LIFE CLIM'FOOT
DELIVERABLE C2.2: METHODOLOGY FOR CONSTITUTING THE NATIONAL DATABASE, GREECE

ΚΑΠΕ CRES | CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING

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Contents

Acronyms and abbreviations

ADEME	The French Environment and Energy Management Agency
AWMS	Animal waste management system
BOD	Biochemical oxygen demand
CF DB	Clim'Foot database
CFO	Carbon footprint of organisations
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
DEFRA	Department for Environment, Food & Rural Affairs
DOC	Degradable organic carbon
DQR	Data quality rating
EEA	European Environment Agency
EF	Emission factor
EFDB	Emission factor database
EMEP	European Monitoring and Evaluation Programme
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
IEA	International Energy Agency
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
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
OECD	Organisation for Economic Co-operation and Development
OX	Oxidation factor
SO_x	Sulphur oxide
TeR	Technological representativeness
TiR	Time representativeness

U	Uncertainty

1. Introduction

The creation of EF National databases, including country-specific and reliable data, is necessary to support the implementation of the carbon footprint of organisations (CFO) in public and private organizations. This document aims to provide the necessary information as an accompanying document, on the completion of the national database for emission factors by identifying key data sources, the conditions of obtaining and using the data on emission factors, the methodology applied in order to calculate the emission factors, the main hypotheses and a general uncertainty evaluation.

In the Clim'Foot database that has been developed, additional and more extensive information are available, such as:

- Metadata - provide description of the data set aimed to guarantee comprehensive information to support the end user in choosing the correct dataset for the Carbon Footprint calculation;
- Elementary flows - comprise all greenhouse gases (GHG) emitted in the environment by human activities and are described in the database;
- 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 database.

2. Methodology

Overall, the methodology was prepared in accordance with the Deliverable "A2.2 Methodology for constituting national databases" (1), prepared within the LIFE Clim'Foot project. Data have been collected from several sources and have been calculated in accordance with the proposed methodology. Moreover, the emission factor database of the Bilan Carbone® calculation tool, version 7.4 adjusted for the project LIFE Clim'foot was used as a guide for the relevance and level of analysis of emission factors that should be included in the national database.

The National Inventory Report (2) was used as a reliable data source wherever it was feasible and as a guide for key data sources and calculation methodologies. However, due to the level of disaggregation required for the definition of national emission factors and the lack of detailed data in the NIR, several other sources have been also used for the constitution of the national database, such as Life Cycle Inventory (LCI) databases and literature data. Moreover, emission factors have been calculated according to the methodologies provided by 2006 IPCC Guidelines for national greenhouse gas inventories (3), EMEP/EEA air pollutant emission inventory guidebook 2013 (4), Base Carbone (5) and DEFRA methodology paper for emission factors (6).

The main issue encountered during the constitution of the national database was the lack of detailed data, which in some cases led to assumptions. This fact in combination with the complicated nature of some methodologies prevented the adaptability of these methodologies. The specific methodologies used and the assumptions made are presented in detail for each case in the subsequent sections. In order to avoid significant errors due to unreliable data input, in some cases it was decided to focus on the methodologies, approaches and emission factors that allowed for a certain degree of reliability instead of providing emission factors that did not ensure reliability and possibly promoted errors.

Another issue encountered was the lack of disaggregation of the emission factors by greenhouse gas. Moreover, in the cases where data from existing databases have been used, according to the methodology presented in Deliverable A2.2, the data present some issues regarding their applicability for calculating an organisation's carbon footprint within the Bilan Carbone® tool.

The national database includes the greenhouse gases covered by the Kyoto Protocol. The following GHGs are included:

- Fossil carbon dioxide (CO_2)
- Biogenic carbon dioxide (CO_2b)
- Fossil methane (CH_4f)
- Nitrous oxide (N_2O)

- Sulphur hexafluoride (SF_6)
- Hydrofluorocarbons (HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143, HFC-245fa)
- NF_3.

The main sectors responsible for GHG emissions in Greece are energy, transport, industrial processes and product use, agriculture and waste management.

In 2014, fuel combustion and fugitive emissions from fuels (without transport) contributed about 55% of total emissions. Transport (including international aviation) was the second most important sector (about 20%), industrial processes and product use contributed 12%; while agriculture and waste made up 8% and 5% of total emissions respectively.

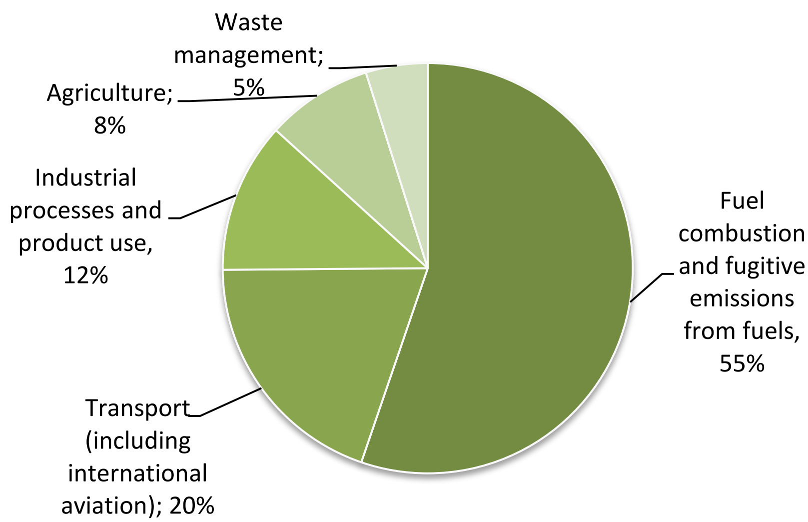

Figure 1: Greenhouse gas emissions, by sector in Greece, 2014 (Source: European Environment Agency (7))

Based on the points mentioned above, the national database of emission factors considers the following categories:

- Energy
  - Fossil fuels
  - Electricity
  - Thermal energy and steam
- Transport
  - Road transport
  - Rail transport
  - Air transport
  - Sea transport/navigation
- Agriculture (animals)
- Products and processes, food

- Waste
- Materials
- Land Use, Land Use Change and Forestry (LULUCF)

The emission factors that have been calculated are included in the Excel document Greek National Database Clim'Foot DB with related information about the 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.

The Chapters 3.1 – 3.12 contain detailed information on:

- Technical description
- Methodology and data sources
- Data quality and uncertainty analysis

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

The description of the methodology for the calculation of emission factors provides information on the methodology used. The data sources for the emission factors calculation are also presented.

A quality rating has been performed for each criterion:

- Technological representativeness (TeR)
- Time representativeness (TiR)
- Geographical representativeness (GeR)
- Uncertainty (U)

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

3. Database analysis

3.1 Fossil fuels

3.1.1Technical description

The emission factors that have been calculated in the national database cover the stationary fuel combustion of fossil fuels, divided in three categories: solid, liquid and gaseous, in accordance with their presentation in the National Inventory Report (2). Emissions are representative of the Greek energy system; the fuel consumed and fuel characteristics. The emission factors include CO_2, CH_4 and N_2O emissions and are not differentiated by technology. The boundary is gate-to-gate.

The fossil fuels covered by the Greek NIR are the following:

Liquid fuels
- Crude oil
- Refinery gas
- Liquefied Petroleum Gas
- Kerosene
- Gasoline
- Diesel oil
- Heavy fuel oil
- Naphtha
- Petroleum coke
- Other oil products

Solid fuels
- Steam coal
- Lignite
- Oven and gas coke
- BKB/Patent fuel

Gaseous fuels
- Natural gas
- Gas works gas

The emission factors for mobile fuel combustion have also been calculated in accordance with their presentation in the National Inventory Report (2). These include the following fuels:

- Aviation gasoline
- Jet kerosene
- Gasoline for road transportation
- Diesel oil for road transportation
- Liquefied petroleum gas for road transportation
- Residual fuel oil for navigation
- Gas/diesel oil for navigation

These emission factors include CO_2, CH_4 and N_2O emissions. The boundary is gate-to-gate.

In addition, the upstream part of fuel use was considered. In the case of three gases (crude oil, natural gas and lignite) national data were available and have been collected from the Life Cycle Data Network (LCDN) Thinkstep AG (8) database. In this case, the data set represents the national consumption mix (supply mix) including domestic production and imports. The calculated emission factors cover the entire supply chain and the emissions from all greenhouse gases covered by the Kyoto Protocol. This includes extraction, production and processing, as well as transportation. The three emission factors that have been included are:

- Supply of lignite to power plants, steel works and other consumers
- Supply of natural gas to power plants and other final consumers
- Supply of crude oil to refineries

In total 26 emission factors on fossil fuels were created.

3.1.2 Methodological issues

The CO_2 emission factors for the combustion of fossil fuels (stationary and mobile) were obtained by the Greek National Inventory Report (2) according to the methodology presented in Deliverable A2.2, Chapter 6.1.1.1 Italian Combustion mix of Natural gas (1). For the calculation of the emission factors an average of the last 5 years has been considered because the annual change can be large. The standard emission factors have been converted into different units based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (3) and the International Energy Agency (IEA) conversion factors (9). Regarding the emission factors for CH_4 and N_2O, they were calculated proportionally according to CO_2 emission factors and Tier 1 default emission factors for stationary combustion provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (3).

The emission factors collected from the Life Cycle Data Network (LCDN) Thinkstep AG database have also been calculated according to the methodology provided in Deliverable A2.2, Chapters 4.3.1 Elementary flows, 4.3.2 Characterization flows in CO_2eq and 4.3.3 Emission factors (1). All elementary flows and relevant characterization factors have been taken into account. The emission factor is the sum of emissions as CO_2 eq.

The results of the calculation for the emission factors for fossil fuels used in Greece are presented in Tables 3.1.1 and 3.1.2.

Table 3.1.1: Emission factors for fossil fuels, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per kWh)

Fossil fuels	Breakdown of GHG emissions by gas					
	CO_2		CH_4		N_20	
	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
Steam coal	0.011	0.342	0.018	0.000	0.000	0.001
Lignite	0.005	0.357	0.009	0.000	0.000	0.000
Oven and gas coke	0.012	0.382	0.020	0.000	0.000	0.000
BKB/Patent fuel	0.010	0.334	0.016	0.000	0.000	0.001
Crude oil (kg CO_2eq per tonne)	232	2125	128	0	1	0
Refinery gas	-	0.217	-	0.000	-	0.000
Liquefied Petroleum Gas	0.027	0.226	0.010	0.000	0.000	0.000
Kerosene	0.024	0.257	0.009	0.000	0.000	0.001
Gasoline	0.048	0.254	0.009	0.002	0.000	0.002
Diesel oil	0.025	0.265	0.008	0.000	0.000	0.001
Heavy fuel oil	0.030	0.278	0.009	0.000	0.000	0.001
Naphtha	0.027	0.261	0.008	0.000	0.000	0.001
Petroleum coke	0.041	0.338	0.004	0.000	0.000	0.001
Other oil products	0.026	0.262	0.000	0.000	0.000	0.001
Natural gas	0.024	0.199	0.017	0.000	0.000	0.000
Gas works gas	-	0.185	-	0.000		0.000
Aviation gasoline	0.049	0.247	0.005	0.000	0.000	0.002
Jet kerosene	0.021	0.254	0.008	0.000	0.000	0.003
Gasoline for road transport	0.048	0.254	0.009	0.002	0.000	0.002
Diesel oil for road transport	0.030	0.264	0.009	0.001	0.001	0.002
Liquefied petroleum gas for road transport	0.027	0.230	0.010	0.001	0.000	0.001
Residual fuel oil for navigation	0.024	0.279	0.008	0.001	0.000	0.002
Gas/diesel oil for navigation	0.051	0.271	0.005	0.000	0.000	0.029

Table 3.1.2: Emission factors for fossil fuels, total and biomass-related (kg CO_2 eq per kWh)

Fossil fuels	Total emissions		Biomass-related emissions	
	Upstream	Combustion	Upstream	Combustion
Steam coal	0.029	0.344	0.000	0.000
Lignite	0.014	0.357	0.000	0.000
Oven and gas coke	0.032	0.382	0.000	0.000
BKB/Patent fuel	0.026	0.335	0.000	0.000
Crude oil (CO_2eq per tonne)	361	3125	-0.281	0.281
Refinery gas	-	0.218	-	0.000
Liquified Petroleum Gas	0.037	0.226	0.000	0.000
Kerosene	0.033	0.258	0.000	0.000
Gasoline	0.057	0.258	0.000	0.000
Diesel oil	0.034	0.266	0.000	0.000
Heavy fuel oil	0.039	0.279	0.000	0.000
Naphtha	0.036	0.262	0.000	0.000
Petroleum coke	0.045	0.338	0.000	0.000
Other oil products	0.026	0.263	0.000	0.000
Natural gas	0.040	0.199	0.000	0.000
Gas works gas	-	0.185	-	0.000
Aviation gasoline	0.054	0.249	0.000	0.000
Jet kerosene	0.029	0.256	0.000	0.000
Gasoline for road transport	0.057	0.258	0.000	0.000
Diesel oil for road transport	0.040	0.266	-0.011	0.011
Liquefied petroleum gas for road transport	0.037	0.232	0.000	0.000
Residual fuel oil for navigation	0.032	0.282	0.000	0.000
Gas/diesel oil for navigation	0.057	0.300	0.000	0.000

3.1.3 Data quality and uncertainty analysis

According to the NIR, "the uncertainty of emissions of the stationary combustion sector is relatively small. The uncertainty associated with activity data is less than 5%... the uncertainty associated with emission factors is also very low for the case of CO_2, less than 5%" (2). The emission factors for CH_4 and especially N_2O are highly uncertain, but their contribution to the total emissions is relatively small.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and very good in terms of uncertainty (QR: 1). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.25, which corresponds to excellent quality.

