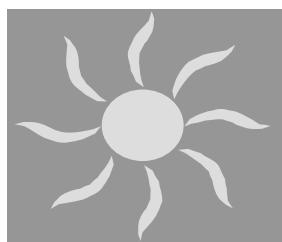




**MINISTRY OF
ENVIRONMENT AND
ENERGY**

CLIMATE CHANGE



EMISSIONS INVENTORY

**ANNUAL INVENTORY SUBMISSION OF
GREECE UNDER THE CONVENTION AND
KYOTO PROTOCOL FOR GREENHOUSE AND
OTHER GASES FOR THE YEARS 1990-2014**

APRIL 2016

**ANNUAL INVENTORY SUBMISSION
UNDER THE CONVENTION AND KYOTO PROTOCOL
FOR GREENHOUSE AND OTHER GASES
FOR YEARS 1990-2014**

According to Decision 13/CP.20 of the Conference of the Parties to the UNFCCC, the CRF Reporter version 5.0.0 was not functioning in order to enable Annex I Parties to submit their CRF tables. In the same Decision, the Conference of the Parties reiterated that Annex I Parties may submit their CRF tables after April 15 2015, but no longer than the corresponding delay in the CRF Reporter availability. Decisions 20/CP.21 and 10/CMP.11 further noted that the CRF reporter was still not functioning.

"Functioning" software means that the data on the greenhouse emissions/removals are reported accurately both in terms of reporting format tables and XML format. The CRF reporter version 5.12.0, released on 27th November 2015, as well as its subsequent hotfixes, still contain issues in the reporting format tables and XML formats, in particular in relation to Kyoto Protocol requirements.

In 2015, Greece made an inventory submission under UNFCCC, but not under Kyoto Protocol because the CRF Reporter could not deliver CRF tables for Kyoto Protocol LULUCF activities without errors. **The present report is the official inventory submission of Greece for the year 2016 under the UNFCCC and for the years 2015 and 2016 under the Kyoto Protocol**, despite certain deficiencies indicated above in CRF Reporter and underlining CRF tables. Greece should not be held liable for errors caused by the CRF Reporter in the review of the submitted information.

The inventory data reported in the 2015 submission under the UNFCCC have been slightly revised in this submission. **Therefore, this submission should be considered as a resubmission of the estimates with regard to the 2015 UNFCCC submission.**

EXECUTIVE SUMMARY

ES.1 Greenhouse gas inventories and climate change

The present report, prepared by Greece contains estimates of GHG emissions for the period 1990-2014. The methodologies applied for the estimation of GHG emissions are discussed and the activity data and emission factors used are presented. This report was prepared by the Ministry of Environment and Energy, with the external consultancy assistance of the National Technical University of Athens (School of Chemical Engineering) and an independent LULUCF expert.

Greenhouse gas emissions inventories

Annual inventories of greenhouse and other gases emissions form an essential element of each national environmental policy-making process. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the progress of existing abatement measures for the reduction of greenhouse gases emissions and the fulfilment of the KP target.

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

The “UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Annex I Parties)” require each Annex I Party, by 15 April each year, to provide its annual GHG inventory covering emissions and removals of direct GHGs (carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃)) from five sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry (LULUCF); and waste), and for all years from the base year (or period) to two years before the inventory is due (e.g. the inventories due 15 April 2016 cover emissions and removals for all years from the base year to 2014).

Institutional arrangements and inventory preparation

In article 5, paragraph 1 of the Protocol, it is specified that "Each Party included in Annex I shall have in place, no later than one year prior to the start of the first commitment period, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol". A national system includes all institutional, legal and procedural arrangements made within an Annex I Party of the Convention that is also a Party to the Protocol for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and for reporting and archiving inventory information.

The Ministry of Environment and Energy, MEEN is the governmental body responsible for the development and implementation of environmental policy in Greece, as well as for the provision of information concerning the state of the environment in Greece in compliance with relevant requirements defined in international conventions, protocols and agreements. Moreover, the MEEN is responsible for the co-ordination of all involved ministries, as well as any relevant public or private organization, in relation to the implementation of the provisions of the Kyoto Protocol, according to the Law 3017/2002 with which Greece ratified the Kyoto Protocol.

