given in Tables 3.5-7 and 3.5-8.

Table 3.5-7: CO_2, CH_4 and N_2O EFs for travel by train

Travel by train	Breakdown of GHG emissions by type (kg CO_2e per passenger.km)					
	CO_2		CH_4 f		N_2O	
Type of train	upstream	combustion	upstream	combustion	upstream	combustion
Diesel powered	1.27E-02	6.72E-02	4.12E-05	9.03E-05	2.61E-05	6.87E-03
Electricity powered	5.42E-05	4.35E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 3.5-8: Total CO_2e EFs with biomass-related CO_2 EFs for travel by train

Travel by train	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per passenger.km		kg CO_2e per passenger.km	
Type of train	upstream	combustion	upstream	combustion
Diesel powered	1.27E-02	7.42E-02	0.00E+00	0.00E+00
Electricity powered	5.42E-05	4.35E-02	0.00E+00	0.00E+00

Sea and waterway transport

EFs developed for water borne transportation sector consists of two parts; combustion and upstream part. Combustion part is calculated based on GHG emissions given in Croatian NIR 2017 and passenger-kilometres data given in Croatian Statistical Yearbook for 2016. For the calculation of the EFs, an average of GHG emissions and statistical data for the last 5 years were used. For each gas the sum of all emissions is divided by the tonne kilometres travelled to have the EFs of sea and waterway ravel by kilometres travelled as reported in Tables 3.5-9 and 3.5-10. EFs was created only for domestic transportation. For now, it is not possible to estimate the international transportation because available data on fuel include only the part of the fuel in Croatia that is sold to international transportation. For the upstream part of EFs, national database developed by EIHP was used. EFs created for Sea and waterway transport category are given in Tables 3.5-9 and 3.5-10.

Table 3.5-9: CO_2, CH_4 and N_2O EFs for sea and waterway travel

Sea and waterway travel	Breakdown of GHG emissions by type (kg CO_2e per passenger.km)					
	CO_2		CH_4 f		N_2O	
	upstream	combustion	upstream	combustion	upstream	combustion
Domestic	3.79E-02	2.03E-01	1.23E-04	5.75E-04	7.81E-05	1.45E-03

Table 3.5-10: Total CO_2e EFs with biomass-related CO_2 EFs for sea and waterway travel

Sea and waterway travel	Total emissions		Biomass-related CO_2 emissions	
	kg CO_2e per passenger.km		kg CO_2e per passenger.km	
	upstream	combustion	upstream	combustion
Domestic	3.81E-02	2.05E-01	0.00E+00	0.00E+00

Data quality and uncertainty analysis

For all passenger transport sectors, good overall data quality was estimated. National energy balance was used for all fuel consumption data. Statistical Yearbook for 2016 was used for data on tonne kilometres travelled. The estimated uncertainty of data from energy balance is below 5%. Data from statistical yearbook are generally well determined too. The accuracy of data on net calorific values, which were also taken from national energy balance, is high. CO_2 EFs for fuels are generally well determined within 5%, as they are primarily dependent on the carbon content of the fuel. 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 EFs applied while the fuel consumption data (national energy balance) are rather good. Implementation of COPERT IV model for estimation of CH_4 and N_2O emissions from Road transport lead to certain uncertainty reduction.

<u>Data quality rating (DQR)</u>

Overall quality rating of the EFs for each passenger transport sector using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good, except road passenger transport that is very good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.5-11.

Table 3.5-11: Data quality rating

Passenger transport sector	TiR	TeR	GeR	U	DQR
Air passenger transport	good	very good	good	poor	**good**
Road passenger transport	good	very good	good	very good	**very good**
Rail passenger transport	good	very good	good	poor	**good**
Sea and waterway passenger transport	good	very good	good	poor	**good**

3.6 Land use, land-use change and forestry

In case of LULUCF sector and determination of national EFs that should be developed under the Clim'Foot project, Croatia provide information that concerns soil pool and litter (presented together) and categories of land that are subject of conversion. These data and information make integral part of the Croatian NIR 2017.

Due to the incomplete information about the methodology that needs to be applied and clear guidelines as well as the lack of data on national level, it is not possible to provide more data and information about national EFs in LULUCF sector as required under the auspice of Clim'Foot project.

Technical description

Data and information presented in this report in case of LULUCF sector and soil and litter pools (presented together) were taken from the Croatian NIR 2017.

EFs that are reported in national database are obtained from the CRF database and Croatian report for year 2017 and they refer to Implied Emission Factor (IEF) calculated from the Common Reporting Format (CRF), as a medium value in period of last five years (2011 - 2015).

Methodological issues

In 2012 Croatian Agency for Environment and Nature (CAEN) initiated a separate project which task was to determine carbon stocks in soil pool in specific IPCC land use categories of land. Data and information on carbon stocks available in previously conducted project by Croatian Geological Institute were examined and were used for determination of carbon stocks in soils (including the litter) according to the IPCC land use categories.

Since the method applied for the determination of carbon stocks was found inadequate, in 2013 additional analysis was conducted. This time the dry combustion method was used instead of previously used wet combustion method. Since then Croatia uses values on soil carbon stocks as defined under the analyses conducted in year 2013.

For the estimation of carbon stock changes in soil pool in case of lands that are subject of changes, Croatia uses IPCC Guidelines, Tier 1 methodology and equation:

$$\Delta SOC = (SOC0 – SOC0\text{-}T)/20$$

where:

ΔSOC = annual change in carbon stock soil
SOC0 = Croatian soil organic carbon stock in the inventory year
SOC0-T = Croatian soil organic carbon stock T years prior to the inventory
T = Assessment period (20 years)

In the process of GHG Inventory compilation, values of ΔSOC for each type of conversion (where emissions occur) are used together with activity data (land areas) to calculate carbon stock gains/losses. Gains, losses and net change of the carbon stock are then imported into CRF application that calculates IEF and, at the end, generates CRF tables for each reporting year.

Average values of IEF for the last five years from the Croatian NIR 2017 submission were used as EFs for this purpose. Biogenic CO_2 has characterization factor equals to zero, so carbon pool such as aboveground biomass, belowground biomass and dead wood have been omitted in this estimation. In addition, EFs have been estimated for six types of land conversion where emissions occur from the litter and soil carbon pools under three LULUCF subcategories (Land converted to Cropland, Land converted to Wetlands and Land converted to Settlements).

Changes in Carbon Stocks in Soil of Forest land converted to Cropland

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 of perennial cropland to Forest land. Estimation was done using the following soil C stocks:

- perennial cropland: 77.8 t C/ha
- forestland: 84.5 t C/ha

Changes in Carbon Stocks in Soil of Grassland converted to Cropland

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 as follows:

- 46.35 t C/ha for annual cropland
- 77.81 t C/ha for perennial cropland

SOC_T = soil organic carbon stock T years prior to the inventory, equals 70.64 t C/ha.

Changes in Carbon Stocks in Soil of Cropland Converted to Wetlands

For the calculation of the average annual change in carbon stock of mineral soils of cropland converted to wetlands, country specific data were used and the IPCC GPG Tier 1 equation was applied, as follows: 1) for annual cropland 46.4 t C/ha annually 2) for perennial cropland 77.8 t C/ha annually After = carbon stock in soil immediately after conversion to wetland (default = 0 t C/ha).

Changes in Carbon Stocks in Soil of Forest Land Converted to Settlements

The calculation of the emissions from soils as a result of the conversion of forest land to settlements was made by using national data for carbon stocks in soils in forest land (84.7 t C/ha) and carbon stocks in soils of settlements (55.04 t C/ha for the unsealed settlement area or 2.5 t C/ha for the total settlement area).

Changes in Carbon Stocks in Soil 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 (46.4 t C/ha) and perennial cropland (77.8 t C/ha), as well as carbon stocks in soils of settlements (55.0 t C/ha for the unsealed settlement area or 2.5 t C/ha for the total settlement area).

Changes in Carbon Stocks in Soil of Grassland Converted to Settlements

The calculation of emissions from soils as a result of conversion of grassland to settlements was made by using national data for carbon stocks in soils in grassland (70.6 t C/ha) and carbon stocks in soils of settlements (55.0 t C/ha for the unsealed settlement area or 2.5 t C/ha for the total settlement area).

It is expected that for NIR 2017 Resubmission Croatia will use new values for the soil carbon stocks since the new project were performed in 2016.