As far as emission factors for mobile fuel combustion are concerned, according to the NIR in road transport "Several input data in applying the methodology can obviously be only estimates… There is a certain degree of uncertainty in estimating these data… variables associated with large uncertainty as for example the distribution of mileage in driving conditions and the respective average travelling speeds are those variables for which most attention should be given in most of the cases. Additionally, consumption statistics in some cases should not be considered as very accurate as they cannot reflect fuel smuggling and other illegal uses. In principle systematic errors may be distinguished into two categories: Errors concerning emission factors and measurements and errors concerning assessment of vehicle park and usage". In aviation, "an important uncertainty parameter is the assessment of aircraft types. In our case the lack of relevant data does not allow the application of a higher Tier methodology and, hence, the emission factors used only partially reflect the aircraft fleet". And "In the navigation sector uncertainty is mostly connected to the general lack of data concerning the type of the engines of the ships as well as their use and ship movement information" (2).

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and according to the information provided on uncertainty a very good value has been assigned (QR: 3). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.25, which corresponds to excellent quality.

Concerning the emission factors calculated from the relevant database, the quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is good in terms of time representativeness (QR: 2), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and since no information is provided on uncertainty, a conservative approach has been applied and a fair value has been assigned (QR: 3). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2, which corresponds to very good quality.

The overview of the data quality rating for fossil fuels is presented in Table 3.1.3.

Table 3.1.3: Data quality rating for fossil fuels

Fossil fuels	TeR	TiR	GeR	U	DQR
Stationary combustion	Good	Very good	Very good	Very good	**Excellent**
Mobile combustion	Good	Very good	Very good	Very good	**Excellent**
Fuel supply	Good	Good	Very good	Fair	**Very good**

3.2 Electricity

3.2.1 Technical description

In the case of electricity, the emission factors that have been calculated were in accordance with the available emission factors in the Bilan Carbone® emission factor database and include the emission factors for:

- ❖ The Greek electricity mix for the years between 2008 and 2014
- ❖ The Greek electricity losses for the years between 2008 and 2014
- ❖ The upstream part for the Greek electricity mix for the years between 2008 and 2014

Regarding the emission factors from the Greek electricity mix, they refer to the mix of electricity production without grid losses for the selected years, ie. the electricity production is the net of the losses grid. The factors change on a yearly basis due to changes in the production mix. The emission factors include emissions for CO_2, CH_4 and N_2O. The emission factors on electricity losses refer to the emissions relating to transmission and distribution losses, ie. the scope 3 emissions associated with grid losses. The emission factors include emissions for CO_2, CH_4 and N_2O. The upstream part refers to emissions related to the production, transport and distribution of the fuels used in the electricity production mix, the scope 3 emissions of extraction, refining and transportation of primary fuels before their use in the generation of electricity. The emission factors include emissions for all greenhouse gases covered by the Kyoto Protocol.

Moreover, the emission factors by plant type have been calculated:

- ❖ Coal power plant
- ❖ Oil power plant
- ❖ Natural gas power plant

Concerning the emission factors by plant type, they refer to the average value for electricity production by type of power unit. Figures relate to combustion in power stations, while emissions from production and delivery of fuels to power stations are not included. The emission factors only include CO_2 emissions.

Also, the emission factors for electricity production by main electrivity producer have been calculated. Emission factors on electricity production by producer refer to the average total electricity production by producer and include only CO_2 emissions.

In addition, several emission factors have been calculated with data collected by the Life Cycle Data Network (LCDN) Thinkstep AG (8) database. These include the emission factors for the:

- Supply of medium voltage electricity to final consumers
  - Average value

  and by type:
  - Biogas
  - Hard coal
  - Heavy fuel oil (HFO)
  - Lignite
  - Natural gas
  - Hydro power
  - Photovoltaic
  - Waste
  - Wind power
- Supply of low voltage electricity

These emission factors for the supply of medium and low voltage electricity represent the average national electricity mix including main activity producers and autoproducers, as well as electricity imports and transmission/distribution losses. In the case of the breakdown of the supply of medium voltage electricity by type the main technologies are considered according to the national situation and the data sets cover all relevant process steps and technologies along the supply chain. These emission factors cover the emissions from all greenhouse gases covered by the Kyoto Protocol.

In total 26 emission factors on electricity were created, 9 of which refer to the national average per year, 7 of which refer to conventional plant types, 5 of which refer to renewable plant types and 5 of which refer to specific electricity producers.

3.2.2 Methodological issues

The emission factors for electricity represent the average emissions from the Greek national grid per kWh of electricity produced. The calculation was made in accordance with the methodology provided in Deliverable A2.2 (1). Emission data were obtained by the NIR for Greece, while electricity production data were obtained by Eurostat, extraction June 2016 (10). These data were in accordance with the national energy balance. Data on grid losses were calculated based on the national energy balance and they were also checked and confirmed with relevant data available from OECD/IEA (11).

The upstream part of emissions has been calculated using the relevant upstream emission factors for the fuel mix used in the production of electricity and data on fuels used for electricity generation from the national energy balance.

In order to calculate the emission factors by plant type for conventional sources (coal-fired plants, gas power plants and oil power plants) production data by production unit were collected by the Independent power transmission operator (12) in Greece and the Hellenic electricity distribution network operator S.A. (13). Emissions by production unit were obtained by the EU Emissions Trading Scheme Registry (14). The calculation is the average value for electricity production by plant type. All figures only concern emissions related to combustion in power stations, while emissions from production and delivery of fuels to power stations are not included.

The emission factors per electricity producer were acquired after communication with the producer companies; except for DEI, for which the relevant data were available on the company's website (15). All figures only concern emissions related to combustion in power stations, while emissions from production and delivery of fuels to power stations are not included.

The emission factors collected from the Life Cycle Data Network (LCDN) Thinkstep AG (8) database have also been calculated according to the methodology provided in Deliverable A2.2, Chapters 4.3.1 Elementary flows, 4.3.2 Characterization flows in CO_2eq and 4.3.3 Emission factors (1). All elementary flows and relevant characterization factors have been taken into account. The emission factor is the sum of emissions as CO_2eq.

The results of calculation are 26 emission factors for electricity used in Greece as presented in Tables 3.2.1 to 3.2.6 below.

Table 3.2.1: Emission factors for the electricity mix, breakdown by gas (CO_2, CH_4, N_2O, other gases) and biomass-related (kg CO_2 eq per kWh)

Electricity production	Breakdown of GHG emissions by gas				Biomass-related emissions
	CO_2	CH_4	N_2O	Other gases	
2008	0.792	0.011	0.002	0.000	0.000
2009	0.796	0.011	0.002	0.000	-0.001
2010	0.801	0.011	0.002	0.000	-0.001
2011	0.823	0.012	0.002	0.000	-0.001
2012	0.827	0.012	0.003	0.000	-0.001
2013	0.734	0.012	0.002	0.000	-0.001
2014	0.750	0.011	0.003	0.000	-0.001

Table 3.2.2: Emission factors for the electricity mix, total (kg CO_2 eq per kWh)

Electricity production	Total emissions		
	Upstream	Production	Losses
2008	0.025	0.781	0.067
2009	0.024	0.785	0.044
2010	0.026	0.789	0.056
2011	0.026	0.811	0.040
2012	0.026	0.816	0.022
2013	0.027	0.721	0.053
2014	0.026	0.738	0.066

Table 3.2.3: Emission factors for electricity production by plant type, conventional sources (kg CO_2 eq per kWh)

	kg CO2e per kWh
Electricity production from conventional sources	Production
Coal fired plant	1.489
Gas fired plant	0.410
Oil fired plant	0.702
Hard coal fired plant, medium voltage	1.484
Heavy fuel oil fired plant, medium voltage	1.029
Lignite fired plant, medium voltage	1.511
Gas fired plant, medium voltage	0.580

Table 3.2.4: Emission factors for electricity production by plant type, renewable sources (kg CO_2 eq per kWh)

	kg CO2e per kWh
Electricity production from renewable sources	Upstream/production
Biogas, medium voltage	0.570
Hydro power, medium voltage	0.007
Photovoltaic, medium voltage	0.036
Waste, medium voltage	0.652
Wind power, medium voltage	0.007

Table 3.2.5: Emission factors for electricity production by electricity producer (kg CO_2 eq per kWh)

	kg CO2e per kWh
Electricity production be electricity producer	**Production**
DEI	1.120
Elpedison	0.383
Protergia, 2014	0.330
Protergia, 2015	0.335
Heron	0.460

Table 3.2.6: Emission factors for the electricity mix including main activity producers and autoproducers, electricity imports and transmission/distribution losses (kg CO_2 eq per kWh)

	Total	CO_2	CH_4	N_2O	Other gases	CO_2 b
Electricity mix, medium voltage	1.022	0.976	0.043	0.003	0.000	-0.001
Electricity mix, low voltage	1.058	1.011	0.044	0.003	0.000	-0.001

3.2.3 Data quality and uncertainty analysis

The uncertainty of emission calculation for electricity production is relatively small. As far as the emission factors relating to the Greek electricity mix are concerned, the quality rating is very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and very good in terms of uncertainty (QR: 1). Therefore, the overall data quality is excellent.

The emission factors calculated by plant type and by producer only include CO_2 emissions. The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), very good in terms of technological representativeness (QR: 1), very good in terms of geographical representativeness (QR: 1) and very good in terms of uncertainty (QR: 1). Therefore, the overall data quality is excellent.

Concerning the emission factors calculated from the relevant database, the main issue relates to the fact that the emission factors cover the entire supply chain and there is no differentiation between several steps of the supply chain. The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is good in terms of time representativeness (QR: 2), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and since no information is provided on uncertainty, a good value has been assigned (QR: 2) to conventional and renewable sources and a very good value has been assigned (QR: 1) to network electricity. Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.75 and 1.50 respectively, which corresponds to very good and excellent quality.

The overview of the data quality rating for electricity production is presented in Table 3.2.7.

Table 3.2.7: Data quality rating for electricity production

Electricity	TeR	TiR	GeR	U	DQR
Network electricity	Good	Very good	Very good	Very good	**Excellent**
Electricity production from conventional sources	Very good	Very good	Very good	Very good	**Excellent**
Electricity production from conventional sources, medium voltage	Good	Good	Very good	Good	**Very good**
Electricity production from renewable sources	Good	Good	Very good	Good	**Very good**
Electricity production per electricity producer	Very good	Very good	Very good	Very good	**Excellent**
Network electricity including main activity producers and autoproducers, electricity imports and transmission/distribution losses	Good	Good	Very good	Very good	**Excellent**

3.3 Thermal energy and steam

3.3.1 Technical description

Due to lack of other data sources, the emission factors for thermal energy and steam have been calculated with data collected by the Life Cycle Data Network (LCDN) Thinkstep AG (8) database. These include the emission factors for the:

- Supply of thermal energy to final consumers:
  - average value

  and by type
  - Biogas
  - Heavy fuel oil (HFO)
  - Light fuel oil (LFO)
  - Lignite and
  - Natural gas

These emission factors represent the average national specific thermal energy production. In the case of breakdown by type, the main technologies are considered according to the national situation and the data sets cover all relevant process steps and technologies along the supply chain. The national energy carrier mix is used for the thermal energy production for the corresponding reference year. A detailed power plant model is used, which combines measured with calculated emission values. In general, the thermal energy efficiency is 100%. The inventory is partly based on primary industry data, partly on secondary literature data. These emission factors cover the emissions from all greenhouse gases covered by the Kyoto Protocol.

- Supply of process steam to final consumers:
  - Process steam from biogas 85%
  - Process steam from biogas 90%
  - Process steam from biogas 95%
  - Process steam from heavy fuel oil (HFO) 85%
  - Process steam from heavy fuel oil (HFO) 90%
  - Process steam from heavy fuel oil (HFO) 95%
  - Process steam from light fuel oil (LFO) 85%
  - Process steam from light fuel oil (LFO) 90%
  - Process steam from light fuel oil (LFO) 95%
  - Process steam from lignite 85%
  - Process steam from lignite 90%
  - Process steam from lignite 95%
  - Process steam from natural gas 85%
  - Process steam from natural gas 90%
  - Process steam from natural gas 95%

The data set represents the average national specific process steam production by type and for different efficiencies. The data set covers all relevant process steps and technologies along the supply chain. The national energy carrier mix is used for the process steam production for the corresponding reference year. A detailed power plant model is used, which combines measured with calculated emission values. In general, the process steam efficiencies are: 85%, 90% and 95%. The inventory is partly based on primary industry data, partly on secondary literature data. These emission factors cover the emissions from all greenhouse gases covered by the Kyoto Protocol.