In this context, the MEEN has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Kyriakos Psychas, Address: Patission 147, Athens, Greece, e-mail: k.psychas@prv.ypeka.gr, tel.: +30210 8665938).

The entities participating in National Inventory System are:

- ✓ The MEEN designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays an active role in the inventory planning, preparation and management.
- ✓ The National Technical University of Athens (NTUA) / School of Chemical Engineering, which has the technical and scientific responsibility for the compilation of the annual inventory for all sectors except LULUCF sector. The inventory of LULUCF sector has been assigned, on a contract basis, to an independent consultant by MEEN.
- ✓ Governmental ministries and agencies through their appointed focal persons, ensure the data provision.

International or national associations, along with individual public or private industrial companies contribute to data providing and development of methodological issues as appropriate.

The compilation of the inventory is completed in three main stages:

Stage 1: The first stage consists of data collection and check for all source/sink categories. The main data sources used are the Hellenic Statistical Authority, the national energy balance, the government ministries/agencies involved and large private enterprises, along with the verified reports from installations under the EU ETS.

Quality control of activity data include the comparison of the same or similar data from alternative data sources (e.g. Hellenic Statistical Authority and ETS reports) as well as time-series assessment in order to identify changes that cannot be explained. In cases where problems and/or inconsistencies are identified, the agency's representative, responsible for data providing, is called to explain the inconsistency and/or help solving the problem.

Stage 2: Once the reliability of input data is checked and certified, emissions/removals per source/sink category are estimated. Emissions estimates are then transformed to the format required by the CRF Reporter. This stage also includes the evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the 2006 IPCC Guidelines.

Quality control checks, when at this stage, are related to time-series assessment as well as to the identification and correction of any errors / gaps while estimating emissions / removals and filling in the CRF Reporter.

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within technical consultants) check. The official approval procedure follows for one month period of interactions between the Inventory Team (NTUA) and the Climate Team (MEEN), starting on the 1st of February of the year of submission. During this period, the Inventory Team (NTUA and LULUCF consultant) has to revise the report according to the observations and recommendations of the Climate Team. On the basis of this interaction process, the final version of the report is compiled. The General Director for

the Environment of MEEN, who supervises the National System, approves the inventory and then the MEEN submits the NIR to the European Commission and to the UNFCCC Secretariat.

The information that is related to the annual GHG emissions inventory is kept at the Centralized Inventory File.

ES.2 Emissions trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO₂, CH₄, N₂O, HFC, PFC and SF₆) for the period 1990 - 2014 are presented in *Table ES.1* (in kt CO₂ eq).

It is noted that according to the 2006 IPCC Guidelines, emissions estimates for international marine and aviation bunkers were not included in the national totals, however they are reported separately as memo items.

Base year GHG emissions for Greece (1990 for CO₂, CH₄, and N₂O - 1995 for F-gases) were estimated at 107.7 Mt CO₂ eq. Given that *LULUCF* was a net sink of GHG emissions in 1990 (and for the rest of the reporting period) the relevant emissions / removals are not considered in estimating base year emissions for Greece.

In 2014, GHG emissions (without *LULUCF*) amounted to 101.4 Mt CO₂ eq showing a decrease of 5.82% compared to base year emissions and of 3.27% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the decrease would be 4.27 % (from 102.55 Mt CO₂ eq in 1990 to 98.17 Mt CO₂ eq in 2014).

Carbon dioxide emissions accounted for 78.53% of total GHG emissions in 2014 (without *LULUCF*) and decreased by approximately 4.53% from 1990. Methane emissions accounted for 11.04% of total GHG emissions in 2014 and decreased by 11.49% from 1990, while nitrous oxide emissions accounted for 4.62% of the total GHG emissions in 2014 and decreased by 36.70% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 5.68% of total GHG emissions in 2014 were increased by 39.63% from 1995 (base year for F-gases).