Data quality and uncertainty analysis

The main data provider for the estimation of emissions in soil pool due to land use changes is CAEN. After the survey described above was conducted obtained data were discussed among relevant stakeholders in Croatia which includes a scientific community in Croatia. The input data as well as estimation of emissions/removals in this pool goes through regular cycle of quality assurance and quality control that is performed on annual basis according to the IPCC requirements. Uncertainty estimate was performed using the IPCC Guidelines and Tier 1 methodology. Uncertainty of EFs in soil pool that appears due to conversion of lands is as follows:

4.B.2.1 Forest land converted to cropland: 70.0%
4.B.2.2 Grassland converted to cropland: 60.0%
4.D.2.2 Cropland converted to wetlands: 75.0%
4.E.2.1 Forest land converted to settlements: 100.0%
4.E.2.2 Cropland converted to settlements: 70.0%
4.E.2.3 Grassland converted to settlements: 80.0%

while the uncertainty of soil C stock in mineral soil in specific land use categories according to the Croatian NIR 2017 are:
92.0% for Forest land
57.1% for annual Cropland
76.3% for perennial Cropland
61.2% for Grassland category
67.0% for Wetland category
64.5% for Settlement category

Data quality rating (DQR)

Overall quality rating of the EFs from the soil pool using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.6-1.

Table 3.6-1: Data quality rating

LUC	TiR	TeR	GeR	U	DQR
Forest land converted to cropland	good	good	very good	very poor	**good**
Grassland converted to cropland	good	good	very good	very poor	**good**
Cropland converted to wetlands	good	good	very good	very poor	**good**
Forest land converted to settlements	good	good	very good	very poor	**good**
Cropland converted to settlements	good	good	very good	very poor	**good**
Grassland converted to settlements	good	good	very good	very poor	**good**

3.7 Waste

In the area of Waste, database includes EFs from the following categories:

- Municipal solid waste (MSW) disposal
- Composting of organic waste
- Incineration of waste
- Treatment of domestic wastewater

Technical description

Municipal solid waste (MSW) disposal

Two categories are included:

- MSW disposal at managed landfills
- MSW disposal at unmanaged landfills

MSW is defined as waste collected by municipalities or other local authorities. Waste composition is one of the main factors influencing emissions from solid waste disposal, as different waste types contain different amount of degradable organic carbon (DOC) and fossil carbon. Disposal of municipal, biodegradable industrial and other biodegradable solid waste produces significant amounts of CH_4. Decomposition of organic material derived from biomass sources is the primary source of CO_2 released from waste. These CO_2 emissions are not included in national totals, because the carbon is of biogenic origin. CO_2 emissions from waste collection and operating of landfilling are calculated and included in emission estimates.

Implementation and establishment of the integral waste management system in Croatia are ensured by applying and fulfilling the objectives defined by the Sustainable Waste Management Act (OG 94/13). According to the Waste Management Plan of the Republic of Croatia for the period 2017 – 2022 (OG 05/17) the backbone of the system will be recycling centres with sorting of waste. However, apart from a certain amount of waste collected separately, most of MSW quantities are still sent to landfills and disposed without previous treatment. The infrastructure currently available for the management of municipal waste and environment protection measures on landfills are still of inadequate standard. Remediation processes for all official landfills registered in the Republic of Croatia are ongoing or completed. During the period until 2018, remediation and closing 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 (implementing mechanical-biological treatment), complying with the requirements of the Landfill Directive.

Landfills in Croatia are classified into several categories, according to applied waste management activities, legality, volume and status. Croatian Waste Management Information System contains various data on landfills, such as implementation of technical measures (e.g. fence, scale, flares…) or environment protection measures (e.g. degassing, compacting, aligning, monitoring,..). Database also contains data on the status of remediation of landfills (ongoing/finished) and status of operation (active/closed). In the process of adjustment the country-specific to IPCC classification, some assumptions have been made. Landfills on which remediation activities were reported as finished and those having fully surrounding landfill fences as well 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 (≥ 5 m) or unmanaged shallow (< 5 m).

Composting of organic waste

Composting is an aerobic fermentation of the organic matter in the waste. The estimated CH_4 released into the atmosphere ranges from less than 1% to a few percent of the initial carbon content in the material. Composting can also produce emissions of N_2O. The range of the estimated emissions varies from less than 0.5% to 5% of the initial nitrogen content of the material. Advantages of the composting include reduced volume in the waste material, stabilisation of the waste and destruction of pathogens in the waste material. The end products of the composting can, depending on its quality, be recycled as fertiliser and soil amendment (the production of compost averts the use of artificial nitrogenous fertilisers), or be disposed in landfills.

CH_4 and N_2O emissions from composting of municipal and industrial solid waste, sludge and other organic waste as well CO_2 emissions from waste collection and functioning of processing plant are calculated and included in emission estimates.

Incineration of waste

Two categories are included:

- Incineration of hazardous industrial waste
- Incineration of hazardous clinical waste

Waste incineration is a process of combustion of solid waste in controlled incineration facilities. Combustors for incineration of hazardous industrial and clinical waste have specially designed combustion chambers, which provide high combustion temperatures and long residence times for more complete combustion.

CO_2 and N_2O emissions from incineration of hazardous industrial and clinical waste as well CO_2 emissions from waste collection and functioning of processing plant are calculated and included in emission estimates.

Treatment of domestic wastewater

Disposal of domestic wastewater, particularly in rural areas where systems such as septic tanks are used, are partly anaerobic, which results with CH_4 emissions. Disposal of domestic wastewater in septic tank is one of the form of individual solutions for purification and drainage in areas where public sewerage system is not yet built. In the septic tank, process of sedimentation takes place and the accumulated solids are digested by anaerobic decomposition at the bottom of the tank. 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.

CH_4 emission from treatment of domestic wastewater in septic tanks is calculated and included in emission estimates.

Methodological issues

Municipal solid waste (MSW) disposal

Production of landfill gas and CH_4 is calculated according to 2006 IPCC Guidelines using First Order Decay (FOD) method. Detailed explanation is presented in the Croatian NIR 2017. For the calculation of CH_4 EF, an average for the last five years is considered for all parameters included in the model. A combination of national and recommended IPCC parameters is used for the calculation.

Main source for activity data on municipal and industrial waste that is disposed at landfills is Environmental Pollution Register Database and Waste Management Information System Database (previously Landfill Inventory Database), operated by Croatian Agency for the Environment and Nature (CAEN). Data on the quantity of generated and disposed municipal and industrial solid waste for the period 2011 - 2015 were obtained from the Environmental Pollution Register - reports delivered by the operators of active landfills. Data on the quantity of disposed biodegradable municipal and industrial solid waste as well sludge from wastewater treatment for the period 2011 - 2015 were obtained from the Waste Management Information System - reports on landfills and waste disposal. In the process of defining managed and unmanaged landfills for the period 2011 - 2015 (adjustment the country-specific to IPCC classification), the set of criteria were defined using the data available in Waste Management Information System.

According to the data included in the Croatian NIR 2017, an average fraction of solid waste that is disposed at landfills of the last five years amounts 86% (of which 70% refers to managed landfills and 30% to unmanaged landfills).

Parameters description

Data for 3-5 years' half-lives for the waste deposited at the landfills is included in order to achieve accurate emission estimate.

Methane generation rate constant for Climate zone Boreal and Temperate/Wet, proposed by 2006 IPCC Guidelines, has been used for the calculation.

Weighted average methane correction factor (MCF) for each type of landfills (managed, unmanaged deep and unmanaged shallow) has been assessed. Proportion of waste (by weight) for each type of landfills are multiplied by corresponding MCF proposed by 2006 IPCC Guidelines. The total weighted average MCF is obtained by summing of weighted average MCF for each type of landfills.

The quantity of CH_4 emitted during decomposition process is directly proportional to the fraction of DOC, which is defined as the carbon content of different types of organic biodegradable wastes. DOC was estimated by using country-specific data on waste composition and quantities using carbon content values proposed by 2006 IPCC Guidelines.

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. Approximately 50% of total DOC actually degrades and converts to landfill gas, as proposed by 2006 IPCC Guidelines.

The CH_4 fraction in landfill gas for managed landfills was estimated by using country-specific data on landfill gas composition. The CH_4 fraction in landfill gas for unmanaged landfills is taken to be 0.5 according to proposed value by 2006 IPCC Guidelines.

The most of landfills are not covered with aerated material and because of that value for oxidation factor (OX), which equals zero, is used.

Data set for managed landfills includes landfill gas treatment - CH_4 burned in a flare (without energy recovery) as well CH_4 recovered for power generation that is subtracted from generated CH_4. Data set for unmanaged landfills do not include landfill gas treatment.

Upstream transportation and operating

Waste collection and operating of landfilling are included in the data sets for managed and unmanaged landfills.

The collection of most household waste in Croatia is carried out using refuse trucks. The consumption of trucks, owing to frequent stops, represents even to 80 litres of diesel every 100 km, depending on the age of the equipment and devices. A truck must cover an average over 15 km to collect one tonne of household waste, depending on the population in certain areas and distances between settlements. The estimate not include rarely populated areas. Applying the methodology presented in Base Carbon Version 1.01, CO_2 EF was estimated.

Emissions for functioning of landfills concern the construction of sites, consumed electricity, the activity of machinery on site, the production of consumables, etc. Applying the methodology presented in Base Carbon Version 1.01, the proposed average CO_2 EF was used.