In total 20 emission factors on thermal energy and steam were created, 15 of which refer to the supply of process steam and 5 to supply of thermal energy.

3.3.2 Methodological issues

The emission factors collected from the Life Cycle Data Network (LCDN) Thinkstep AG database have also been calculated according to the methodology provided in Deliverable A2.2, Chapters 4.3.1 Elementary flows, 4.3.2 Characterization flows in CO_2eq and 4.3.3 Emission factors. All elementary flows and relevant characterization factors have been taken into account. The emission factor is the sum of emissions as CO_2 eq.

In Tables 3.3.1 and 3.3.2, 20 emission factors for thermal energy and steam in Greece are presented.

Table 3.3.1: Emission factors for the thermal energy and steam, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per kWh)

Thermal energy and steam	Breakdown of GHG emissions by gas		
	CO_2	CH_4	N_2O
Thermal energy from biogas	0.121	0.031	0.011
Thermal energy from heavy fuel oil (HFO)	0.310	0.012	0.001
Thermal energy from light fuel oil (LFO)	0.304	0.013	0.001
Thermal energy from lignite	0.445	0.016	0.001
Thermal energy from natural gas	0.228	0.020	0.000
Process steam from biogas 85%	0.142	0.037	0.012
Process steam from biogas 90%	0.134	0.035	0.012
Process steam from biogas 95%	0.127	0.033	0.011
Process steam from heavy fuel oil (HFO) 85%	0.365	0.014	0.001
Process steam from heavy fuel oil (HFO) 90%	0.344	0.013	0.001
Process steam from heavy fuel oil (HFO) 95%	0.326	0.012	0.001
Process steam from light fuel oil (LFO) 85%	0.357	0.015	0.001
Process steam from light fuel oil (LFO) 90%	0.338	0.014	0.001
Process steam from light fuel oil (LFO) 95%	0.320	0.013	0.001
Process steam from lignite 85%	0.521	0.019	0.002
Process steam from lignite 90%	0.493	0.018	0.002
Process steam from lignite 95%	0.467	0.017	0.002
Process steam from natural gas 85%	0.268	0.024	0.000
Process steam from natural gas 90%	0.253	0.022	0.000
Process steam from natural gas 95%	0.240	0.021	0.000

Table 3.3.2: Emission factors for thermal energy and steam, total and biomass-related (kg CO_2 eq per kWh)

Thermal energy and steam	Total emissions	Biomass-related emissions
Thermal energy from biogas	0.162	-0.052
Thermal energy from heavy fuel oil (HFO)	0.322	0.000
Thermal energy from light fuel oil (LFO)	0.317	0.000
Thermal energy from lignite	0.462	0.000
Thermal energy from natural gas	0.248	0.000
Process steam from biogas 85%	0.191	-0.061

Thermal energy and steam	Total emissions	Biomass-related emissions
Process steam from biogas 90%	0.180	-0.058
Process steam from biogas 95%	0.171	-0.055
Process steam from heavy fuel oil (HFO) 85%	0.379	0.000
Process steam from heavy fuel oil (HFO) 90%	0.358	0.000
Process steam from heavy fuel oil (HFO) 95%	0.339	0.000
Process steam from light fuel oil (LFO) 85%	0.373	0.000
Process steam from light fuel oil (LFO) 90%	0.352	0.000
Process steam from light fuel oil (LFO) 95%	0.334	0.000
Process steam from lignite 85%	0.541	0.000
Process steam from lignite 90%	0.512	0.000
Process steam from lignite 95%	0.486	0.000
Process steam from natural gas 85%	0.292	0.000
Process steam from natural gas 90%	0.276	0.000
Process steam from natural gas 95%	0.261	0.000

3.3.3 Data quality and uncertainty analysis

Due to lack of relevant data, the emission factors for heat and steam supply were obtained by the Life Cycle Data Network (LCDN) Thinkstep AG database. The main issue concerning these data relates to the fact that the emission factors cover the entire supply chain and there is no differentiation between several steps of the supply chain.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is good in terms of time representativeness (QR: 2), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and since no information is provided on uncertainty, a conservative approach has been applied and a fair value has been assigned (QR: 3). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2, which corresponds to very good quality.

The overview of the data quality rating for thermal energy and steam is presented in Table 3.3.3.

Table 3.3.3: Data quality rating for thermal energy and steam

Thermal energy and steam	TeR	TiR	GeR	U	DQR
Thermal energy	Good	Good	Very good	Fair	**Very good**
Steam	Good	Good	Very good	Fair	**Very good**

3.4 Road transport

3.4.1 Technical description

The emission factors included in the national database cover two parts, the upstream part adjusted in order to be representative of the national situation for vehicle, fuel type and vehicle size (the boundary is cradle-to-gate) and the fuel combustion part for road transportation by vehicle, fuel type and vehicle size representative of the national situation (the boundary is gate-to-gate). The emission factors include CO_2, CH_4 and N_2O emissions.

The emission factors that have been calculated regarding passenger transport include:

- Passenger car, average, by fuel
  - Diesel
  - Gasoline
  - LPG
- Passenger car, diesel, by size
  - <1.4 l
  - 1,4 l – 2.0 l
  - >2.0 l
- Passenger car, gasoline, by size
  - <1.4 l
  - 1,4 l – 2.0 l
  - >2.0 l
- Motorcycles
  - Average

  and by size:
  - < 0.75 l
  - >0.75 l
- Bus average

The emission factors that have been calculated regarding freight transport include:

- Heavy duty truck
  - Average

  and by size:
  - 3.5 – 7.5 t
  - 7.5 – 16 t
  - 16 – 32 t
  - >32 t
- Light duty truck by fuel
  - Diesel
  - Gasoline

Moreover, based on literature review, the emission factors for average carbon dioxide emissions per km from new passenger cars for 2014 and 2015, were extracted by Environmental European Agency (EEA) reports (16) (17).

In total 22 emission factors on road transport were created, 15 of which refer to passenger transport (upstream and combustion) and 7 to freight transport (upstream and combustion).

3.4.2 Methodological issues

The calculation of road transport emission factors was based on 2006 IPCC Guidelines for national greenhouse gas inventories (3) and according to the methodology provided in Deliverable A2.2, Chapter 7.1 Example: road transport (1).

For the combustion part according to IPCC, estimated emissions from road transport can be based on fuel consumption and vehicle kilometers data. The amount of fuel sold is required to calculate CO_2 emissions, while the distance traveled by vehicle type and road type is required for the calculation of CH_4 and N_2O emissions as they depend on vehicle technology, fuel and operating characteristics. Therefore, even if specific national data are unavailable it is advised to use higher tiered emission factors and calculate vehicle distance travelled data based on national road transportation fuel use data and an assumed fuel economy value.

Energy consumption data by fuel type for road transport for Greece in 2014 were obtained by Eurostat (10), extraction June 2016. The Greek NIR only provides graphs regarding mileage and stock of vehicles. As a result, the fuel data and vehicle-km data split into vehicle and fuel categories was made based on the following sources.

Data on the vehicle fleet in Greece for 2014 were obtained by the Hellenic Statistical Authority (ELSTAT) (18), extraction June 2016. In order to breakdown the passenger car fleet by fuel type, relevant data were available on ACEA (European Automobile Manufacturers Association) (19) at country level for Greece for 2014. The breakdown of light duty trucks fleet by fuel type was obtained by TREMOVE economic transport and emissions model (2015), data for Greece for 2015 (20).

Average fuel consumption (effective efficiency) data in litres per 100 km per vehicle type for Greece were obtained by Systra transport modeling with adjustments, where necessary; in order to better represent national conditions. The annual distance travelled per vehicle category was assessed taking into account the country's fuel consumption data.

The split by vehicle and fuel category was followed by a split into the distance travelled on different road classes and by Euro standard in order to better calculate CH_4 and N_2O emissions. Data for the categorisation of the vehicle fleet by Euro standard for Greece in 2014 were collected by TREMOVE economic transport and emissions model (2015) (20). Data on average speed per vehicle type and share of mileage driven on different road classes (urban, rural, highway) were taken from the COPERT model, Ntziachristos and Samaras (2000) (21).

Emissions from road transport were calculated in accordance with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (3). The emission factors used were road transport default CO_2 emission factors by fuel type (69300 kg/TJ for motor gasoline, 74100 kg/TJ for gas/diesel oil and 63100 for liquefied petroleum gases) and N_2O and CH_4 emission factors for European vehicles, COPERT IV model by vehicle type, fuel, vehicle technology and road class (Table 3.2.5 Emission factors for European gasoline and diesel vehicles in IPCC guidelines (3)). Due to the fact that the emission factors provided regarding vehicle class present data up to Euro 4 standard, the assumption was made that the emission factors for Euro 5 and Euro 6 standard are equal to the emission factors for Euro 4. Based on the above mentioned sources, the average emission factors were calculated by fuel and vehicle type.

The further breakdown of the emission factors by vehicle size was made through a new allocation of fuel consumption data by vehicle type and fuel to different vehicle sizes. In order to acquire this further disaggregation of data, vehicle fleet data by TREMOVE economic transport and emissions model (2015) (20) were used, where available, in order to obtain the breakdown of the fleet by size and fuel. The breakdown of the vehicle fleet by vehicle size was followed by an application of differentiated average fuel consumptions to different vehicle sizes, while the assumption was made that the kilometres traveled for different vehicle sizes remain equal to the average values and remain uninfluenced by vehicle size. The emission factors applied to fuel consumptions by vehicle size and fuel were the default fuel-based emission factors for CO_2, CH_4 and N_2O (Table 3.2.1 Road transport default CO_2 emission factor and Table 3.2.2 Road transport default emission factors and uncertainty ranges in IPCC guidelines (3)). Based on the above mentioned sources, the emission factors for combustion by vehicle type, fuel and vehicle size were calculated.

For the upstream part of the emission factors, data from the ELCD v3 database (22) and Base Carbone database (23) were used to characterise the supply chain situation of each gas in a representative manner and the dataset covers all relevant process steps/technologies over the supply chain of the represented cradle to gate inventory. The emission factors for fuel supply were adjusted in order to be representative of the national situation for vehicle, fuel type and vehicle size.

Regarding freight transport data, emission factors were also calculated in tonne-km units for comparison and convenience in the use by organisations. These emission factors were obtained by vehicle-km emission factors for each vehicle type. Due to lack of specific data for Greece regarding average payload, the average payload by vehicle size applied was in accordance with the relevant average payloads presented in DEFRA's "UK Government conversion factors for Company Reporting" (24) due to the fact that vehicle size categories were similar in both cases.

The national emission factors for road freight transport in Greece are presented in Tables 3.4.1 to 3.4.4 below; while the national emission factors for road passenger transport in Greece are presented in Tables 3.4.5 to 3.4.10.

Table 3.4.1: Emission factors for road freight transport, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per vehicle-km)

Road freight transport	**Breakdown of GHG emissions by gas (kg CO_2 eq per vehicle-km)**					
	CO_2		**CH_4 f + CH_4 b**		**N_2O**	
Vehicle type	**Upstream**	**Combustion**	**Upstream**	**Combustion**	**Upstream**	**Combustion**
Light duty vehicle, average, gasoline	0.044	0.226	0.008	0.001	0.000	0.002
Light duty vehicle, average, diesel	0.030	0.263	0.009	0.000	0.002	0.001
Heavy duty vehicle, average, diesel	0.104	0.910	0.032	0.003	0.005	0.008
Heavy duty vehicle, 3.5 - 7.5 t	0.084	0.737	0.026	0.001	0.004	0.010
Heavy duty vehicle, 7.5 - 16 t	0.100	0.874	0.031	0.001	0.005	0.012
Heavy duty vehicle, 16 - 32 t	0.125	1.092	0.038	0.002	0.006	0.015
Heavy duty vehicle, > 32 t	0.130	1.138	0.040	0.002	0.007	0.016

Table 3.4.2: Emission factors for road freight transport, total and biomass-related (kg CO_2 eq per vehicle-km)

Road freight transport	**Total emissions**			**Biomass-related emissions**		
	kg CO_2 eq per vehicle-km			**kg CO_2 eq per vehicle-km**		
Vehicle type	**Manufacturing**	**Upstream**	**Combustion**	**Manufacturing**	**Upstream**	**Combustion**
Light duty vehicle, average, gasoline	0.040	0.053	0.229	0.000	0.000	0.000
Light duty vehicle, average, diesel	0.030	0.041	0.265	0.000	-0.011	0.011
Heavy duty vehicle, average, diesel	0.075	0.141	0.921	0.000	-0.037	0.037
Heavy duty vehicle, 3.5 - 7.5 t	0.043	0.115	0.749	0.000	-0.030	0.030
Heavy duty vehicle, 7.5 - 16 t	0.069	0.136	0.887	0.000	-0.035	0.035
Heavy duty vehicle, 16 - 32 t	0.103	0.170	1.109	0.000	-0.044	0.044
Heavy duty vehicle, > 32 t	0.110	0.177	1.155	0.000	-0.046	0.046