Table ES.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2002*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
A. GHG emissions per gas (excluding LULUCF)													
CO ₂	83,403.72	83,390.35	84,949.03	84,263.01	86,425.86	86,980.65	89,134.43	93,839.87	98,663.19	97,979.78	103,019.66	105,407.31	105,051.47
CH ₄	12,644.74	12,624.31	12,709.99	12,700.94	12,823.74	12,944.66	13,099.87	12,976.79	13,194.14	13,165.01	12,934.08	11,881.96	11,872.45
N ₂ O	7,402.64	7,269.55	7,129.88	6,564.38	6,480.19	6,669.81	6,846.91	6,686.39	6,621.56	6,604.32	6,346.05	6,207.73	6,172.36
HFC	1,182.82	1,400.08	1,149.07	2,032.44	2,712.11	4,157.38	4,820.17	5,166.49	5,767.51	6,721.15	5,261.83	4,781.39	5,090.07
PFC	190.26	191.19	187.74	112.94	70.31	62.85	53.73	125.64	155.48	105.31	122.26	84.10	88.29
SF ₆	2.93	3.02	3.11	3.20	3.29	3.42	3.51	3.56	3.60	3.69	3.81	3.88	4.06
Total	104,827.11	104,878.50	106,128.82	105,676.90	108,515.50	110,818.77	113,958.62	118,798.72	124,405.49	124,579.27	127,687.69	128,366.36	128,278.69
B. GHG emissions/removals from LULUCF													
CO ₂	-2,346.12	-2,510.94	-2,556.15	-2,940.54	-2,682.27	-2,941.80	-2,640.29	-1,833.77	-1,986.24	-2,637.76	-2,107.42	-2,377.62	-2,881.78
CH ₄	62.23	30.95	91.44	81.62	76.10	43.13	26.09	57.32	156.06	11.89	205.70	27.70	3.78
N ₂ O	5.10	2.54	7.50	6.69	6.24	3.54	2.15	4.71	12.80	0.98	16.87	2.28	0.32
Total	-2,278.78	-2,477.46	-2,457.21	-2,852.22	-2,599.92	-2,895.13	-2,612.06	-1,771.74	-1,817.38	-2,624.89	-1,884.85	-2,347.64	-2,877.68
C. GHG Emissions from International Transport													
CO ₂	10,479.79	9,480.49	10,665.72	12,221.26	13,272.17	13,883.18	12,418.33	12,364.54	13,642.22	12,710.50	13,890.86	13,387.52	12,225.58
CH ₄	16.79	15.28	17.35	20.37	21.52	22.79	20.30	20.40	23.06	20.45	23.78	23.45	21.00
N ₂ O	259.88	252.98	311.33	344.47	381.81	442.84	366.17	363.89	369.45	344.99	368.54	316.98	286.43
Total	10,756.46	9,748.75	10,994.41	12,586.10	13,675.51	14,348.81	12,804.79	12,748.83	14,034.74	13,075.94	14,283.18	13,727.95	12,533.01