Avoided emissions - electrical recovery

The only one landfill generates electricity and transmits it to the power grid. About 20% of total waste is disposed at this landfill. According to the data on electricity generation, it is estimated that 76 kWh is generated per tonne of waste. Applying the national EF for average electrical kWh that amounts 0.3523 kg CO_2e/kWh, avoided emissions were estimated.

EFs for upstream transportation and operating of landfilling, waste treatment and avoided emissions for MSW disposal at managed and unmanaged landfills are presented in Tables 3.7-1, 3.7-2 and 3.7-3.

Table 3.7-1: EFs for upstream transportation and operating

Waste collection and treatment facilities	kg CO_2e per tonne	Breakdown of GHG emissions by type (kg CO_2e per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Waste collection	26.38	26.38	0.00	0.00	0.00
Operating of treatment facilities – landfilling	15.00	15.00	0.00	0.00	0.00

Table 3.7-2: EFs for waste treatment – without uptake

Waste treatment	kg CO_2e per tonne	Breakdown of GHG emissions by type (kg CO_2e per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
MSW disposal at managed landfills	1176.69	41.38*	1135.31	0.00	153.27
MSW disposal at unmanaged landfills	777.43	41.38*	736.05	0.00	99.37

* *upstream transportation and operating are included*

Table 3.7-3: EF for avoided emissions

Avoided emissions	kg CO_2e per tonne	Electrical recovery	
		kWh LHV generated per tonne	kg CO2e per tonne
MSW disposal at managed landfills	-26.70	75.78	-26.70
MSW disposal at unmanaged landfills	0	0	0

<u>Composting of organic waste</u>

CH_4 and N_2O emissions from composting of municipal and industrial solid waste, sludge and other organic waste are calculated according to 2006 IPCC Guidelines, using Tier 1 methodology. Detailed explanation is presented in Croatian NIR 2017. For the calculation of CH_4 and N_2O EFs, an average for the last five years is considered for all parameters included in the methodology. A combination of national and recommended IPCC parameters is used for the calculation.

Main source for activity data on different type of waste that is composed is Environmental Pollution Register Database and Waste Management Information System Database operated by CAEN. CH_4 and N_2O EFs have been estimated using recommended range estimates for parameters such as fraction of DOC, fraction of nitrogen in dry matter and moisture content of composted waste.

According to the data included in the Waste Management Plan of the Republic of Croatia for the period 2017 – 2022, an average fraction of waste that is recovered by composting amounts 2%.

Upstream transportation and operating

Waste collection and functioning of processing plant are included in the data sets for composting of organic waste. Applying the methodology presented in Base Carbon Version 1.01, CO_2 EFs were adjusted to country-specific conditions.

Avoided emissions

The use of compost avoids the use of artificial nitrogenous fertilisers, which means that it will reduce emissions from fertilizer production. In addition, a fraction of the CO_2 contained in the compost that is spread will be confined in the soil. According to the fraction of nutritive elements in the compost, presented in Base Carbon Version 1.01, and manufacturing emissions for artificial products, the total saved emissions by using one tone of compost rather than artificial fertilisers were estimated.

Total saved emissions per tonne of waste sent for composting were estimated according to assessment that 3.3 tonnes of biodegradable waste are needed to make 1 tonne of compost. Assessment provided by the AEA Technology, presented in Base Carbon Version 1.01, was used for confinement.

EFs for upstream transportation and operating, composting of organic waste and avoided emissions are presented in Tables 3.7-4, 3.7-5 and 3.7-6.

Table 3.7-4: EFs for upstream transportation and operating

Waste collection and treatment facilities	**kg CO_2e per tonne**	**Breakdown of GHG emissions by type (kg CO_2e per tonne)**			
		CO_2	**CH_4 f + CH_4 b**	**N_2O**	**CO_2 b**
Waste collection	26.38	26.38	0.00	0.00	0.00
Operating of treatment facilities – composting	15.00	15.00	0.00	0.00	0.00

Table 3.7-5: EFs for composting

Organic waste streams	**kg CO_2e per tonne**	**Average value without avoidance Breakdown of GHG emissions by type (kg CO_2e per tonne)**			
		CO_2	**CH_4 f + CH_4 b**	**N_2O**	**CO_2 b**
Composting	216.98	41.38*	112.00	63.60	0

** upstream transportation and operating are included*

Table 3.7-6: EF for avoided emissions

Organic waste streams	**Average value avoided emissions**
	kg CO_2e per tonne
Composting	-21.33

Incineration of waste

CO_2 and N_2O emissions from incineration of hazardous industrial and clinical waste are calculated according to 2006 IPCC Guidelines, using Tier 1 methodology. Detailed explanation is presented in the Croatian NIR 2017. For the calculation of CO_2 and N_2O EFs, an average for the last five years is considered for all parameters included in the methodology. A combination of national and recommended IPCC parameters is used for the calculation.

Main source for activity data on different type of waste that is incinerated is Environmental Pollution Register Database operated by CAEN. CO_2 and N_2O EFs have been estimated using recommended range estimates for parameters such as fraction of carbon content, fraction of fossil carbon and oxidation factor.

Upstream transportation and operating

Waste collection and functioning of processing plant are included in the data sets for incineration of hazardous industrial and clinical waste. Applying the methodology presented in Base Carbon Version 1.01, CO_2 EFs were adjusted to country-specific conditions.

EFs for upstream transportation and operating and incineration of hazardous industrial and clinical waste are presented in Tables 3.7-7 and 3.7.-8.

Table 3.4-7: EFs for upstream transportation and operating

Waste collection and treatment facilities	kg CO_2e per tonne	Breakdown of GHG emissions by type (kg CO2e per tonne)			
		CO2	CH_4 f + CH_4 b	N_2O	CO_2 b
Waste collection	20.00	20.00	0.00	0.00	0.00
Operating of treatment facilities - incineration	18.00	18.00	0.00	0.00	0.00

Table 3.4-8: EFs for incineration of hazardous industrial and clinical waste

Hazardous waste	kg CO_2e per tonne	Average value without avoidance			
		Breakdown of GHG emissions by type (kg CO_2e per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Hazardous industrial waste	1714.50	1688.00*	0.00	26.50	0.00
Hazardous clinical waste	944.50	918.00*	0.00	26.50	0.00

* *upstream transportation and operating are included*

Treatment of domestic wastewater

CH_4 emission from disposal of domestic wastewater in septic tank is calculated according to 2006 IPCC Guidelines, using Tier 1 methodology. Detailed explanation is presented in Croatian NIR 2017. For the calculation of CH_4 EF, an average for the last five years is considered for all parameters included in the methodology. A combination of national and recommended IPCC parameters is used for the calculation.

Main source for activity data on the systems for collection and treatment of domestic wastewater are providers of water services. The quality of the original data depends on their internal data tracking systems and information providing, but systematic flow of information is not yet established. 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 153/09, 130/11, 56/13, 14/14) and relevant by-laws. 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 estimates.

Data for population with individual system of drainage and data on degradable organic component in kg biochemical oxygen demand (BOD) are used in the calculation. Water consumption in rural areas was estimated to be 120 litres/person/day and 70% of this amount is returned to the drainage system (overflows in septic tanks). Therefore, according to expert judgement, fraction of treated wastewater in septic tank has been estimated to be 30%. CH_4 EF has been estimated using recommended range estimates for parameters such MCF for anaerobic system and maximum methane producing capacity.

CH_4 EF for disposal of domestic wastewater in septic tank, what could be compared with wastewater rejected in a stagnant environment presented in Bilan Carbone® tool - version 7.4, is presented in the Table 3.7-9.

Table 3.7-9: EF for treatment of domestic wastewater – disposal in septic tank

Wastewater, methods by m³ and BOD	
kg of CH_4 per kg of BOD	0.09

Data quality and uncertainty analysis

Municipal solid waste (MSW) disposal

Good quality of data for quantity of solid waste disposed to different types of landfills and the main characteristic of landfills. Data are estimated according to information from Environmental Pollution Register Database and Waste Management Information System Database. Adjustment the country-specific to IPCC landfills classification represents uncertainty in the estimation of country-specific values for MCF. Another uncertainty is related to estimation of country-specific values for DOC. In addition, the uncertainties are related to usage of recommended IPCC methane generation rate constant (k). Consequently, uncertainty estimate associated with CH4 EF amounts 50%, based on the expert judgement and the recommended uncertainty range estimates provided in 2006 IPCC Guidelines. Uncertainty estimate associated with CO_2 EF from upstream transportation and operating amounts 50%, based on the recommended values in Bilan Carbone® tool - version 7.4.

Composting of organic waste

Good quality of data for quantity of composted organic waste. Data are estimated according to information from Environmental Pollution Register Database and Waste Management

Information System Database. CH_4 and N_2O EFs are adjusted according to recommended IPCC parameters that is the reason of uncertainty. Uncertainty estimate associated with EFs amounts >50%, based on the expert judgement and the recommended uncertainty range estimates provided in 2006 IPCC Guidelines. Uncertainty estimate associated with CO_2 EF from upstream transportation and operating amounts 50%, based on the recommended values in Bilan Carbone® tool - version 7.4.