Table 3.4.3: Emission factors for road freight transport, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne-km)

Road freight transport	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne-km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
Vehicle type	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
Light duty vehicle, average, gasoline	0.089	0.452	0.016	0.002	0.001	0.004
Light duty vehicle, average, diesel	0.060	0.526	0.019	0.000	0.003	0.003
Heavy duty vehicle, average, diesel	0.014	0.121	0.004	0.000	0.001	0.001
Heavy duty vehicle, 3.5 - 7.5 t	0.070	0.614	0.022	0.001	0.004	0.009
Heavy duty vehicle, 7.5 - 16 t	0.044	0.380	0.013	0.001	0.002	0.005
Heavy duty vehicle, 16 - 32 t	0.023	0.199	0.007	0.000	0.001	0.003
Heavy duty vehicle, > 32 t	0.011	0.099	0.003	0.000	0.001	0.001

Table 3.4.4: Emission factors for road freight transport, total and biomass-related (kg CO_2 eq per tonne -km)

Road freight transport	Total emissions			Biomass-related emissions		
	kg CO_2 eq per tonne -km			kg CO_2 eq per tonne -km		
Vehicle type	Manufacturing	Upstream	Combustion	Manufacturing	Upstream	Combustion
Light duty vehicle, average, gasoline	0.081	0.106	0.458	0.000	0.000	0.000
Light duty vehicle, average, diesel	0.061	0.082	0.529	0.000	-0.021	0.021
Heavy duty vehicle, average, diesel	0.010	0.019	0.123	0.000	-0.005	0.005
Heavy duty vehicle, 3.5 - 7.5 t	0.036	0.095	0.624	0.000	-0.025	0.025
Heavy duty vehicle, 7.5 - 16 t	0.030	0.059	0.386	0.000	-0.015	0.015
Heavy duty vehicle, 16 - 32 t	0.019	0.031	0.202	0.000	-0.008	0.008
Heavy duty vehicle, > 32 t	0.010	0.015	0.100	0.000	-0.004	0.004

Table 3.4.5: Emission factors for road passenger transport, passenger cars, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per vehicle-km)

Road passenger transport	Breakdown of GHG emissions by gas (kg CO_2 eq per vehicle-km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
Vehicle type	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
Private car, average, diesel	0.018	0.159	0.006	0.000	0.001	0.002
Private car, average, gasoline	0.035	0.180	0.006	0.000	0.000	0.001
Private car, average, LPG	0.019	0.155	0.007	0.002	0.000	0.001
Private car, gasoline < 1.4 l	0.033	0.170	0.006	0.002	0.000	0.005
Private car, gasoline, 1.4 - 2.0 l	0.038	0.191	0.007	0.002	0.000	0.006
Private car, gasoline > 2.0 l	0.046	0.234	0.008	0.003	0.000	0.007
Private car, diesel < 1.4 l	0.016	0.143	0.005	0.000	0.001	0.002
Private car, diesel, 1.4 - 2.0 l	0.018	0.157	0.006	0.000	0.001	0.002
Private car, diesel > 2.0 l	0.021	0.181	0.006	0.000	0.001	0.003

Table 3.4.6: Emission factors for road passenger transport, passenger cars, total and biomass-related (kg CO_2 eq per vehicle-km)

Road passenger transport	**Total emissions**			**Biomass-related emissions**		
	kg CO_2 eq per vehicle-km			**kg CO_2 b per vehicle-km**		
Vehicle type	**Manufacturing**	**Upstream**	**Combustion**	**Manufacturing**	**Upstream**	**Combustion**
Private car, average, diesel	0.040	0.025	0.161	0.000	-0.006	0.006
Private car, average, gasoline	0.040	0.042	0.181	0.000	0.000	0.000
Private car, average, LPG	0.040	0.026	0.158	0.000	0.000	0.000
Private car, gasoline < 1.4 l	0.040	0.040	0.177	0.000	0.000	0.000
Private car, gasoline, 1.4 - 2.0 l	0.040	0.045	0.199	0.000	0.000	0.000
Private car, gasoline > 2.0 l	0.040	0.055	0.244	0.000	0.000	0.000
Private car, diesel < 1.4 l	0.040	0.022	0.145	0.000	-0.006	0.006
Private car, diesel, 1.4 - 2.0 l	0.040	0.024	0.160	0.000	-0.006	0.006
Private car, diesel > 2.0 l	0.040	0.028	0.184	0.000	-0.007	0.007

Table 3.4.7: Emission factors for road passenger transport, buses, breakdown by gas (CO_2, CH_4 and N_2O)

Road passenger transport	**Breakdown of GHG emissions by gas**					
	CO_2		**CH_4 f + CH_4 b**		**N_2O**	
Vehicle type	**Upstream**	**Combustion**	**Upstream**	**Combustion**	**Upstream**	**Combustion**
Buses (kg CO_2 eq per vehicle-km)	0.116	1.016	0.036	0.002	0.006	0.008
Buses (kg CO_2 eq per passenger-km)	0.012	0.102	0.004	0.000	0.001	0.001

Table 3.4.8: Emission factors for road passenger transport, buses, total and biomass-related

Road passenger transport	**Total emissions**			**Biomass-related emissions**		
Vehicle type	**Manufacturing**	**Upstream**	**Combustion**	**Manufacturing**	**Upstream**	**Combustion**
Buses (kg CO_2 eq per vehicle-km)	0.000	0.158	1.027	0.000	-0.041	0.041
Buses (kg CO_2 eq per passenger-km)	0.000	0.016	0.103	0.000	-0.004	0.004

Table 3.4.9: Emission factors for road passenger transport, motorcycles, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per vehicle-km)

Road passenger transport	**Breakdown of GHG emissions by gas (kg CO_2 eq per vehicle-km)**					
	CO_2		**CH_4 f + CH_4 b**		**N_2O**	
Vehicle type	**Upstream**	**Combustion**	**Upstream**	**Combustion**	**Upstream**	**Combustion**
Motorcycles, average	0.016	0.081	0.003	0.005	0.000	0.001
Motorcycles < 0.75 l	0.015	0.075	0.003	0.001	0.000	0.002
Motorcycles >0.75 l	0.020	0.100	0.004	0.001	0.000	0.003

Table 3.4.10: Emission factors for road passenger transport, motorcycles, total and biomass-related (kg CO_2 eq per vehicle-km)

Road passenger transport	Total emissions			Biomass-related emissions		
	kg CO_2 eq per vehicle-km			kg CO_2 b per vehicle-km		
Vehicle type	Manufacturing	Upstream	Combustion	Manufacturing	Upstream	Combustion
Motorcycles, average	0.037	0.019	0.086	0.000	0.000	0.000
Motorcycles < 0.75 l	0.037	0.018	0.079	0.000	0.000	0.000
Motorcycles >0.75 l	0.037	0.023	0.105	0.000	0.000	0.000

3.4.3 Data quality and uncertainty analysis

The main issue encountered during the calculation of the emission factors related to the data gaps and the level of disaggregation of data required to obtain the calculations. As a result, several data sources have been used. In order to ensure the best quality of data available, quality checks and comparisons between sources took place. However, in some cases assumptions and estimates were required, as described in detail above.

As far as the emission factor uncertainties for the upstream part are concerned, according to ELCD v3 and Base Carbone, the energy carrier extraction and processing data is of good data quality.

As far as the emission factor uncertainties for the combustion part are concerned, according to IPCC, the uncertainty in the CO_2 emission factors are between 2-5%. The uncertainties in emission factors for CH_4 and N_2O are relatively high (especially for N_2O) and are likely to be a factor of 2-3. Regarding tonne-km data, the lack of national data on average payload increases the uncertainty.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), very good in terms of technological representativeness (QR: 1), very good in terms of geographical representativeness (QR: 1) and poor in terms of uncertainty (QR: 4). In the case of tonne-km data, the uncertainty is very poor (QR:5). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.75 for all data except for the truck values on tonne-km for which the overall data quality rating (DQR) is 2, both of which correspond to very good quality.

The overview of the data quality rating for road transport is presented in Table 3.4.11.

Table 3.4.11: Data quality rating for road transport

Road transport	TeR	TiR	GeR	U	DQR
Passenger cars	Very good	Very good	Very good	Poor	**Very good**
Motorcycles	Very good	Very good	Very good	Poor	**Very good**
Buses	Very good	Very good	Very good	Poor	**Very good**
Trucks (vehicle-km)	Very good	Very good	Very good	Poor	**Very good**
Trucks (tonne-km)	Very good	Very good	Very good	Very poor	**Very good**

3.5 Rail transport

3.5.1 Technical description

Rail transport causes emissions of CO_2, CH_4 and N_2O. In the methodology prepared, the focus has been on national railways and in particular diesel. The calculated emission factors include two emission factors; one emission factor for goods freight by rail and one emission factor for transportation of passengers by rail. The emissions from other rail transport have not been calculated due to lack of relevant data.

3.5.2 Methodological issues

Railway locomotives are generally of three types: diesel, electric and steam. According to the EMEP/EEA (4) methodology, emissions from electric locomotives are accounted for under stationary combustion; while the contribution of steam locomotives to emissions is small. As a result, the calculation of emission factors from rail transport focused on emissions from diesel engines, which use gas/diesel oil. This was in accordance with the National Inventory Report 2016 (2).

In the calculation the main data sources and assumptions used were the following: Rail consumption data by fuel, data on goods transported in million tonne-kilometres and data on passengers transported in million passenger-kilometres were obtained by Eurostat, extraction July 2016. Due to lack of data in passenger tonne-kilometres, the relevant data on passenger-kilometres were converted to tonne-kilometres using the assumption that each passenger and their luggage weigh 100 kg. The breakdown of gas/diesel oil consumption in rail transport to goods and passengers was based on the tonne-kilometers allocation.

Emissions for goods rail transport and passenger rail transport were calculated using the default emission factors for diesel for rail transport for CO_2, CH_4 and N_2O from IPCC, 2006 Guidelines for National Greenhouse Gas Inventories (CO_2: 74100 kg/TJ, CH_4:4.15

kg/TJ, N_2O: 28.6 kg/TJ) (3). The emission factors were calculated based on the tonne-km and passenger-km data provided by Eurostat.

The national emission factors for rail freight transport in Greece are presented in Tables 3.5.1 and 3.5.2 below; while the national emission factors for rail passenger transport in Greece are presented in Tables 3.5.3 to 3.5.4.

Table 3.5.1: Emission factors for rail freight transport, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne-km)

Rail freight transport	Breakdown of GHG emissions by gas (kg CO_2e per tonne-km)		
	CO_2	CH_4 f + CH_4 b	N_2O
Train, diesel	0.497	0.001	0.051

Table 3.5.2: Emission factors for rail freight transport, total and biomass-related (kg CO_2 eq per tonne-km)

Rail freight transport	Total emissions	Biomass-related emissions
Train, diesel	0.548	0.000

Table 3.5.3: Emission factors for rail passenger transport, breakdown by gas (kg CO_2, CH_4 and N_2O) (CO_2 eq per passenger-km)

Rail passenger transport	Breakdown of GHG emissions by gas (kg CO_2e per passenger-km)		
	CO_2	CH_4 f + CH_4 b	N_2O
Train, diesel	0.050	0.000	0.005

Table 3.5.4: Emission factors for rail passenger transport, total and biomass-related for rail passenger transport (CO_2 eq per passenger-km)

Rail passenger transport	Total emissions	Biomass-related emissions
Train, diesel	0.055	0.000

3.5.3 Data quality and uncertainty analysis

The 2006 IPCC Guidelines for national greenhouse gas inventories (3) provide ranges of lower and upper values in the proposed emission factors indicating the uncertainties of diesel fuel emission factors. CO_2 emission factors for fuels are generally determined within a 5% uncertainty. The uncertainty of CH_4 emission factors is estimated within a 40% range and the uncertainty of N_2O emission factors is estimated to a factor of 2. As far as the uncertainty in activity data is concerned, an important uncertainty parameter is the allocation of fuel consumption data to goods and passengers.

The quality level and rating for the quality criteria for rail transport, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), fair in terms of technological representativeness (QR: 3), very good in terms of geographical representativeness (QR: 1) and fair in terms of uncertainty (QR: 3) for rail passenger transport and very poor in terms of uncertainty (QR:5) for rail freight transport. Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2, which corresponds to very good for rail passenger transport and 2.5, which corresponds to good for rail freight transport.

The overview of the data quality rating for rail transport is presented in Table 3.5.5.

Table 3.5.5: Data quality rating for rail transport

Rail transport	TeR	TiR	GeR	U	DQR
Passenger transport	Fair	Very good	Very good	Fair	**Very good**
Freight transport	Fair	Very good	Very good	Very poor	**Good**

3.6 Air transport

3.6.1 Technical description

The emission factors that have been calculated regarding air transport are comprised of two parts, the upstream part and the combustion part. They include CO_2, CH_4 and N_2O emissions and are representative of the national situation.

The emission factors that have been calculated include:

- Passenger air transport in national flights
  - 0-50 seats
  - 51-100 seats
  - 101-180 seats
  - >180 seats
- Freight air transport in national flights
  - 0-50 seats
  - 51-100 seats
  - 101-180 seats
  - >180 seats

Overall, 8 emission factors were created; 4 of which refer to freight transport (upstream and combustion) and 4 of which refer to passenger transport (upstream and combustion).