Table ES.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2003-2014*

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
A. GHG emissions per gas (excluding LULUCF)												
CO ₂	109,126.57	109,571.06	113,219.82	111,777.74	114,127.55	110,255.77	103,969.8	97,035.08	94,102.94	90,710.57	82,910.63	79,628.27
CH ₄	11,768.35	11,754.69	11,758.80	11,851.05	11,653.11	11,606.06	11,449.02	11,647.41	11,484.39	11,354.56	11,260.27	11,191.26
N ₂ O	6,050.25	6,054.53	5,882.95	5,730.83	5,825.36	5,610.97	5,325.96	5,526.83	5,317.62	4,912.06	4,670.44	4,686.09
HFC	4,733.36	4,927.91	5,077.45	2,722.45	3,245.14	3,710.35	3,964.12	4,388.67	4,661.66	5,061.78	5,650.22	5,758.13
PFC	89.28	87.86	91.51	87.21	103.04	118.95	91.35	129.44	110.53	147.77	172.56	134.63
SF ₆	4.06	4.26	6.16	7.98	9.46	7.18	5.02	5.86	5.13	5.05	5.15	4.92
Total	131,771.86	132,400.31	136,036.69	132,177.27	134,963.67	131,309.28	124,805.3	118,733.29	115,682.27	112,191.78	104,669.27	101,403.31
B. GHG emissions/removals from LULUCF												
CO ₂	-2,588.73	-2,808.08	-3,078.07	-3,219.66	-1,818.25	-3,175.96	-3,289.33	-3,278.29	-3,321.17	-3,293.86	-3,165.77	-3,246.86
CH ₄	5.31	13.48	8.80	20.71	318.14	43.09	45.69	16.23	17.74	43.46	15.99	9.39
N ₂ O	0.45	1.12	0.74	1.71	26.09	3.55	3.76	1.35	1.48	3.58	1.33	0.80
Total	-2,582.97	-2,793.47	-3,068.53	-3,197.24	-1,474.02	-3,129.32	-3,239.88	-3,260.71	-3,301.96	-3,246.83	-3,148.45	-3,236.67
C. GHG Emissions from International Transport												
CO ₂	13,173.30	13,340.43	11,511.49	12,712.18	12,969.70	12,872.75	10,961.76	10,796.79	11,144.45	9,854.93	9,568.31	8,878.27
CH ₄	21.74	22.02	19.77	21.39	21.96	21.55	18.24	18.89	19.41	15.93	15.08	13.20
N ₂ O	277.10	269.94	224.41	239.28	230.03	220.57	197.93	204.67	194.63	171.44	172.64	168.11
Total	13,472.14	13,632.39	11,755.67	12,972.85	13,221.69	13,114.87	11,177.93	11,020.35	11,358.48	10,042.30	9,756.03	9,059.59

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2014 are presented in *Table ES.2*.

Emissions from *Energy* in 2014 accounted for 77.90% of total GHG emissions (without LULUCF) and decreased by approximately 2.22% compared to 1990 levels.

The living standards improvement, due to the economic growth, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from Energy for the period 1990 – 2007. For the period 2008 - 2014, the emissions have a decreasing trend.

The living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO₂ emissions per electricity produced have decreased mainly as a result of the introduction of the natural gas and RES into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 was not followed by a similar increase of emissions because of the penetration of natural gas and the high availability of hydropower.

The decreasing trend of emissions of energy of the years 2008-2014 is attributed mainly to the economic recession that the country is facing, but also to the effect of mitigation actions (i.e. RES, energy efficiency measures, road infrastructure and public transportation improvements, etc).

The majority of GHG emissions (61.1%) in 2014 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 23.4%, 7.3% and 6.6% respectively. The rest 1.6% of total GHG emissions from Energy derived from fugitive emissions from fuels. Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an increase of 21.0%, followed by energy industries with a 6.2% increase compared to 1990, respectively. Emissions from manufacturing industries and construction emissions and other sectors (i.e. residential, tertiary and agriculture sectors) had decreased by around 41.8% and 41.3%, respectively, compared to 1990. The decrease in the other sectors is noticeable during the recent years. Finally, fugitive emissions from fuels decreased by 0.8% for the period 1990 – 2014.

Emissions from *Industrial Processes and Product use* in 2014 accounted for 9.93% of the total emissions (excluding LULUCF) and increased by 10.17% compared to 1990 levels. In 2014 mineral products production has continued the decreasing trend of the previous years, following the decrease of all the subcategories of the sector, mainly due to the effects of the economic recession. There is an increase in emissions since 2011 (44.59%), which followed the intense decrease of 2011. Emissions from chemical industry have decreased by 79.66% since 1990. Emissions from metal industry slightly increased with regards to 2011 by 1.76%, due to the increased production of aluminium and nickel.