Incineration of waste

Good quality of data for quantity of incinerated hazardous industrial and clinical waste. Data are estimated according to information from Environmental Pollution Register Database. CO_2 and N_2O EFs are adjusted according to recommended IPCC parameters that is the reason of uncertainty. Uncertainty estimate associated with EFs amounts 50%, based on the expert judgement and the recommended uncertainty range estimates provided in 2006 IPCC Guidelines. Uncertainty estimate associated with CO_2 EF from upstream transportation and operating amounts 50%, based on the recommended values in Bilan Carbone® tool - version 7.4.

Treatment of domestic wastewater

Good quality of data for population with individual system of drainage and data on degradable organic component. Data are estimated according to information provided by Croatian Water Information System. CH_4 EFs are adjusted according to recommended IPCC parameters that is the reason of uncertainty. Uncertainty estimate associated with EF amounts >30%, based on the expert judgement and the recommended uncertainty range estimates provided in 2006 IPCC Guidelines.

Data quality rating (DQR)

Overall quality rating of the EFs from the waste sector categories using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.7-10.

Table 3.7-10: Data quality rating

Waste sector	**TiR**	**TeR**	**GeR**	**U**	**DQR**
MSW disposal at managed landfills	good	good	good	poor	**good**
MSW disposal at unmanaged landfills	good	good	good	poor	**good**
Composting of organic waste	good	fair	good	very poor	**good**
Incineration of hazardous industrial waste	good	good	good	poor	**good**
Incineration of hazardous clinical waste	good	good	good	poor	**good**
Treatment of domestic wastewater	good	fair	good	poor	**good**

3.8 Agriculture

Technical description

Livestock rearing generates GHG emissions from several sources:

- CH_4 emissions from enteric fermentation as direct product of animal metabolism generated during the digestion process;
- CH_4 and N_2O emission during the storage and treatment of manure in animal waste management systems;
- N_2O emissions from soil due to applied organic fertilizer (manure) or animals on pasture;
- Alimentation of animals (including fodder production and heating of animal enclosures).

Carbon footprint EFs for animals were developed per animal type (kg CO_2e/head/year) and can be used to estimate yearly GHG emissions from the process of rearing selected animal types that are representative for Croatian conditions (breed, management types, feed etc.), but should not be used for unique or specialised rearing processes, or for imported animals.

Methodological issues

Methodology used for the calculation of EF estimates is based on the 2006 IPCC Guidelines, Deliverable A.2.2 Methodology for constituting the National Databases and Base Carbone Version 1.01 Guidelines.

Methodologies proposed by the 2006 IPCC Guidelines are used for the calculation of national GHG emissions from the Agriculture sector of Croatian NIR 2017. Although the 2006 IPCC methodological approach was used for emission estimates, there is a key difference in reporting method: NIR emission are reported in Common Reporting Format (CRF) tables per IPCC source categories, not per livestock (animal type) as presented here, so the total emission estimates from all IPCC sources were segregated and were for each livestock type. This in particular applies to CH_4 and N_2O emissions during the storage and treatment of manure in animal waste management systems and N_2O emissions from soil and pasture range due to applied manure.

In addition, although certain implied emission factors (specifically - IEF for CH_4 from enteric fermentation and manure management) for animals submitted in Croatian NIR 2017 were directly used in the carbon footprint EFs development, correct approach for using emission estimates (as described in Deliverable A.2.2 Methodology for constituting the National Databases) is to develop an average data of the last 5 years if available and representative, meaning they are not directly comparable to the CRF values submitted in Croatian NIR 2017.

NIR 2017 provides the source of both nationally developed EFs as well as recommended emission parameters comparable to national conditions (recommended IPCC values) to form the national EFs for the yearly GHG emissions/animal due to enteric fermentation process, manure treatment and emissions from soils.

Total CO_2e emissions from all sources for the years 2011 - 2015 are given in the Table 3.8-1, while a breakdown of the approach used to apply the NIR data and the IPCC 2006 methodology is presented in Chapters 3.5.2.1 and 3.5.2.2. Complete national circumstances breakdown and detailed descriptions of approach used for the national GHG emission estimates, such as analysis of activity data, are beyond the scope of this document but are available for review in the Croatian NIR 2017.

Final EFs (Table 3.8-1) also include emission values due to alimentation of animals, taken from the Bilan Carbone® tool - version 7.4 dataset (presented separately in the Table 3.8-2) for the relevant animal types. This generally consists of CO_2 emissions from the usage fuel for heating, feed etc. Nationally developed per-animal national emission values for enteric fermentation, manure management and emission from soils were found to be comparable with the Bilan Carbone digestion/manure emissions, thus the alimentations values were considered to be acceptable standardized value replacement for national alimentation values.

Table 3.8-1: EFs for rearing of selected animal types including alimentation

Livestock type	kg CO_2e / head / year	Breakdown of GHG emissions by type (kg CO_2e / head / year)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Dairy cattle	5,736.34	638.77	4,029.51	1,068.06	0.00
Young cattle (calf)	3,040.40	598.85	1,619.99	821.56	0.00
Sheep	378.88	25.60	221.89	131.40	0.00
Layer hen	159.55	0.00	142.94	16.61	0.00
Market pig	40.48	0.43	1.93	38.13	0.00

Table 3.8-2: Total emissions due to alimentation only

Livestock type	kg CO_2e / head / year	Breakdown of GHG emissions by type (kg CO_2e / head / year)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Dairy cattle	1,196.06	638.77	13.86	543.42	0.00
Young cattle (calf)	1,121.30	598.85	13.00	509.46	0.00
Sheep	91.28	25.60	1.46	64.22	0.00
Layer hen	0.00	0.00	0.00	0.00	0.00
Market pig	1.06	0.43	0.00	0.63	0.00

Source: Bilan Carbone® tool - version 7.4 dataset

CH_4 emissions

Biogenic CH_4 emissions pathways from livestock production are CH_4 emissions from enteric fermentation and emissions from livestock manure management systems. CH_4 emissions from manure management tend to be smaller than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems. Total combined emissions from these two sources for the years 2011 – 2015 (average value) are given in the Table 3.8-3.

Table 3.8-3: Total emissions of biogenic CH_4 from enteric fermentation and manure management

Livestock type	unit	Total CH_4 b emissions from EF and MM
Dairy cattle	kg CH_4/head/year	143.42
Young cattle (calf)	kg CH_4/head/year	57.39
Sheep	kg CH_4/head/year	7.87
Layer hen	kg CH_4/head/year	0.07
Market pig	kg CH_4/head/year	7.65

Enteric fermentation

CH_4 is a direct product of animal metabolism generated during the digestion process. The greatest producers of CH_4 are ruminants (cows, other cattle and sheep). The amount of CH_4 produced and excreted depends on the animal digestive system and the amount and type of the animal feed.

Averaged 2011 - 2015 emission estimate values from Croatian NIR 2017 are presented in the Table 3.8-4. The IPCC methodology has been used to calculate CH_4 emission from enteric fermentation, using national EFs for animal species developed with the assistance of experts from the Faculty of Agriculture, University of Zagreb. This methodology relies on the analysis of diet digestibility as a base for the calculation of methane conversion factor (Ym) which, in turn, together with the data for daily food intake, is the base for the calculation factors of CH_4 emission. While Ym depends primarily on the type and digestibility of forage, daily food intake is dependent on the quality (digestibility) of the forage and the amount of production of milk and meat. Ym value was calculated according to the following equation: Ym=9.75-0.05*DE%, with possible deviations up to 5%.

Table 3.8-4: Emissions of CH_4 *from enteric fermentation for selected livestock types*

Livestock type	unit	Enteric Fermentation emissions (CH_4 b)
Dairy cattle	kg CH_4/head/year	109.31
Young cattle (calf)	kg CH_4/head/year	47.42
Sheep	kg CH_4/head/year	7.74
Layer hen	kg CH_4/head/year	0.00
Market pig	kg CH_4/head/year	1.36

<u>Dairy cattle</u>

National values for the 2006 IPCC Tier 2 emission calculation for cattle were developed with the assistance of the experts from the Faculty of Agriculture, University of Zagreb, with the default value for milk fat percentage (4%, Holstein breed, increase of milk production of Simmental breed) based on the data for the years 2011 - 2015. In order to meet the nutritional requirements of mentioned breeds, feed is based on a combination of high-quality forage (corn silage and alfalfa/grass) and concentrated forage (cereals and oilseeds). At least 40% daily food intake comes in the form of a concentrated high digestibility forage (~82-85% digestibility). The remaining 60% (40%) are good digestibility forages, of which 50% is composed of corn silage (~70-72% digestibility) and 50% grass silage, clover/grass mixture and alfalfa (~60-65% digestibility). This results in the digestibility value for the dairy cows' meal of an average 70-75%.