3.6.2 Methodological issues

The calculation of domestic aviation emission factors was based on the detailed EMEP/EEA methodology (4). The focus was on domestic passenger flights, as the available data on domestic air freight were unclear and presented several ambiguities. Data on total fuel consumption for domestic aviation were obtained by Eurostat, extraction June 2016 (10). Data on the number of flights and number of passengers transported by destination and type of aircraft were also obtained by Eurostat (10). Data on distances between airports were obtained by flightmapper.net (25). In Greece all domestic flight distances are in the range 0-1000 km (specifically between 0-500 km).

Regarding the combustion part, total emissions from aircrafts are the sum of various technologies, but in the EMEP/EEA methodology there is a simplification into two classes of flying modes, Landing Take-Off (LTO) and cruise. EMEP/EEA provides a detailed table with data on fuel burnt and emissions per aircraft type and stage length for both climb/cruise/descent and LTO. In case the exact aircraft type was not available, the closest available was chosen.

The fuel consumption for LTO activities per aircraft type was obtained by synthesizing data on number of flights per aircraft type and fuel use data for LTO per aircraft type and stage length, as provided by EMEP/EEA and IPCC (this value is independent of distance). Data on number of flights by type of aircraft did not refer to the exact aircraft model, but to all models by aircraft type. As a result, a representative, most suitable aircraft model was used for each aircraft type based on passenger number data, flight number data, the average number of passengers per flight and number of seats per aircraft type, data for which were obtained by each company's site. The sum of all fuel consumption by LTO activities for all aircraft types gave the total fuel consumption for all aircrafts during LTO.

Regarding domestic cruise activities, cruise fuel use data per aircraft type and stage length were also obtained by EMEP/EEA in accordance to flight distance by destination. The same assumptions as in LTOs were used regarding aircraft models; while traffic by destination data was obtained by Eurostat, extraction July 2016 (10). Due to the fact that the available data referred to aircraft types by main airport and did not provide details on the destinations the assumption that all flights are destined to Athens was made. Flight distance data were adjusted as an extra 70 km mileage was added in order to better simulate real life conditions. This is common practice as presented in relevant methodologies on emission calculations by flights by ICAO (26) and myclimate (27). The fuel consumption for cruise activities per aircraft type was obtained based on the number of flights and fuel consumption during cruise for each aircraft type and stage length in accordance with EMEP/EEA. The sum of all fuel consumption by all aircraft types provided the total fuel consumption for all aircrafts during cruise.

The total fuel consumption per aircraft type is the sum of cruise and LTO consumption per aircraft type. The total estimated fuel use for domestic aviation was then compared to statistics on fuel consumption by domestic aviation as provided by Eurostat in order to ensure that the estimate and direct observation do not deviate.

According to IPCC (28), the emissions in the two flying phases, LTO and cruise, are estimated separately. Emissions in the LTO phase are estimated with default emission factors per LTO, while cruise emissions are dependent on the length of the flight and the fuel used during the cruise phase. The estimated fuel use is multiplied with default emission factors to estimate emissions; while according to default emission factors, methane is not emitted in the cruise phase of the flight.

Therefore, in order to calculate the relevant emission factors and acquire a disaggregation by aircraft type, initially, the fuel consumption by flight-kilometre was calculated for the cruise phase of the flight for each aircraft type. Aircrafts were divided into 4 categories, according to the available number of seats: 0-50, 51-100, 101-180 and >180. The average cruise consumption per flight-kilometre was calculated for each aircraft type and then the weighted average cruise consumption by aircraft category based on the share of flight-km by aircraft type.

In order to make the allocation per passenger, the number of seats per aircraft type was obtained by information on each company's site, while the load factor was estimated using data on number of passengers and number of flights by Eurostat. Due to the fact that the passenger load factors appeared to be very low in some cases of aircrafts (in the categories of 0-50 seats and 51-100 seats), the assumption was made that the load factors in these cases were 55%. Again, the weighted average of passengers for each aircraft category was obtained based on the share of flight-km by aircraft type and the relevant number of seats and load factors for each aircraft.

The emissions by aircraft category and flight-kilometre were then calculated using default emission factors per average aircraft for LTO and cruise, as provided in Table 2 by IPCC (28). According to IPCC, CH_4 emissions are negligible and are assumed to be zero during cruise. A part of resulting emissions (approximately 5%) was considered to be allocated to freight transported to passenger services, according to ICAODATA (27). The emissions per flight-km were then allocated to each passenger according to the weighted average according to number of seats and load factors, as described above.

Due to lack of concrete data on domestic air freight transport in Greece and ambiguities in data, the analysis of domestic air freight transport was based on values obtained through the methodology applied to passengers and the conversion was made based on the assumption that approximately 1 passenger-km equals 0.1 freight tonne-km, as presented in the methodology for Base Carbone (23).

For the upstream part of the emission factors, data from the ELCD v3 database (22) were used to characterise the supply chain situation of each gas in a representative manner and the set covers all relevant process steps/technologies over the supply chain. The emission factors for fuel supply were adjusted in order to be representative of the national situation. The data set represents a cradle to gate inventory for kerosene supply only, as it makes up approximately 99% of national domestic aviation consumption.

The national emission factors for air freight transport in Greece are presented in Tables 3.6.1 and 3.6.2 below; while the national emission factors for air passenger transport in Greece are presented in Tables 3.6.3 and 3.6.4.

Table 3.6.1: Emission factors for air freight transport, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne-km)

Freight air transport in national flights	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne-km)					
	CO2		CH4 f + CH4 b		N2O	
Type of flight	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
0-50 seats	0.251	3.048	0.096	0.004	0.002	0.026
51-100 seats	0.175	2.125	0.067	0.003	0.001	0.026
101-180 seats	0.112	1.365	0.043	0.001	0.001	0.010
>180 seats	0.101	1.232	0.039	0.001	0.001	0.010

Table 3.6.2: Emission factors for air freight transport, total and biomass-related (kg CO_2 eq per tonne-km)

Freight air transport in national flights	Total emissions		Biomass-related emissions	
	kg CO_2 eq per tonne-km		kg CO_2 b per tonne-km	
Type of flight	Upstream	Combustion	Upstream	Combustion
0-50 seats	0.348	3.077	0.000	0.000
51-100 seats	0.243	2.154	0.000	0.000
101-180 seats	0.156	1.376	0.000	0.000
>180 seats	0.141	1.243	0.000	0.000

Table 3.6.3: Emission factors for air passenger transport, breakdown by gas (kg CO_2, CH_4 and N_2O) (CO_2 eq per passenger-km)

Passenger air transport in national flights	Breakdown of GHG emissions by gas (kg CO_2 eq per passenger-km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
Type of flight	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
0-50 seats	0.025	0.305	0.010	0.000	0.000	0.003
51-100 seats	0.017	0.213	0.007	0.000	0.000	0.003
101-180 seats	0.011	0.136	0.004	0.000	0.000	0.001
>180 seats	0.010	0.123	0.004	0.000	0.000	0.001

Table 3.6.4: Emission factors for air passenger transport, total and biomass-related (kg CO_2 eq per passenger-km)

Passenger air transport in national flights	Total emissions		Biomass-related emissions	
	kg CO_2 eq per passenger-km		kg CO_2 b per passenger-km	
Type of flight	Upstream	Combustion	Upstream	Combustion
0-50 seats	0.035	0.308	0.000	0.000
51-100 seats	0.024	0.215	0.000	0.000
101-180 seats	0.016	0.138	0.000	0.000
>180 seats	0.014	0.124	0.000	0.000

3.6.3 Data quality and uncertainty analysis

The most significant uncertainty parameters relate to the assumptions made regarding activity data. The lack of relevant data required for several assumptions, which have been presented in detail in the methodology section.

As far as the emission factors uncertainty ranges are concerned, according to IPCC (28), the CO_2 emission factor is within a 5% uncertainty, while the uncertainty for the methane emission factor can be as high as a factor of 2 and the uncertainty of N_2O can be orders of magnitude.

For the upstream part, the data set covers all relevant process steps / technologies over the supply chain of the represented cradle to gate inventory with a good overall data quality. Energy carrier extraction and processing data are of sufficient to good data quality. The lack of relevant activity data required for several assumptions.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and poor in terms of uncertainty (QR: 4). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2, which corresponds to very good quality.

The overview of the data quality rating for air transport is presented in Table 3.6.5.

Table 3.6.5: Data quality rating for air transport

Air transport	TeR	TiR	GeR	U	DQR
Passenger transport	Good	Very good	Very good	Poor	**Very good**
Freight transport	Good	Very good	Very good	Poor	**Very good**

3.7 Sea transport/Navigation

3.7.1 Technical description

The emission factors developed for sea transport/navigation consist of two parts, the upstream part and combustion. Sea transport causes emissions of CO_2, CH_4 and N_2O. In the methodology prepared, the focus has been on domestic navigation of ferries that carry passengers, cars and freight.

The calculated emission factors include:
- Shipment of goods by sea using ferries
- Transportation of passengers without cars by sea using ferries
- Transportation of passengers with cars by sea using ferries
- Transportation of passengers by sea using ferries average

On the contrary, the emissions from other freight transport ship have not been calculated due to lack of relevant data. According to the NIR, domestic navigation emissions are calculated according to Tier 1 default methodology, as the application of a higher Tier methodology requires detailed data, which are not available.

In total 4 emission factors on sea transport were created, 3 of which refer to passenger transport (upstream and combustion) and 1 to freight transport (upstream and combustion).

3.7.2 Methodological issues

Domestic navigation consumption data by fuel were extracted by Eurostat, extraction July 2016 (10). However, fuel consumption data in domestic navigation include consumption not only by ferries carrying passengers and freight, but also data for goods freight. According to a study (29), based on information by the main fuel selling companies in Greece, the percentage of fuel sold for domestic ferry navigation reached 82% in 2010. Overall, between 2010 and 2014 domestic navigation consumption declined by 38%, however due to lack of more recent data, the share of ferry navigation to total consumption was assumed to be approximately 80%. CO_2 emissions from ferries were calculated according to the default emission factors provided by 2006 IPCC guidelines for greenhouse gas inventories (74100 kg/TJ for gas/diesel oil and 77400 kg/TJ for fuel oil).

In order to allocate emissions from ferries between passengers and freight, an approach similar to the one provided by DEFRA methodology paper for emission factors (6) was used. Emissions were allocated according to the tonnes transported (freight, vehicles and passengers and luggage). The main assumptions were that each car weighs 1.20

tonnes and each passenger with their luggage 0.100 tonnes. Data on passenger numbers and car numbers transported, as well as data on total freight were obtained by the Hellenic Statistical Authority (ELSTAT) (18). Compared to the total weight, the emissions allocated to passengers with luggage and cars accounted for approximately 12%, while emissions allocated to freight accounted for 88%.

In order to calculate passenger-km, data on sea distances were gathered by https://sea-distances.org/ (30) and http://www.searoutes.com/routing (31). Due to lack of more precise data, in order to calculate total tonne-km an average distance of 180 km was applied to the total tonnes transported by ferries.

The emission factor for passengers was calculated from the emissions excluding freight and the number of passenger-km; while a distinction was made further between passengers on foot and passengers with cars. Accordingly, the emission factor for ferry freight was calculated using data from the emission allocation to freight and tonne-km. CH_4 and N_2O emission factors were calculated using domestic navigation emissions data from the NIR 2016 relatively to CO_2 emissions.

For the upstream part of the emission factors, data from the ELCD v3 database (22) for fuel oil and Base Carbone (32) for marine diesel oil were used to characterise the supply chain situation of each gas in a representative manner and the set covers all relevant process steps/technologies over the supply chain of the represented cradle to gate inventory. The emission factors for fuel supply were adjusted in order to be representative of the national situation for vehicle, fuel type and vehicle size. The data sources used are presented in detail in the combustion part.

The national emission factors for sea freight transport in Greece are presented in Tables 3.7.1 to 3.7.2 below; while the national emission factors for sea passenger transport in Greece are presented in Tables 3.7.3 to 3.7.4.

Table 3.7.1: Emission factors for sea freight transport/navigation, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne-km)

Freight sea transport	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne-km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
Ferry boat	0.023	0.179	0.004	0.000	0.000	0.008

Table 3.7.2: Emission factors for sea freight transport/navigation, total and biomass-related (kg CO_2 eq per tonne-km)

Freight sea transport	Total emissions		Biomass-related emissions	
	kg CO_2 eq per tonne-km		kg CO_2 b per tonne-km	
	Upstream	Combustion	Upstream	Combustion
Ferry boat	0.028	0.187	0.000	0.000

Table 3.7.3: Emission factors for sea passenger transport/navigation, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per passenger-km)

Passenger sea transport	Breakdown of GHG emissions by gas (kg CO_2 eq per passenger-km)					
	CO_2		CH_4 f + CH_4 b		N_2O	
	Upstream	Combustion	Upstream	Combustion	Upstream	Combustion
Ferry boat, average	0.007	0.055	0.001	0.000	0.000	0.003
Ferry boat, passenger without car	0.005	0.020	0.001	0.000	0.000	0.001
Ferry boat, passenger with car	0.011	0.114	0.002	0.000	0.000	0.005

Table 3.7.4: Emission factors for sea passenger transport/navigation, total and biomass-related (kg CO_2 eq per passenger-km)

Passenger sea transport	Total emissions		Biomass-related emissions	
	kg CO_2 eq per passenger-km		kg CO_2 b per tonne-km	
	Upstream	Combustion	Upstream	Combustion
Ferry boat, average	0.009	0.058	0.000	0.000
Ferry boat, passenger without car	0.006	0.021	0.000	0.000
Ferry boat, passenger with car	0.013	0.120	0.000	0.000

3.7.3 Data quality and uncertainty analysis

As described above, the lack of precise data in several cases has led to the assumptions stated in detail in the methodology part, which results to an increase in the uncertainty of the results. The uncertainty regarding CO_2 emission factors, according to 2006 IPCC Guidelines (33) is about 1,5% for diesel oil and 3% for fuel oil. The uncertainty for CH_4 emission factor may range as high as 50%, the uncertainty of N_2O emission factor may range from 40% below to 140% above the default value.

For the upstream part, the data set covers all relevant process steps / technologies over the supply chain of the represented cradle to gate inventory with a good overall data quality. Crude oil mix information based on official statistical information. Energy carrier extraction and processing data are of sufficient to good (e.g. refinery) data quality.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1) and very poor in terms of uncertainty (QR: 5). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2.25, which corresponds to good quality.

The overview of the data quality rating for sea transport/navigation is presented in Table 3.7.5.

Table 3.7.5: Data quality rating for sea transport/navigation

Sea transport/navigation	TeR	TiR	GeR	U	DQR
Passenger transport	Good	Very good	Very good	Very poor	**Good**
Freight transport	Good	Very good	Very good	Very poor	**Good**

3.8 Agriculture, Animals

3.8.1 Technical description

The emission factors that have been calculated include the emissions from animals per animal type. According to the NIR, "Methane is produced during the normal digestion of food by herbivorous animals and the amount emitted depends on the animal species, their digestive system and feed intake. Manure management is responsible for methane and nitrous oxide emissions. Methane is produced during the anaerobic decomposition of manure, while nitrous oxide is produced during the storage and treatment of manure before its use as fertilizer".

The calculated emission factors include CH_4 and N_2O emissions from manure management and CH_4 emissions from enteric fermentation for the following animals:

- Cattle
- Dairy cattle
- Non-dairy cattle
- Sheep
- Swine
- Buffalo
- Goat
- Horse
- Mule and ass
- Poultry

In total 10 emission factors on animals were created.

3.8.2 Methodological issues

The emission factors for animals were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

According to the NIR, "methane emissions from the enteric fermentation of cattle are estimated according to the Tier 2 IPCC methodology. Methane emissions from enteric fermentation for the other animals are estimated according to the Tier 1 IPCC methodology. Methane emissions from enteric fermentation for poultry are estimated based on a country specific emission factor. Manure management is responsible for methane and nitrous oxide emissions. CH_4 emissions from manure management were estimated using IPCC Tier 2 approach for dairy cattle and other cattle and sheep. For the rest of the animals default methodology was used".

The national emission factors for animals in Greece are presented in Tables 3.8.1 to 3.8.3 below.

Table 3.8.1: Emission factors for animals, breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per animal per year)

Emissions per animal	**Breakdown of GHG emissions by gas (kg CO_2 eq per animal per year)**		
	CO_2	**CH_4 f + CH_4 b**	**N_2O**
Cattle	0	2339	94
Dairy cattle	0	4000	191
Non-dairy cattle	0	1933	70
Sheep	0	315	3
Swine	0	525	28
Buffalo	0	1920	59
Goats	0	181	4
Horses	0	610	0
Mules and Asses	0	333	0
Poultry	0	1	0

Table 3.8.2: Breakdown of CH_4 emission factors for animals (CO_2 eq per animal per year)

Emissions per animal	**CH_4 emissions (kg CO_2 eq per animal per year)**	
	Enteric Fermentation	**Manure Management**
Cattle	2174	164
Dairy cattle	3598	403
Non-dairy cattle	1827	106
Sheep	284	31
Swine	45	480
Buffalo	1650	270
Goats	150	31
Horses	540	70
Mules and Asses	300	33
Poultry	1	1

Table 3.8.3: Emission factors for animals, total and biomass-related for animals (kg CO_2 eq per animal per year)

Emissions per animal	Enteric fermentation and manure management	
	Total emissions kg CO_2 eq per animal per year	Biomass-related emissions
Cattle	2433	0
Dairy cattle	4191	0
Non-dairy cattle	2004	0
Sheep	318	0
Swine	553	0
Buffalo	1979	0
Goats	185	0
Horses	610	0
Mules and Asses	333	0
Poultry	2	0

3.8.3 Data quality and uncertainty analysis

According to the NIR, "The combined uncertainty of CH_4 emissions of manure management sector as % of total emissions is estimated at 0.2%. The uncertainty associated with activity data is 5%... the uncertainty associated with emission factors is 50% as it is estimated according to Good Practice Guidance. The combined uncertainty of N_2O emissions of manure management sector is estimated by 0.3%. The uncertainty associated with activity data estimated by 50% ... The uncertainty associated with emission factors is 100% as it is estimated according to Good Practice Guidance".

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is very good in terms of time representativeness (QR: 1), very good in terms of technological representativeness (QR: 1), very good in terms of geographical representativeness (QR: 1) and poor in terms of uncertainty (QR: 4). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.75, which corresponds to very good quality.

Table 3.8.5: Data quality rating for animals

	TeR	TiR	GeR	U	DQR
Cattle	Very good	Very good	Very good	Poor	**Very good**
Dairy cattle	Very good	Very good	Very good	Poor	**Very good**
Non-dairy cattle	Very good	Very good	Very good	Poor	**Very good**
Sheep	Very good	Very good	Very good	Poor	**Very good**
Swine	Very good	Very good	Very good	Poor	**Very good**
Buffalo	Very good	Very good	Very good	Poor	**Very good**

	TeR	TiR	GeR	U	DQR
Goats	Very good	Very good	Very good	Poor	**Very good**
Horses	Very good	Very good	Very good	Poor	**Very good**
Mules and Asses	Very good	Very good	Very good	Poor	**Very good**
Poultry	Very good	Very good	Very good	Poor	**Very good**

3.9 Products and process, food

3.9.1 Technical description

The emission factors that have been included for Greece regarding agricultural products, vegetable were the following:

- ❖ Barley (conventional, minimal tillage and no tillage, rainfed or irrigated)
- ❖ Wheat (conventional, minimal tillage and no tillage, rainfed or irrigated)
- ❖ Maize (conventional, rainfed or irrigated)

These include the direct and indirect CO_2 and N_2O emissions related to the different on-farm activities, such as seed, organic fertilizer, synthetic fertilizer, crop protection, energy use in land work, land use and land use change.

Also, from literature review the emission factors for butter beans (conventional, integrated and organic) have been included (34) and the emission factor for kiwi (35).

Additionally, the emission factors produced for Greece include average CO_2 equivalent emissions for several types of meals. The emission factors that have been calculated refer to:

- ❖ Typical meal
- ❖ Two types of vegan meals
- ❖ Two types of vegetarian meals
- ❖ Two types of red meat meals

In total 29 emission factors on food were created, 7 of which refer to meals, 21 refer to food, agricultural products at farm gate and 1 refers to food, agricultural products at food industry gate.

3.9.2 Methodological issues

Data on barley, wheat and maize have been obtained by the Food and agriculture organisation of the United Nations, Animal Production and Health Division and Livestock Environmental Assessment and Performance (LEAP) **(36)**, data on butter beans have been obtained by literature, specifically the study by Abeliotis et al. **(34)**, while data for kiwi have been obtained by the Environmental product declaration **(35)**.

In order to get a rough estimate on the emissions related to food in Greece, the methodology applied was based on the Bilan Carbone documentation (5) and the creation of an average emission factor by lunch. Initially a database research took place in order to obtain data on the average food consumption in the country by food group. Due to the fact that the EFSA Comprehensive European Food Consumption Database (37), which is a source of information on food consumption across the European Union, only contained data for lactating women in Greece, which were not considered representative, data from the Global nutrition and policy consortium (38), which includes a dietary database, were used. Data referred to 2010. In order to acquire a more complete dataset, data from DAFNE, the Data Food Networking (39) for 2004 were also used.

In each food group a relevant emission factor was applied, the main sources of which were the Base Carbon documentation **(5)** and the Double pyramid: healthy food for people, sustainable food for the planet paper of the Barilla Centre for Food Nutrition **(40)**. According to the Double pyramid document, the data provided refer to the average value of the carbon footprint by food category. In the case of red meat and pasta the data refer to average value with cooking. The emission factors that have been used refer to:

- Whole grains
- Vegetables
- Fruit
- Legumes
- Potatoes

The boundaries for the above mentioned products refer to the agricultural production, including fuel consumption and fertilizer use, any post-harvest cleaning and treatment phases, transport of the products from the field to the distribution centre.

- Pasta
- Bread and rolls
- Sugar

The boundaries for the above mentioned products refer to the agricultural production phase, the industrial processing phase, the production of any packing materials, transport from the field to the distribution centre.

- Red meat
- Milk
- Cheese
- Milk products

The boundaries for the above mentioned products refer to the livestock husbandry phase, including growing of feed, butchering phase (for meat production) and processing of products.

- Eggs
- Seafood
- Fruit juices
- Alcoholic beverages
- Non-alcoholic beverages.

Table 3.9.1 below gives the values for food consumed by adults per day and the allocated emission factor.

Table 3.9.1: Food consumed by adults and equivalent emissions per meal

	gr per lunch	**gr CO_2 eq/kg**	**gr CO_2 eq per meal**
Whole grain	63	1 000	63
Vegetable	367	302	111
Fruit	267	70	19
Legumes	26	1 130	29
Seafood	26	1 833	47
Milk	182	1 138	207
Fruit juices	58	235	14
Red meat	76	31 400	2 371
Alcoholic beverages	60	1 470	88
Non-alcoholic beverages	244	367	90
Bread and rolls	147	983	145
Cheese	55	8 784	483
Eggs	13	3 351	42
Milk products	36	1 138	41
Pasta	28	1 984	56
Potatoes	124	164	20
Sugar	24	470	11
Average per meal			**3 836**

Based on the allocated emission factors and the average daily consumption data per product group, an average value per average lunch was obtained for Greece.

Additionally, several types of menus were also obtained. In particular:

❖ Two types of vegan meals, which include the consumption of whole grains, vegetables, fruits and bread (average daily consumption) and alternatively the consumption of whole grains, potatoes, legumes, fruits and bread (average daily consumption).

❖ Two types of vegetarian meals, which include the consumption of cheese, vegetables, fruits and bread (average daily consumption) and alternatively the consumption of 2 eggs, vegetables, fruits and bread (average daily consumption).

❖ Two types of red meat meals, which include the consumption of red meat (152 gr), pasta and fruit (average daily consumption) and alternatively the consumption of red meat (152 gr), vegetable, bread, cheese, potatoes and fruit (average daily consumption).

The national emission factors for meals in Greece are presented in Table 3.9.2 below. Table 3.9.3 presents the emission factors for food, agricultural products for Greece.

Table 3.9.2: Emission factors for food, meals, total (kg CO_2 eq per meal)

Food, meals	
Type of meal	**kg CO_2 eq per meal**
Typical meal	3.84
Vegan meal (mainly vegetables)	0.34
Vegan meal (mainly legumes/potatoes)	0.28
Vegeterian meal (eggs)	0.36
Vegeterian meal (dairy)	0.76
Typical meat meal (red meat)	4.82
Mainly meat meal (red meat)	5.52

Table 3.9.3: Emission factors for food, agricultural products, total (kg CO_2 eq per type of food)

Food, agricultural products **Type of food at farm gate**	**kg CO_2 eq per tonne**
Gigantes conventional	247
Gigantes integrated	127
Gigantes organic	303
Plake conventional	302
Plake integrated	118
Plake organic	438
Elefantes integrated	87

Food, agricultural products Type of food at farm gate	kg CO_2 eq per tonne
Barley conventional rainfed	685
Barley conventional irrigated	559
Barley minimal tillage rainfed	665
Barley minimal tillage irrigated	546
Barley no tillage rainfed	546
Barley no tillage irrigated	463
Wheat conventional rainfed	678
Wheat conventional irrigated	581
Wheat minimal tillage rainfed	656
Wheat minimal tillage irrigated	566
Wheat no tillage rainfed	534
Wheat no tillage irrigated	479
Maize conventional rainfed	189
Maize conventional irrigated	169
Type of food at food industry gate	**kg CO2e per tonne**
Kiwi	831

3.9.3 Data quality and uncertainty analysis

Due to lack of more recent data concerning average consumption of food per day, taking into account that there may be significant differences in dietary habits over the past few years, there may be uncertainty in the activity data used to the calculations of the emission factors. Moreover, the applied emission factors in limited cases may not refer to the exact type of food, but to the closest type for which emission factors were available. The emission factors from the Barilla Double pyramid documentation (40) present a range of values, the average values were used in this calculation.