Young cattle - calves

National EFs were developed for the cattle category of animal younger than 2 years - this category consists of calves, beef cattle, and male and female breeding animals in growth. Beef cattle accounts for the largest share in this category (about 65%). Feeding beef cattle is based on of corn silage and concentrated forage (milled grain corn meal with the addition of oilseeds and mineral-vitamin supplement) using the minimum amount of hay or straw (1-1.5 kg/head/day). Gains that are obtained during fattening are around 1.2-1.35 kg/day. The high share of grain corn (40% dry matter intake) and corn silage (30% dry matter intake) accounts for the high digestibility (75%) of beef cattle feed. Traditionally, fattening beef cattle in Croatia does not occur in grazing systems. Minor share of heifers is fattened enclosed, with a greater amount of forage with medium digestibility (grass hay, alfalfa, straw) and the addition of ground corn grain. It is estimated that in recent years there was about 17% of such animals and that the average digestibility of their meals was 67%.

Sheep

Sheep are ruminants and release significant amount of CH_4 as a result of enteric fermentation. Similar methodology to the one for cattle is used for calculating the CH_4 EFs, since the digestion process and the type of feed consumed is very similar. When calculating the average digestibility, it is taken into account that it is largely influenced by the production system. In Croatia, most of the sheep are kept in the coastal (sub-Mediterranean) region and in highland area. Indigenous breed ("Pramenka") is the most common breed and has modest requirements regarding keeping and feeding. Feeding is based on grazing on natural pasture (uncultivated) of lower quality, most of the year. In the winter, the animals are kept in stalls or confined areas with shelters where they are fed with hay and very small amounts of grain cereal. Given the structure of pastures and the time of mowing such meadows in these areas, it is estimated that digestibility of the meal is about 55%. A smaller number of sheep in the coastal area that are kept for milk production and particularly those in the northwestern part of the Republic of Croatia are fed with the certain amounts of concentrated feed material and silage during lactation. Therefore, the digestibility in feed of such sheep can range from 60 to 70%. Furthermore, similar digestibility of the meal can be expected in meat sheep breeds from continental Croatia (lowland). They have higher requirements on the type and quantity of feed. Feed for said sheep requires the use of higher quality forage but also a certain amount of grains and it is therefore of higher digestibility (65%). Considering the proportion of animals from each of the production system in the total number of sheep, average digestibility is calculated to be within 55 to 57% range. The reason for the relatively low digestibility is the fact that the largest percentage of total sheep number is in the coastal karst area, with rudimentary vegetation of poor digestibility (about 50%).

Market swine

CH_4 EF from enteric fermentation is determined by dry matter intake, energy content and methane conversion factor that depends on the type and category of animals and the type and digestibility of forage in the meal. Although pigs do not contribute significantly to the emission of CH_4 from enteric fermentation, there are certain differences between different production systems.

Two systems of swine farming can be distinguished. Both farming systems were averaged for the CH_4 emission calculation. One is characteristic for small farms with few animals, mostly for personal use and the other for the intensive farming system, characteristic for commercial producers. Within the commercial producers there are those who keep swine in large industrial type farms with large number of animals (a thousand or more), and family type farms with a smaller number of animals (tens or hundreds of animals).

For small producers, it is characteristic that they keep less productive animals including indigenous breeds and their hybrids with white breeds (Landrace). They are kept mostly in modest facilities with discharge or in the open (pastures). Their feed usually consists of corn germ with the addition of wheat bran, other crop residues from household and green forage (pasture, alfalfa, etc.). The average digestibility of such meal, depending on the proportion of forage, ranges from 60-80%. Since the corn germ (ground maize grain) is the regular meal ingredient for these animals and makes between 50 and 60% of dry matter intake, it is estimated that the average digestibility of such a meal is about 77%.

Commercial producers whose pigs are kept exclusively in closed (controlled) conditions, apply finished feed as the only feed which is adapted to the animal needs depending on age, production stage and genetic potential. Digestibility of such meals for breeding swine is estimated at about 82%, while for the fattening pigs amounts 85%.

Layer hens

Currently there is insufficient data to form the correct IPCC methodology for calculation of the EF for CH_4 emissions from the enteric fermentation for poultry, so the estimated emissions for this particular source amount to zero.

Manure management

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.

Averaged 2011 - 2015 emission estimate values from Croatian NIR 2017 are presented in the Table 3.8-5. The 2006 IPCC methodology has been used for the NIR CH_4 emission estimate from Manure Management, using a combination of national EFs (percentages of animal waste management systems) developed with the assistance of experts from the Faculty of Agriculture, University of Zagreb and recommended default IPCC factors (methane conversion factors, volatile solids excreted and methane producing capacity).

Table 3.8-5: Emissions of CH_4 from manure management for selected livestock types

Livestock type	unit	Manure Management emissions (CH_4 b)
Dairy cattle	kg CH_4/head/year	34.11
Young cattle (calf)	kg CH_4/head/year	9.97
Sheep	kg CH_4/head/year	0.14
Layer hen	kg CH_4/head/year	0.07
Market pig	kg CH_4/head/year	6.29

N_2O emissions

Manure management – direct and indirect emissions

N_2O emissions from manure management vary significantly between the types of management system used and can also result in indirect emissions due to other forms of nitrogen loss from the system. The calculation of the nitrogen loss from manure management systems is also an important step in determining the amount of nitrogen that will ultimately be available in manure applied to managed soils.

N_2O is produced during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment.

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment.

The 2006 IPCC methodology (Tier 2) has been used for the calculation of Direct N_2O emissions from manure management. Emissions were calculated using equation 10.25 (2006 IPCC Guidelines), with country-specific data: nitrogen excretion rates (Nex) for all animal categories and fraction of Nex for each livestock category (T) managed in each manure management system (S), presented in the Table 3.8-6. 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 EFs (Table 10.21 of 2006 IPCC Guidelines) were also used in the calculation.

CRF used for NIR requires only the total N_2O of the Direct Manure Management source to be reported. Averaged value of the 2011 - 2015 dataset of those estimates was thus segregated for each livestock group and then further divided to get the final direct emissions of kg N_2O/head/year presented in the Table 3.8-7.

Table 3.8-6: Nex and manure management emission fractions per AWMS for the year 2014

Livestock Type	Nitrogen Excretion kg/head/yr	Fraction of Manure Nitrogen per AWMS (%/100)					
		Anaerob. lagoon	Liquid system	Solid storage and drylot	Pasture range and paddock	Digester	Other systems
Dairy Cattle	88.61	5.00	49.60	38.40	2.00	4.00	1.00
Other Cattle	50.12	0.00	34.60	55.40	5.00	4.00	1.00
Sheep	8.04	0.00	0.00	17.60	82.40	0.00	0.00
Market swine	9.77	2.00	83.35	10.65	0.00	4.00	0.00
Layers	0.55	0.00	11.00	88.00	1.00	0.00	0.00

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x. The fraction of excreted organic nitrogen that is mineralized to ammonia nitrogen during manure collection and storage depends primarily on time, and to a lesser degree temperature.

For indirect emissions Tier 1 methodology (Equation 10.26, 2006 IPCC Guidelines) has been used. Volatized N in forms of NH_3 and NO_x was calculated for each manure management systems from all livestock categories, summing all N losses. Final N_2O emissions were estimated using Equation 10.27 (2006 IPCC guidelines), using default EFs (Table 11.3, 2006 IPCC Guidelines).

CRF used for NIR requires only the total N_2O of the Indirect Manure Management source to be reported. Averaged value of the 2011 - 2015 dataset of those estimates was thus segregated for each livestock group and then further divided to get the final indirect emissions of kg N_2O/head/year presented in the Table 3.8-8.

Table 3.8-7: Direct emissions of N_2O from manure management for selected livestock types

Livestock type	unit	Manure Management emissions (N_2O)
Dairy cattle	kg N_2O/head/year	0.28
Young cattle (calf)	kg N_2O/head/year	0.23
Sheep	kg N_2O/head/year	0.01
Layer hen	kg N_2O/head/year	0.00
Market pig	kg N_2O/head/year	0.01

Table 3.8-8: Indirect emissions of N_2O from manure management for selected livestock types

Livestock type	unit	Manure Management emissions (N_2O)
Dairy cattle	kg N_2O/head/year	0.48
Young cattle (calf)	kg N_2O/head/year	0.21
Sheep	kg N_2O/head/year	0.00
Layer hen	kg N_2O/head/year	0.01
Market pig	kg N_2O/head/year	0.00

Emission due to animal manure applied to soils

Raising of farm animals adds nitrogen to soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of N_2O emitted. Usage of organic fertilisers and deposited manure, through two primary sources of nitrous oxide emissions are distinguished: Direct N_2O Emissions and Indirect N_2O Emissions from managed soils. To complete the nitrogen emission cycle due to raising of animals, both of these were estimates using the 2006 IPCC Guidelines, Tier 1 methodology, using default recommended EFs.