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is between fair and very poor in terms of time representativeness, depending on the selected source, good in terms of technological representativeness, very good in terms of geographical representativeness; while in terms of uncertainty, the quality is considered to be poor.

The overview of the data quality rating for food, meals and agricultural products is presented in Table 3.9.4.

Table 3.9.4: Data quality rating for meals and food, agricultural products

	TeR	TiR	GeR	U	DQR
Meals	Good	Poor	Very good	Poor	**Good**
Food, agricultural products at farm gate (Barley, wheat, maize)	Very good	Very good	Very good	Poor	**Very good**
Food, agricultural products at farm gate (Beans)	Good	Poor	Very good	Poor	**Good**
Food, agricultural products at industry gate	Very good	Fair	Very good	Poor	**Good**

3.10 Waste

3.10.1 Technical description

The emission factors calculated for Greece include the following waste treatments:

- Disposal on land
  - Managed
  - Unmanaged
- Incineration
- Composting
- Wastewater handling

Solid waste disposal on land (managed and unmanaged)

According to the NIR, "methane emissions from solid waste disposal on land consist of emissions from municipal solid waste disposal on sites, emissions from sewage sludge (generated during municipal wastewater handling) landfilled and emissions from industrial solid waste and construction and demolition solid waste disposal in managed and unmanaged sites. Unmanaged wastes are considered to be landfilled in sites of similar characteristics concerning their composition and management (depth of sites)".

Incineration

The emission factor on incineration of biogenic waste includes emissions from combustion of biomass materials (e.g. paper, food and wood waste) contained in waste, biogenic agricultural residues produced in slaughterhouses. According to the NIR, "for these estimations, data provided by the Hellenic Statistical Authority as waste incinerated without energy recovery in Greece was used. These data were obtained by individual researches of ELSTAT. CO_2 emissions were not estimated for the agricultural residues taking into account that these were of biogenic nature. CH_4 and N_2O emissions were estimated using default methodology and default emission factors for all categories by IPCC 2006 Guidelines".

The emission factor on incineration of medical waste includes emissions from the incineration of clinical waste. According to the NIR, "for the incineration of clinical waste, a central plant, the only existing in Greece, covers the total daily needs of hospitals in Athens. For the estimation of CO_2 emissions from clinical waste and from industrial chemical waste, the default method suggested by the IPCC Good Practice Guidance was used".

The emission factor on incineration of solvents includes emissions from the incineration of small amounts of industrial chemical waste. According to the NIR, "for these estimations, data provided by the Hellenic Statistical Authority as waste incinerated without energy recovery in Greece was used. These data were obtained by individual researches of ELSTAT. For the estimation of CO_2 emissions from clinical waste and from industrial chemical waste, the default method suggested by the IPCC Good Practice Guidance was used".

Composting of municipal solid waste

The emission factor on composting of municipal solid waste includes emissions from biological treatment (Composting) of solid waste. According to the NIR, "for the estimation of CH_4 and N_2O emissions from biological treatment of solid waste Tier 1 approach was used (IPCC, 2006), emission factors are IPCC default values".

Wastewater handling

The emission factor on Domestic wastewater handling includes emissions from domestic wastewater treatment. According to the NIR, "CH_4 and N_2O emissions from domestic wastewater handling and N_2O emissions from commercial wastewater handling were estimated according to the default methodologies suggested by IPCC. CH_4 emissions from commercial wastewater handling were estimated based on country specific data, as well as on IPCC default values. Domestic wastewater treatment systems consist of a primary treated effluent and an advanced secondary biological treatment with activated sludge system for removing organic load and a significant reduction in nitrogen load".

The emission factor on Industrial wastewater handling includes emissions from industrial wastewater treatment. According to the NIR, "the methodology for calculating methane emissions from industrial wastewater is similar to the one used for domestic wastewater".

In total 8 emission factors on waste were created, 2 of which referred to disposal on land, 3 on incineration, 1 on composting and 2 on wastewater handling.

3.10.2 Methodological issues

Solid waste disposal on land (managed and unmanaged)

The emission factors for waste disposal on land were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

Upstream transport and collection
According to the methodology presented in ADEME's Base Carbone documentation (5), the collection of most household waste in Greece is carried out using refuse trucks, the consumption of which, owing to frequent stops, represents 40 litres of diesel every 100km. A truck must cover an average of 15 km to collect one tonne of household waste, and, by applying the emission factor calculated, this gives 19 kg CO_2 eq emissions per tonne collected.

Functioning of processing centres
According to the methodology presented in ADEME's Base Carbone documentation (5), these emissions concern the electricity consumed, the activity of machinery on site, the production of reactive materials and other consumables, or even the construction of sites. The average value is 15 kg CO_2 eq per tonne processed.

Avoided emissions - electrical recovery
According to literature data (41) and data provided in waste management sites (42), recovery constitutes a management practice in the major managed solid waste disposal sites of Greece. According to data on energy generation, one landfill produces CHP. It is estimated that approximately 56 kWh of electricity is generated per tonne of waste and in CHP 56 kWh of electricity is generated per tonne of waste and 99 kWh of thermal energy. Applying the national emission factor for average electrical kWh that amounts to 0.764 kg CO_2 eq/kWh, avoided emissions were estimated. Similarly for thermal energy, the average emission factor for thermal energy, European average 0.279 kg CO_2 eq/kWh is applied and avoided emissions are estimated.

The emission factors for upstream transport and collection, operation of landfilling, waste treatment and avoided emissions for disposal at managed and unmanaged landfills are presented in Tables 3.10.1, 3.10.2 and 3.10.3.

Table 3.10.1: Emission factors for upstream transportation and operating in waste disposal on land, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste collection and treatment facilities	**kg CO_2 eq per tonne**	**Breakdown of GHG emissions by gas (kg CO_2 eq per tonne)**			
		CO_2	**CH_4 f + CH_4 b**	**N_2O**	**CO_2 b**
Waste collection	18.53	18.53	0.00	0.00	0.00
Operating of treatment facilities – landfilling	15.00	15.00	0.00	0.00	0.00

Table 3.10.2: Emission factors for waste disposal on land, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste treatment	**kg CO_2 eq per tonne**	**Breakdown of GHG emissions by gas (kg CO_2e per tonne)**		
		CO_2	**CH_4 f + CH_4 b**	**N_2O**
MSW disposal at managed landfills	596.82	33.19*	563.62	0.00
MSW disposal at unmanaged landfills	11363.96	33.19*	11330.77	0.00

** upstream transportation and operating are included*

Table 3.10.3: Emission factors for waste disposal on land - avoided emissions (kg CO_2 eq per tonne)

Avoided emissions	**Average value**	**Electrical recovery**		**Cogeneration**		
	kg CO_2 eq per tonne	**kWh LHV generated per tonne**	**kg CO_2 eq per tonne**	**Electricity kWh per tonne**	**Thermal kWh per tonne**	**kg CO_2 eq per tonne**
MSW disposal at managed landfills	-25.90	56.40	-43.11	56.40	99.17	-70.78
MSW disposal at unmanaged landfills	0.00	0.00	0.00	0.00	0.00	0.00

Incineration

The emission factors for waste incineration were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1). The only cases for which there is waste incineration in Greece relate to incineration of clinical waste, incineration of industrial chemical waste and incineration of materials such as paper, food and wood waste or agricultural residues produced in slaughterhouses.

Upstream transport

According to the methodology presented in ADEME's Base Carbone documentation (5), it was calculated that the emission factor amounts to 19 kg CO_2 eq emissions per tonne collected.

Functioning of processing centres

According to the methodology presented in ADEME's Base Carbone documentation (5), these emissions concern the electricity consumed, the activity of machinery on site, the production of reactive materials and other consumables, or even the construction of sites. The average value is 18 kg CO_2 eq per tonne processed.

The emission factors for upstream transport, operation and incineration of industrial and clinical waste and non-hazardous material are presented in Tables 3.10.4 and 3.10.5.

Table 3.10.4: Emission factors for upstream transportation and operating in waste incineration, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste collection and treatment facilities	kg CO_2 eq per tonne	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Waste collection	18.53	18.53	0.00	0.00	0.00
Operating of treatment facilities – incineration	18.33	18.33	0.00	0.00	0.00

Table 3.10.5: Emission factors for waste incineration, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste treatment	kg CO_2 eq per tonne	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne)		
		CO_2	CH_4 f + CH_4 b	N_2O
Hazardous industrial waste	2 851.83	2 823.53*	1.80	26.50
Hazardous clinical waste	901.16	872.86*	1.80	26.50
Non-hazardous materials, such as paper, food and wood waste or agricultural residues	65.04	36.86*	1.68	26.50

* *upstream transportation and operating are included*

Composting of municipal solid waste

The emission factors for composting of waste were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

Upstream transport and collection

According to the methodology presented in ADEME's Base Carbone documentation (5), the upstream transport and collection amounts to 19 kg CO_2 eq emissions per tonne collected.

Functioning of processing centres

According to the methodology presented in ADEME's Base Carbone documentation (5), the average value is 15 kg CO_2 eq per tonne processed.

The emission factors for upstream transport and collection, operation and waste treatment for composting are presented in Tables 3.10.7 and 3.10.8.

Table 3.10.7: Emission factors for upstream transportation and operating in composting, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste collection and treatment facilities	kg CO_2 eq per tonne	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Waste collection	18.53	18.53	0.00	0.00	0.00
Operating of treatment facilities – landfilling	15.00	15.00	0.00	0.00	0.00

Table 3.10.8: Emission factors for composting, total and biomass-related, total and breakdown by gas (CO_2, CH_4 and N_2O) (kg CO_2 eq per tonne)

Waste treatment	kg CO_2 eq per tonne	Breakdown of GHG emissions by gas (kg CO_2 eq per tonne)			
		CO_2	CH_4 f + CH_4 b	N_2O	CO_2 b
Composting	232.69	33.19*	120.00	79.50	532.04

* *upstream transportation and operating are included*

Wastewater handling

The emission factors for wastewater handling were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

The emission factors for wastewater handling are presented in Table 3.10.9.

Table 3.10.9: Emission factor for wastewater handling (kg CO_2 eq per kg BOD)

Wastewater, methods by m^3 and BOD	
Domestic wastewater	4.020
Industrial wastewater	7.531

3.10.3 Data quality and uncertainty analysis

Solid waste disposal on land (managed and unmanaged)
According to the NIR "the combined uncertainty of CH_4 emissions from unmanaged solid waste disposal and managed solid waste disposal sites for municipal solid waste as % of total emissions are estimated by 1.0% and 0.4%, respectively. The combined uncertainty of CH_4 emissions from unmanaged solid waste disposal and managed solid waste disposal sites for Industrial waste as % of total emissions are estimated by 0.02% and 0.015%, respectively. The uncertainty associated with activity data is 20% according to Good Practice Guidance for poor quality data. On the other hand, the uncertainty associated with emission factors of CH_4 emissions from unmanaged solid waste disposal and managed solid waste disposal sites are 72 % and 40 % respectively. The combined uncertainty of CH_4 emissions from municipal sludge disposal on land as % of total emissions is estimated by 0.1%. The uncertainty associated with activity data is 20% according to Good Practice Guidance for poor quality data while the uncertainty associated with emission factors is 40 %".

Incineration
According to the NIR "the combined uncertainty of CO_2 emissions of waste incineration sector as % of total emissions is estimated by 0.003%. The combined uncertainty of CH_4 emissions of waste incineration sector as % of total emissions is estimated by 0.000003%. The combined uncertainty of N_2O emissions of waste incineration sector as % of total emissions is estimated by 0.001%. The uncertainty associated with activity data is 5%, while the uncertainty associated with emission factors for all gases is 100% according to Good Practice Guidance".

Wastewater handling
According to the NIR "the combined uncertainty of CH_4 emissions of wastewater handling sector as % of total emissions is estimated by 1.0%. The uncertainty associated with activity data is 30% while the uncertainty associated with emission factor is 100% according to Good Practice Guidance. The combined uncertainty of N_2O emissions of wastewater handling sector as % of total emissions is estimated by 0.04%. The uncertainty associated with activity data is 5% while the uncertainty associated with emission factor is 10% according to Good Practice Guidance".

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is between very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1); while in terms of uncertainty, the quality is considered to be poor or very poor (QR: 4 or QR: 5). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2, which corresponds to very good quality or 2.25, which corresponds to good quality.

The overview of the data quality rating for waste is presented in Table 3.10.10.

Table 3.10.10: Data quality rating for waste

Waste	TeR	TiR	GeR	U	DQR
Disposal on land	Good	Very good	Very good	Poor	**Very good**
Incineration	Good	Very good	Very good	Very poor	**Good**
Composting	Good	Very good	Very good	Very poor	**Good**
Wastewater handling	Good	Good	Very good	Poor	**Very good**

3.11 Materials

3.11.1 Technical description

The emission factors calculated for Greece include data on the production of the following:

❖ Cement production

According to the NIR, "Emissions of CO_2 occur during the production of clinker, which is an intermediate component in the cement manufacturing process. CO_2 emissions are attributed to the calcination of limestone (mainly $CaCO_3$), to produce lime (CaO) and carbon dioxide as a by-product".

❖ Lime production

According to the NIR, "Lime production leads to carbon dioxide emissions because of the calcination of limestone ($CaCO_3$) or dolomite ($CaCO_3.MgCO_3$) to produce lime or dolomitic lime. Lime production in Greece is based on limestone. The calculation of carbon dioxide emissions from lime production is based on the collection of plant-specific data on the type(s) and quantity(ies) of carbonate(s) consumed to produce lime, as well as the respective emission factor(s) of the carbonates consumed".

❖ Glass production

According to the NIR, "Glass production leads to carbon dioxide emissions due to the thermal decomposition of carbonate compounds included in raw materials. The estimation of carbon dioxide emissions from glass production is based on accounting for the carbonate input to the glass melting furnace".

❖ Ammonia production

According to the NIR, "Carbon dioxide is emitted as an intermediate product during the production of anhydrous ammonia. Catalytic steam reforming of the fuel used as feedstock (carbon source) takes place during the production process, leading to the release of CO_2 emissions".

❖ Nitric acid production

According to the NIR, "Emissions of nitrous oxide are generated during nitric acid production and specifically from the process of catalytic oxidation of ammonia under high temperature".

❖ Steel production

According to the NIR, "Steel production in Greece is based on the use of electric arc furnaces (EAF). There are no integrated iron and steel plants for primary production as no units for primary production of iron exist, but there are several iron and steel foundries".

❖ Aluminium production

According to the NIR, "Primary aluminium production is responsible for emissions of CO_2 and PFC. Carbon dioxide is produced when, during electrolysis, the carbon of the anode reacts with alumina (Al_2O_3), and also during the anode baking process due to the pitch volatiles combustion and the combustion of baking furnace packing material (coke). Two PFC (CF_4 and C_2F_6) are formed during the phenomenon known as the anode effect, when the aluminium oxide concentration in the reduction cell electrolyte is low".

❖ Lead production

According to the NIR, "According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO_2 emissions from lead production".

❖ Zinc production

According to the NIR, "According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO_2 emissions from zinc production".

In total 9 emission factors on materials were created.

3.11.2 Methodological issues

The emission factors for materials were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

The emission factors for materials are presented in Table 3.11.1.

Table 3.11.1: Emission factors for materials, total (kg CO_2 eq per tonne)

Materials	Total (kg CO_2 eq per tonne)
Building materials	
Cement production	529
Lime production	634
Glass	
Glass production	139
Chemical products	
Ammonia production	1 710
Nitric acid production	1 160
Metals	
Steel production	66
Aluminium production	1 586
Lead production	401
Zinc production	1 720

3.11.3 Data quality and uncertainty analysis

❖ Cement production

According to the NIR, "The uncertainty of the current category's estimations is quite low (2% for emission factors and activity data), since the emissions are plant-specific and the reports of the emissions are being verified by accredited verifiers (all the cement plants of Greece are members of the EU ETS)".

❖ Lime production

According to the NIR, "The uncertainty of the estimate is medium, although data derive from plant-specific, detailed reports of the plants in the context of the EU ETS. A value of 6% has been used for the emission factor, accounting mainly for the uncertainty of lime composition (although data are available for the recent years, for the previous this was not the case). As regards to AD, a value of 5% has been used, provided the fact that the uncertainty of plant-specific weighting materials is at the level of 1-3%, while minor errors may derive from assuming 100% carbonate source from limestone".

❖ Glass production

According to the NIR, "The estimated uncertainty concerning the glass production category is relatively low. The emission factor is stoichiometric, corresponding to a 3%

uncertainty value, while the uncertainty estimate for the AD mainly lays on the uncertainty of the plant-level weighting of the materials and is considered to be 5%".

❖ Ammonia production

According to the NIR, "Although the data are plant-specific, a level of uncertainty originates from the fact that the gaseous inputs are generally more uncertain that the liquid or solids inputs. Therefore the emission factors uncertainty value used has been evaluated at 6%, based on a country-specific estimation. As regards to the activity data, in general the accounted uncertainty is considered quite lower (3%), on the basis that data are plant-specific and have been quality checked by the input of different sources".

❖ Nitric acid production

According to the NIR, "The uncertainty arisen by the currently implemented methodology has been considered equal to 3% for the emission factor and 2% for the production data used. As regards to the activity data accuracy, the uncertainty value accounts mainly from the uncertainty of theproduced nitric acid quantity".

❖ Steel production

According to the NIR, "The uncertainty associated with the CO_2 emission factors is quite low (5%) since all the carbon content is reported by the plants. The same value has been used for the uncertainty of the activity data, accounting mainly for the weighting error in the plant specific reports of the ETS system. As regards to the CH_4 emissions, the uncertainty values are at the same level, in absence of any other data".

❖ Aluminium production

According to the NIR, "The uncertainties regarding the CO_2 emissions relate mainly to the uncertainty of the production activity data provided by the plant, as well as to the uncertainty of the emission factor. Both values are quite low, at 2%, since highly detailed data are provided by the plant concerning both the EF and the quantities inserted in the described equations. As regards to PFCs emissions, the associated uncertainty is, again, not very high (3% for activity data and 6% for emission factors). All the data and emission factors are plant-specific and the methodology takes into account the smelter-specific operating conditions".

❖ Lead production

According to the NIR, "The uncertainty arisen by the currently implemented methodology has been considered equal to 20% for the emission factor and 2% for the production data used. The high value of the emission factor's uncertainty is attributed to the fact that the default emission factor has been used that is prone to be different from the actual value. Concerning the uncertainty of the activity data the above mentioned value accounts mainly from the uncertainty of the produced lead quantity".

❖ Zinc production

According to the NIR, "The uncertainty arisen by the currently implemented methodology has been considered equal to 20% for the emission factor and 2% for the production data used. The high value of the emission factor's uncertainty is attributed to the fact that the default emission factors has been used that is prone to be different from the actual value. As regards to the activity data accuracy, the uncertainty value accounts mainly from the uncertainty of theproduced zinc quantity".

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is between very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1); while in terms of uncertainty, the quality is considered to be good or very good (QR: 2 or QR: 1). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 1.25, or 1.50, which correspond to excellent quality.

The overview of the data quality rating for materials is presented in Table 3.11.2.

Table 3.11.2: Data quality rating for materials

	TeR	TiR	GeR	U	DQR
Cement production	Good	Very good	Very good	Very good	**Excellent**
Lime production	Good	Very good	Very good	Very good	**Excellent**
Glass production	Good	Very good	Very good	Very good	**Excellent**
Ammonia production	Good	Very good	Very good	Very good	**Excellent**
Nitric acid production	Good	Very good	Very good	Very good	**Excellent**
Steel production	Good	Very good	Very good	Very good	**Excellent**
Aluminium production	Good	Very good	Very good	Very good	**Excellent**
Lead production	Good	Very good	Very good	Good	**Excellent**
Zinc production	Good	Very good	Very good	Good	**Excellent**

3.12 Land use, land use change and forestry

3.12.1 Technical description

The emission factors produced for Greece include:

- ❖ Forest land converted to cropland
- ❖ Grassland converted to cropland
- ❖ Forest land converted to settlements

- Grassland converted to settlements
- Cropland converted to forest land
- Forest land converted to grassland
- Cropland converted to grassland
- Forest land converted to wetland
- Grassland converted to wetland

According to the Greek National Inventory Report (2), "the estimation of GHG emissions from Land Use, Land Use Change and Forestry is based on the methodologies and assumptions suggested by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". Data and information presented below were taken from the NIR.

Conversion to cropland

According to the NIR, "Cropland includes all annual and perennial crops as well as temporary fallow land. Changes in biomass, dead organic matter, and soil carbon stocks associated with forest land and grassland conversion to cropland are addressed in this category. For the area of forest lands and grasslands converted to cropland, direct estimates of spatially disaggregated areas converted annually for each initial forest or grassland type were used in the NIR".

Conversion to settlements

According to the NIR, "Settlements include all developed land, including transportation infrastructure and human settlements of any size. Changes in living biomass and soil organic matter associated with forest land and grassland conversion to settlements, as well as carbon stock changes in dead organic matter in forest land converted to settlements are addressed in this category".

Conversion to forest land

According to the NIR, "The definition of forest land used in the inventory is the definition used to report under the Kyoto Protocol: minimum area of 0.3 hectares, tree crown cover larger than 25 per cent, minimum height of 2 metres, or the potential to achieve it".

Conversion to grassland

According to the NIR, "Changes in biomass and soil C stocks associated with forest land and cropland conversion to grassland, as well as changes in dead organic matter in forest land converted to grassland are addressed in this category".

Conversion to flooded lands

According to the NIR, "CO_2 emissions from dead organic matter and soil organic matter associated with forest land and grassland conversion to flooded lands are addressed in this category".

In total 9 emission factors on land use, land use change and forestry were created.

3.12.2 Methodological issues

The emission factors for land use, land use change and forestry were obtained by the Greek National Inventory Report (2). For the calculation of the emission factors, using the NIRs, an average of the last 5 years has been considered according to the methodology presented in Deliverable A2.2, Chapter 5.3.1 EF for Scope 1: National Inventory Report (NIR) (1).

The emission factors for land use, land use change and forestry are presented in Table 3.12.1.

Table 3.12.1: Emission factors for land use, land use change and forestry, total (t CO_2 eq per hectare)

Land use, land use change and forestry	Total emissions (t CO_2 eq per hectare)
Forest land converted to cropland	3.14
Grassland converted to cropland	4.16
Forest land converted to settlements	4.93
Grassland converted to settlements	3.48
Cropland converted to forest land	-3.91
Forest land converted to grassland	5.54
Cropland converted to grassland	-2.06
Forest land converted to wetland	2.06
Grassland converted to wetland	1.40

3.12.3 Data quality and uncertainty analysis

According to the NIR, "The uncertainty estimates for GHG emissions per gas, with LULUCF were estimated at 2.9% for CO_2 emissions. Uncertainties in estimates from this sector are possibly higher than these reported, since uncertainties introduced by assumptions made and categories or pools not estimated have not been considered ".

The quality level and rating for the quality criteria, according to the quality levels and ratings provided in Deliverable A2.2, Chapter 8.2 Data quality assessment, Table 38 is between very good in terms of time representativeness (QR: 1), good in terms of technological representativeness (QR: 2), very good in terms of geographical representativeness (QR: 1); while in terms of uncertainty, the quality is considered to be very poor (QR: 5). Therefore, the overall data quality rating (DQR), in accordance with Deliverable A2.2, Chapter 8.4 Data quality levels, Table 39 is 2.25, which correspond to good quality.

The overview of the data quality rating for land use, land use change and forestry is presented in Table 3.12.2.

Table 3.12.2: Data quality rating for land use, land use change and forestry

Land use, land use change and forestry	**TeR**	**TiR**	**GeR**	**U**	**DQR**
Forest land converted to cropland	Good	Very good	Very good	Very poor	**Good**
Grassland converted to cropland	Good	Very good	Very good	Very poor	**Good**
Forest land converted to settlements	Good	Very good	Very good	Very poor	**Good**
Grassland converted to settlements	Good	Very good	Very good	Very poor	**Good**
Cropland converted to forest land	Good	Very good	Very good	Very poor	**Good**
Forest land converted to grassland	Good	Very good	Very good	Very poor	**Good**
Cropland converted to grassland	Good	Very good	Very good	Very poor	**Good**
Forest land converted to wetland	Good	Very good	Very good	Very poor	**Good**
Grassland converted to wetland	Good	Very good	Very good	Very poor	**Good**

4. Conclusion

The constitution of the Greek Carbon Footprint Database is very important for future activities, such as:

- ❖ Support carbon accounting in compliance with the ISO 14069:2013 and GHG Protocol standards;
- ❖ Support GHG emissions accounting at national level;
- ❖ Provide background data required for Life Cycle Assessment (LCA) studies;
- ❖ Establishment of LCA in support of policy development and implementation as well enterprises' competitiveness.

The Greek Carbon Footprint Database provides data on several sectors and related categories with the classification system represented by the datasets from:

- ❖ Energy
    - o Fossil fuels
    - o Electricity
    - o Thermal energy and steam
- ❖ Transport
    - o Road transport
    - o Rail transport
    - o Air transport
    - o Sea transport/navigation
- ❖ Agriculture (animals)
- ❖ Products and processes, food
- ❖ Waste
- ❖ Materials
- ❖ Land Use, Land Use Change and Forestry (LULUCF)

The proposed methodological guide defined by the document Methodology for constituting the National Databases (prepared during the LIFE Clim'Foot project) has been taken into account to achieve accuracy, completeness, representativeness, methodological appropriateness and consistency, reproducibility and transparency of the Greek Database.

Data quality is needed in order to allow a correct interpretation of the calculated emission factors, as well as the range of the calculation.

Regarding best practices for constituting the national databases, quality control and verification/validation procedures were performed to verify that all required information are presented and entry level requirements are fulfilled.

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