CRF used for NIR requires only the total values of all Direct and Indirect N2O Emissions from Managed Soils sources to be reported. Averaged value of the 2011 - 2015 dataset of those estimates was thus segregated and grouped for each livestock type and then further divided to get the final emissions of kg N_2O/head/year presented in the Table 3.8-9.

Table 3.8-9: N_2O emission due to animal manure applied to soils for selected livestock types

Livestock type	**unit**	**Manure Management emissions (N_2O)**
Dairy cattle	kg N_2O/head/year	0.77
Young cattle (calf)	kg N_2O/head/year	0.44
Sheep	kg N_2O/head/year	0.01
Layer hen	kg N_2O/head/year	0.02
Market pig	kg N_2O/head/year	0.01

Direct emission due to animal manure applied to soils

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. In Croatia, manure is not used as fuel, feed or for construction, so adjustment of annual amount of animal manure in regards to these fractions was not necessary.

Direct emission due to Urine and Dung deposited

Annual amount of N input deposited on pasture, range and paddock soils by grazing animals. Equation 11.5 from 2006 IPCC Guidelines was used for the estimation calculation. Data on N deposited was obtained from the Direct N_2O emission from Manure Management using country-specific data on nitrogen excretion rates for each livestock species.

Indirect emissions due to volatilization

Volatilisation of N as NH_3 and oxides of N (NO_x), and the deposition of these gases and their products NH_4+ and NO_3- onto soils and the surface of lakes and other waters. N_2O emissions from atmospheric deposition of N volatilised from managed soil were estimated using Tier 1 methodology, using Equation 11.9 from the 2006 IPCC Guidelines, using default EFs and fractions.

Indirect emissions due to nitrogen leaching and run-off

Leaching and run-off, urine and dung due to 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 (run-off) and/or flow through soil macropores or pipe drains.

N_2O emissions resulting from nitrogen from fertilizers and other agricultural inputs that is lost through leaching and run-off were estimated using Tier 1 methodology, using Equation 11.10 from the 2006 IPCC Guidelines, using default EFs and fractions.

Data quality and uncertainty analysis

The uncertainty estimate associated with EFs are based on the expert judgement and the recommended uncertainty range estimates provided in the 2006 IPCC Guidelines. These uncertainty estimates are presented in the Table 3.8-10.

The uncertainty of the calculation is conditioned by the use of EFs recommended by the methodology and the input data unreliability. According to the bibliography, uncertainty of the recommended EFs is high. Highest uncertainty estimate is associated with the EFs for the indirect emissions from animal manure/urine dung applied to soils which amount up to 400%, according to information on default factors uncertainty range provided in the IPCC Guidelines.

Table 3.8-10: Ratios of emissions from various GHG sources and their uncertainty for selected livestock types

Emission Source Category (GHG)	uncertainty		% in total emission				
	(-)%	(+)%	Dairy cow	Calf	Sheep	Market swine	Layer hen
Enteric Fermentation (CH_4)	20	20	53.4%	43.7%	57.2%	15.1%	0.0%
Manure Management (CH_4)	20	20	16.7%	9.2%	1.0%	69.6%	10.4%
Direct from Manure Management (N_2O)	50	100	1.3%	2.0%	0.8%	1.0%	5.4%
Indirect from Manure Management (N_2O)	30	30	2.2%	1.8%	0.2%	0.0%	20.1%
Direct from Managed Soils (N_2O)	30	30	4.0%	4.5%	8.8%	8.2%	12.5%
Indirect from Manages Soils (N_2O)							
Atmospheric deposition	250	250	0.8%	1.0%	6.0%	3.7%	48.8%
Nitrogen leaching and run-off	400	400	0.9%	0.9%	2.0%	1.9%	2.8%
Alimentation	50	50	20.9%	36.9%	24.1%	0.4%	0.0%

Data quality rating (DQR)

Using the expert judgement and fraction of each emission source per animal, final quality level and rating was estimated. Overall quality rating of the EFs for all animal using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as good, with the layer hen EF uncertainty estimated as fair, due to the large fraction of the indirect emissions for atmospheric deposition, leaching and run-off in the total emission. Assessments under the each of criteria and resulting data quality are presented in the Table 3.8-11.

Table 3.8-11: Data quality rating

Livestock type	TiR	TeR	GeR	U	DQR
Dairy cow	very good	good	good	poor	**good**
Calf	very good	good	good	poor	**good**
sheep	very good	good	good	poor	**good**
Layer hen	very good	good	good	very poor	**good**
Market pig	very good	good	good	poor	**good**

3.9 Purchasing of goods

The following materials have been chosen for determining EFs in the National database:

- Container glass
- Low-alloyed steel
- Packaging paper
- Rock stone wool
- Quicklime

Technical description

Container glass

Container glass is input material for other producers, mainly used by bottlers and food producers as a container for their products. Container glass is produced in glass furnaces at temperature above 1000°C. The most common fuel for heating the furnaces is natural gas.

Only one installation is covered by the calculation of national EFs. It produces both clear and coloured container glass and uses cullet as secondary raw material, but amounts and share of cullet in raw material is unknown. Primary raw materials are quartz sand, soda ash, dolomite, calcite, coke and feldspar.

Low-alloyed steel

Steel is an alloy of iron and other elements, primarily carbon and can be used for the production of variety of products. EF was developed for electric arc furnace which is one of the most common types of furnaces in modern steelmaking (beside blast furnace and oxygen furnace). The main raw material for the production is steel waste, but pig iron is also used with addition of coke, lime, mineral additives and alloying elements. The share of scrap material in total production input is unknown. Natural gas and coal are used as main fuels.

Packaging paper

Packaging paper and paper generally is very widely used and it is almost impossible to list all possible applications. EF was developed for a paper mill which produces wrapping paper and paper packaging using natural gas as the main fuel. Final products are fluting and testliner wrapping paper and paper packaging including corrugated cardboard. Raw materials used are mainly waste paper and starch.

Rock stone wool

Stone wool and generally mineral wool is material used most often in construction as an insulation material. The most known application of mineral wool is thermal insulation, but it can also be applied for filtration, soundproofing, fireproofing and even as hydroponic growth medium. It is produced from molten rocks in furnace at temperatures about 1600°C. Raw material for production of stone wool can be supplemented by various waste materials of a similar chemical composition. In particular case eruptive rocks, slag, dolomite and cement briquettes are used in the production process. Briquettes are made of stone wool waste and residual materials from other industries, but there were no data about share of waste materials in production.

Quick lime

Quicklime is mainly used for lime mortar and lime plaster, but there are many other uses. It can be used in its original form or it can be subsequently mixed with water to produce hydrated (slaked) lime. Depending on the content of magnesium carbonate in raw material lime can be calcitic or dolomitic. Dolomitic lime is produced from material that is rich with magnesium carbonate. Also, there are several types of lime kilns and the main types are shaft and rotary kilns with former being more common nowadays. EF was calculated for shaft kiln in a factory that uses limestone from the nearby quarry and produces calcitic lime. The main fuels used to be coke, but its share in total fuel energy is decreasing while the share of biomass fuels is increasing.

Methodological issues

Overall EF for calculating climate footprint from purchasing of goods consists of the following components:

- material production from virgin material (direct emissions – Scope 1),
- material production from virgin material (indirect emissions – Scope 2).

There are also two separate categories, EFs for production of material using recycled material as input:

- material production from recycled material (Scopes 1 and 2),

and EF for final phase of material lifecycle when it is treated as waste:

- end of life (indirect emissions – Scope 3 downstream).

EFs for materials under Scope 1 were determined based on Croatian NIR 2017. Reliable data are available only from year 2013 due to the fact that was the year of Croatian industrial installations inclusion in European Emissions Trading System (EU ETS). Since data collected for annual emissions reports and used for NIR are available for 2013 onwards and the latest data contained in Croatian NIR 2017 are 2015 data, period 2013 – 2015 was chosen for calculating direct emissions. EFs that represent direct emission for each material were calculated as average value of annual EFs for the period specified.

Annual emission reports under EU ETS do not include direct emissions from fuels (mainly diesel fuel) consumed by mobile sources at installations, for example emissions from transporting vehicles as forklifts used on site are not included. Therefore, EFs had to be increased to account for those additional direct emissions. Annual consumption of fuel expressed as a percentage of EFs for direct emissions was assumed for production of each material individually based on production data. Presumption was made that daily consumption of fuels on site is equal to 1000 litres of diesel fuel.

Calculation of EF for recycled materials was performed by using established virgin to recycled material ratio from Bilan Carbone® tool - version 7.4 model. For example, if in Bilan Carbone datasheet EF of virgin material was 1000 and EF of recycled material was 300, then ratio of 0.3 (or 30%) was applied for the same material in national calculation. It was not possible to set such ratio for quicklime, since there can be no material to be fed back to the production process. Share of 60% of virgin emission was applied for container glass, 35% for steel, 50% for stone wool (estimated, not existing in Bilan Carbone tool) and 100% for paper.

Results of calculation of EFs for the virgin materials are presented in the Table 3.9-1.

Table 3.9-1: EFs under scope 1 – virgin materials

Material	Group	EF (kg CO_2e/kg)
Glass bottles	(glass)	0.407
Steel	(metals)	0.226
Paper	(paper)	0.436
Stone wool	(building materials)	0.623
Quicklime	(building materials)	1.015

For calculating EF component resulting from energy indirect emissions under Scope 2 the same electricity grid EF (expressed as kg CO_2e/kWh) was used for all materials under consideration. The same factor was applied since all producers are in Croatia and they are supplied by electricity from the same electricity network. For electricity grid EF value of 0.3523 kg CO_2e/kWh was used as this is the national EF for Croatia calculated particularly for the purpose of the LIFE Clim'Foot project.

Taking into account annual electricity consumption for production of each material and total annual mass of production average annual specific consumption of electricity per tonne of product was calculated for each material. By using electricity grid EF described previously, it was possible to determine EF expressed in kg CO_2e/kg. Electricity consumption data and annual production data were collected from the Ministry of Environment and Energy (MEE). Only data for sequence 2005 – 2010 were available, so it is assumed that EFs were overestimated having in mind probable increase in efficiency of electricity consumption.

There was no other source of indirect emission detected for any of material producers (no heat or steam purchased) therefore this is the EF that represents all indirect emissions under Scope 2.

Results of calculation of EFs under Scope 2 for each chosen material are presented in the Table 3.9-2.

Table 3.9-2: EFs under Scope 2

Material	Group	EF (kg CO_2e/kg)
Glass bottles	(glass)	0.266
Steel	(metals)	0.602
Paper	(paper)	0.282
Stone wool	(building materials)	0.101
Quicklime	(building materials)	0.025

Results of calculation of EFs under Scopes 1 and 2 for the chosen materials are presented in the Table 3.9-3. Each EF was calculated by summing EFs under scope 1 and scope 2.

Table 3.9-3: EFs under Scopes 1 and 2 – virgin materials

Material	Group	EF (kg CO_2e/kg)
Glass bottles	(glass)	0.673
Steel	(metals)	0.828
Paper	(paper)	0.718
Stone wool	(building materials)	0.724
Quicklime	(building materials)	1.040

Apart from EFs for virgin materials, that is - production with 100% raw material, without any recycled material used, EFs for recycled materials only are also calculated. These factors are based on both factors under Scope 1 and Scope 2 because recycling factors have to be compared to overall production of materials, including direct and indirect emissions. Results of calculation of EFs under Scopes 1 and 2 for the recycled materials are presented in the Table 3.9-4. Please note the recycled/virgin ratio. Those factors provide calculation of overall emission in case there is share of recycled materials used for production.

Table 3.9-4: EFs under Scopes 1 and 2 – recycled materials

Material	Group	EFr/EFv* (%)	EF (kg CO_2e/kg)
Glass bottles	(glass)	60	0.404
Steel	(metals)	35	0.290
Paper	(paper)	100	0.718
Stone wool	(building materials)	50	0.362
Quicklime	(building materials)	0	0

* ratio between EF for recycled material and ratio factor for virgin material (both scope 1 and scope 2)

According to data from Bilan Carbone® - version 7.4 model, end of life EF covers several ways of handling materials when they reach this stage of overall lifecycle, namely:

- operation of collection and treatment facilities,
- incineration,
- recycling,
- composting,
- methanisation.

It is obvious that it is not possible to apply processes such as composting and methanisation to the chosen materials. It is also assumed that only paper can practically be incinerated, but there are no operational incineration plants in Croatia so this method is not relevant as well. Therefore, the only processes that can be actually applied are operation of collection and treatment facilities and recycling, while recycling is possible only in case of glass bottles, steel and paper.

EF for recycling is composed of waste collection component and sorting component. Since there are no reliable data available for the level of emissions for those activities in Croatia, the same value of 33 kg CO_2e/t determined in Bilan Carbone model will be used as long as nationally specific factor is calculated (18 for waste collection plus 15 for sorting). Recycling rates for glass bottles was estimated at 50%, for steel and stone wool 15% and for paper 25%.

In the case of the operation of collection and treatment facilities for the same reason EFs for waste collection and waste storage were taken from Bilan Carbone model. It was 33 kg CO_2e/t, of which 18 is for waste collection and 15 for waste storage this time. Since treatment in facilities and recycling are only two modes of waste management recognized, their shares summed should equal 100%. Therefore, a part of material that was not recycled had to be treated at waste facilities. Of the treated material 70% was presumed to be stored at facilities without uptake for glass, steel and paper and 100 % for stone wool and quicklime.

Results of calculation of EFs under scope 3 for each chosen material are presented in the Table 3.9-5.

Table 3.9-5: EFs under Scope 3

Material	Group	Recycled (%)	EF (kg CO_2e/kg)
Glass bottles	(glass)	50	0.033
Steel	(metals)	15	0.021
Paper	(paper)	25	0.149
Stone wool	(building materials)	0	0.021
Quicklime	(building materials)	0	0.017

Based on all the calculations previously described, overview of EFs for chosen materials are presented in the Table 3.9-6.

*Table 3.9-6: Overview of national EFs**

Material	Manufacturing		End-of-life
	new	ex-recycled	
	kg CO_2e/t	kg CO_2e/t	kg CO_2e/t
Glass bottles	673	404	33
Steel	828	290	21
Paper	718	718	149
Stone wool	724	362	21
Quicklime	1040	0	17

* to be applied in the Bilan Carbone model

Data quality and uncertainty analysis

Regarding Scope 1 data quality can be evaluated as very good due to the fact NIR data was used as a main source. Data used for NIR are the same as data used for reporting obligations under EU ETS and this is very reliable data set because it is subject of thorough checks by accredited ETS verifiers.

Annual emission report of material producers does not include direct emissions from mobile sources on site as those emissions are outside the scope of ETS, so a presumption had to be made about level of fuel consumption. It is a source of uncertainty, but emissions from mobile sources are much smaller than emissions from stationary sources, so it can be concluded that this uncertainty cannot result in a significant error.

The situation is a bit different regarding EF for recycled material. Unfortunately, no data could be collected to calculate potential emission reductions by recycling, so shares defined in Bilan Carbone model were applied. It is difficult to say what could be the actual difference between model data and Croatian data.

Calculation of EF for indirect emissions was based on national electricity grid EF that is calculated every year on national level and is regarded as reliable. Annual electricity consumption and production data can also be regarded as quality ones, since they were collected by the competent authority for reporting purposes. The only difficulty is that the latest data are not available and some are 8 to 12 years old, so it is questionable to what extent they represent actual state of production efficiency. Therefore, it can be concluded that EFs for indirect emission are moderately reliable.

When calculating EF under Scope 3, a number of values were used based on expert judgement. Fortunately, due to the Croatian circumstances the set of waste management activities was confined to only two and these were waste collection (with treatment) and recycling. Anyway, shares of recycled waste materials were estimated by an expert, as well as shares of waste with or without uptake at treatment facilities. Bilan Carbone values were used for EFs for collection, storage and recycling. Although there is high uncertainty of calculation of EFs under Scope 3, there is a convenient fact that carbon footprint of materials under scope 3 is much smaller in contrast to the footprint of production activities under Scopes 1 and 2.

Data quality rating (DQR)

Overall quality rating of the EFs for each material using the time-related, technological, geographical representativeness and uncertainty criteria has been determined as good. Assessments under the each of criteria and resulting data quality are presented in the Table 3.9-7.

Table 3.9-7: Data quality rating

Material	TiR	TeR	GeR	U	DQR
Glass bottles	good	very good	very good	fair	**good**
Steel	good	good	very good	poor	**good**
Paper	good	very good	very good	fair	**good**
Stone wool	good	very good	very good	poor	**good**
Quicklime	good	good	very good	fair	**good**

3.10 Refrigerants

Category Refrigeration and air conditioning accounts for the majority of hydrofluorocarbons (HFCs) emissions in Croatia. It includes the following sub-applications:

- Domestic refrigeration
- Commercial refrigeration
- Industrial refrigeration
- Transport refrigeration
- Stationary air-conditioning
- Mobile air-conditioning

Technical description

Emissions are released by the consumption of HFC-32, HFC-125, HFC-134a, HFC-143a, or different blends containing HFCs, which are used as substitutes for cooling gases in refrigerating and air-conditioning systems that deplete the ozone layer.

Domestic refrigeration includes equipment used in households. HFC-134a is used as refrigerant in domestic refrigeration equipment.

Commercial refrigeration includes different types of equipment, from vending machines to centralised refrigeration systems. Blend R-404A containing HFC-125 (44%), HFC-134a (4%) and HFC-143a (52%) is used as refrigerant in commercial refrigeration systems.

Industrial refrigeration includes cold storage used in the food and other industries. Blends R-407C, R-410A and R-507A are used as refrigerants in industrial refrigeration. R-407C contains HFC-32 (23%), HFC-125 (25%) and HFC-134a (52%). R-410A contains HFC-32 (50%) and HFC-125 (50%). R-507A contains HFC-125 (50%) and HFC-143a (50%).

Transport refrigeration includes equipment and systems used in refrigerated trucks and trailers. HFC-134a is used as refrigerant in transport refrigeration.

Stationary air-conditioning includes chillers for building and residential applications. Blends R-407C and R-410A are used as refrigerants in stationary air-conditioning equipment.

Mobile air-conditioning systems are commonly used in passenger cars, truck cabins, buses, and trains. For now, in Croatia the category mobile air conditioning includes only mobile air conditioning in passenger cars that use HFC-134a as refrigerant.

Methodological issues

IPCC Tier 2 methodology is used for HFCs emission calculation, based on the data on the amount of HFCs in operating systems (average annual stocks) for Domestic refrigeration (HFC-134a), Commercial refrigeration (HFC-125, HFC-134a, HFC-143a), Industrial refrigeration (HFC-32, HFC-125, HFC-134a, HFC-143a), Transport refrigeration (HFC-134a), Stationary air-conditioning (HFC-32, HFC-125, HFC-134a) and Mobile air-conditioning (HFC-134a).

Installed quantities of HFCs in refrigeration equipment are multiplied by the EF in % of initial charge/year – operation emission. EF represents annual emission rate during operation (product life factor), accounting for annual leakage and average annual emissions during servicing. The 2006 IPCC Guidelines propose a range of values, where lower value is proposed for developed countries and higher value for developing countries. Average values of EFs are calculated for each sub-application to adjust it to national circumstances. Table 3.10-1 shows an average of total HFCs (gases or blends of gases) installed in existing systems of the last five years and EFs per sub-applications.

Table 3.10-1: Total installed amount of HFCs and EFs per sub-applications

Sub-application / System		Total amount of HFCs installed in existing systems (kg)	Product life factor (% of initial charge/year)
Domestic refrigeration	HFC-134a	93500	0.30
Commercial refrigeration	R-404A	162000	22.50
Industrial refrigeration	R-407C	46000	16.00
	R-410A	44800	
	R-507A	1480	
Transport refrigeration	HFC-134a	90560	32.50
Stationary air-conditioning	R-407C	127000	5.00
	R-410A	124400	
Mobile air-conditioning	HFC-134a	724600	15.00

Ministry of Environment and Energy (MEE) collects data on installed quantities of HFCs in refrigeration and air-conditioning equipment as well as added and recovered quantities and data on consumption of HFCs (import and export data). Operators of equipment are obliged to fill up the form prescribed in the Croatian Ozone Depleting Substances (ODS) and F-gas Regulation (OG 92/14) and send to MEE (in future to the CAEN). Service technicians are obliged to send data on added and recovered quantities of HFCs (Form prescribed in the Croatian Regulation) to MEE. Pursuant to Article 3 paragraph 6 of the Regulation (EC) No. 842/2006 on Certain Fluorinated Greenhouse Gases, it is required to submit data for devices and equipment containing 3 kg or more of fluorinated GHGs. Other data are estimated based on data on gas consumption and data from Croatian Bureau of Statistics (CBS). In accordance with Article 6 of the Regulation (EC) No. 842/2006, with respect to the information on the consumption of HFCs, there is no legal basis for requesting the importer/exporter to supply quantities of less than 1 tonne of HFCs or their mixtures. Consumption of HFCs is related to servicing of the existing installed equipment and is only for the minor part related to the filling or refilling of new equipment that is being installed because the equipment generally comes to the market already filled with gas.

Currently, there are no available data on decommissioning and disposal of the refrigeration and air-conditioning equipment. Croatia has established the system of collecting the refrigeration and air-conditioning equipment that uses HFCs. This collection is free for end users, which means that the authorized company collects all devices and transports them to the plant where they are being dismantled and the gas is being collected from the cooling system and the insulating foam (in the refrigeration equipment). Gas is also being collected from the air conditioners in motor vehicles that are brought to disposal sites. All servicing operators are required to collect gas during servicing and especially after switching off the device from use, and to deliver it to a collection centre. Several regional centres for the collection, reuse and recovery of these substances have been established. If the recovery is not possible, waste gases are exported to be destroyed. However, MEE does not have any information on recovered HFCs, as centres for the collection, reuse and recovery currently store minor collected amounts and are unable to recover HFCs due to lack of proper equipment and inability for analysis of these substances. MEE does not have any information on the destroyed quantities of these substances, nor on the quantities of equipment containing HFCs that are no longer in use. The reason for this is that the lifespan of the equipment is 20 years and more if it is regularly maintained by a certified professional. The current economic situation in the country also extends the use of the equipment because the end users are not able to acquire new equipment as is the case in developed countries. HFC-s started to be used in larger extent in the middle of the last decade and taken into consideration that lifespan of the equipment is 20 years and more, if it is regularly maintained, such equipment where not disposed yet.

In Croatia, there are large amount of stationary air-conditioning equipment that use HCFC-22 because it is allowed to use this refrigerant by end of 2014 and after that owner can use equipment without servicing if it is work properly. Because of that, quantities of installed HFC are not so huge. In many hotels, industry and commercial refrigeration HCFC-22 based equipment is still in use. In addition, according to actual economic situation, import and placing of transport refrigeration was decreased on the Croatian market.

Data quality and uncertainty analysis

Uncertainty estimate associated with calculation of HFCs emissions is high because estimates are based on range of values for leak rates in operation. In addition, lack of information on decommissioning and disposal of the refrigeration and air-conditioning equipment, heterogeneous nature of sub-applications and small unit size of most equipment is the reason of uncertainty. Uncertainty estimate associated with EFs (>50%) are based on the expert judgement, as proposed by 2006 IPCC Guidelines.

Data quality rating (DQR)

Overall quality rating of the EFs for each refrigeration and air-conditioning sub-application using the time-related, technological, geographical representativeness and uncertainty criteria (TiR, TeR, GeR and U) has been determined as fair. Assessments under the each of criteria and resulting data quality are presented in the Table 3.10-2.

Table 3.7-2: Data quality rating

Refrigeration and air-conditioning sub-applications	TiR	TeR	GeR	U	DQR
Domestic refrigeration	good	poor	good	very poor	**fair**
Commercial refrigeration	good	poor	good	very poor	**fair**
Industrial refrigeration	good	poor	good	very poor	**fair**
Transport refrigeration	good	poor	good	very poor	**fair**
Stationary air-conditioning	good	poor	good	very poor	**fair**
Mobile air-conditioning	good	poor	good	very poor	**fair**

4. Conclusion

Constituting of the Croatian Carbon Footprint Database is very important for the future activities, such as:

- support carbon accounting in compliance with standard;
- support GHG emissions accounting at national level;
- provide background data required for Life Cycle Assessment (LCA) studies;
- provide quality data relevant to products and processes in order to support LCA studies in a specific context – national, regional, EU;
- establishment of LCA in support of policy development and implementation as well enterprises competitiveness;
- identification of product/process benchmark in relation to sector standard.

Croatian Carbon Footprint Database provides data on several economic sectors and related categories with the classification system of processes/products represented by the datasets from:

- Freight transport
- Passenger transport
- Land Use, Land Use Change and Forestry (LULUCF)
- Waste
- Agriculture
- Purchasing of goods
- Refrigerants

From a practical point of view, the short description of the process/product is included to provide applicability and documentation of CF DB.

Proposed methodological guide defined by the document Methodology for constituting the National Databases (made within the LIFE Clim'Foot project) have been taken into account to achieve accuracy, completeness, representativeness, methodological appropriateness and consistency, reproducibility as well transparency of CF DB.

The data quality is needed in order to allow a correct interpretation of calculated EFs as well as its limits. Other information associated to data quality such as representativeness (geographical, time-related and technological) as well uncertainty have been considered.

Regarding best practices for constituting National DBs, quality control and verification/validation procedures were performed to verify that all required information are presented and entry level requirements are fulfilled. Effective evaluation of the datasets included in CF DB was carried out.

5. References

Deliverable A.2.1 Benchmark of National Databases on Carbon Footprint, LIFE Clim'Foot project

Deliverable A.2.2 Methodology for constituting the National Databases, LIFE Clim'Foot project

Deliverable C.2.1 User guide for filling in the National Databases, LIFE Clim'Foot project

Bilan Carbone® - version 7.4 (adapted for the Clim'Foot project), ADEME, 2015

Base Carbone Version 1.01, ADEME, 2013

2006 IPCC Guidelines for National Greenhouse Gas Inventories, IGES, 2006

Croatian Greenhouse gas inventory for the period 1990 - 2015 (NIR 2017), Croatian Agency for the Environment and Nature, 2017

2016 Statistical Yearbook of the Republic of Croatia, Croatian Bureau of Statistics, 2016

Waste Management Options and Climate Change, Final report to the European Commission, DG Environment, AEA Technology, 2001