Emissions from *Agriculture* that accounted for 7.75% of total emissions in 2014 (without *LULUCF*), decreased by approximately 14.16% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N₂O emissions from agricultural soils, because of the reduction in the use of synthetic nitrogen fertilizers. The decrease in the use of synthetic nitrogen fertilizers is attributed to the increase of organic farming, the high price of fertilizers and the impact of initiatives to promote good practice in fertilizer use. The changes of the rest determining parameters of GHG emissions from the sector (e.g. animal population, crops production etc.) have a minor effect on GHG emissions trend.

Emissions from the *Waste* Sector (4.42% of the total emissions, without *LULUCF*), decreased by approximately 21.77% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions. However, the increase of recycling along with the exploitation of the biogas produced limits the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2014. The sink capacity of the LULUCF sector fluctuates between 1.47 Mt CO₂ eq. and 3.30 Mt CO₂ eq., showing an increasing trend. This is the result of the decrease of the sink capacity of the Cropland category on the one hand, and the increase of the sink capacity of the Forest Land category on the other.

Table ES.2a *Total GHG emissions (in kt CO₂ eq) by sector for the period 1990-2002*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Energy	76,914.70	77,063.80	79,075.96	78,713.57	80,938.49	81,003.18	83,221.30	87,755.24	92,483.28	91,945.60	96,742.40	99,182.55	99,008.53
IPPU	11,226.96	11,163.40	10,577.36	11,028.32	11,636.59	13,569.65	14,338.11	14,835.60	15,552.78	16,389.35	15,176.38	14,575.50	14,768.63
Agriculture	10,185.94	10,209.49	9,943.55	9,387.34	9,231.21	9,565.43	9,632.26	9,548.06	9,532.25	9,528.41	9,229.33	9,132.64	9,155.18
Waste	6,499.52	6,441.81	6,531.95	6,547.67	6,709.21	6,680.50	6,766.95	6,659.83	6,837.18	6,715.90	6,539.59	5,475.67	5,346.35
Total ¹⁾	104,827.11	104,878.50	106,128.82	105,676.90	108,515.50	110,818.77	113,958.62	118,798.72	124,405.49	124,579.27	127,687.69	128,366.36	128,278.69
LULUCF	-2,278.78	-2,477.46	-2,457.21	-2,852.22	-2,599.92	-2,895.13	-2,612.06	-1,771.74	-1,817.38	-2,624.89	-1,884.85	-2,347.64	-2,877.68
Index per sector													
Energy	100.00	100.19	102.81	102.34	105.23	105.32	108.20	114.09	120.24	119.54	125.78	128.95	128.73
IPPU	100.00	99.43	94.21	98.23	103.65	120.87	127.71	132.14	138.53	145.98	135.18	129.83	131.55
Agriculture	100.00	100.23	97.62	92.16	90.63	93.91	94.56	93.74	93.58	93.54	90.61	89.66	89.88
Waste	100.00	99.11	100.50	100.74	103.23	102.78	104.11	102.47	105.20	103.33	100.62	84.25	82.26
Total ²⁾	100.00	100.05	101.24	100.81	103.52	105.72	108.71	113.33	118.68	118.84	121.81	122.46	122.37

¹⁾ Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

²⁾ *Land Use, Land Use Change and Forestry* is not included

Table ES.2b *Total GHG emissions (in kt CO₂ eq) by sector for the period 2003-2014*

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Energy	102,896.09	103,389.50	106,442.89	105,180.57	107,634.15	104,382.40	99,928.86	92,765.39	91,467.72	87,394.22	78,867.41	75,206.62
IPPU	14,532.25	14,673.33	15,425.62	12,739.51	13,173.76	12,987.40	11,185.04	11,661.84	10,320.16	11,140.31	11,974.28	12,368.83
Agriculture	8,940.86	8,981.46	8,769.53	8,692.46	8,812.99	8,607.75	8,659.70	8,945.17	8,738.11	8,695.63	8,785.14	8,743.10
Waste	5,402.65	5,356.02	5,398.65	5,564.75	5,342.77	5,331.73	5,031.65	5,360.89	5,156.27	4,961.62	5,042.45	5,084.76
Total ¹⁾	131,771.86	132,400.31	136,036.69	132,177.27	134,963.67	131,309.28	124,805.25	118,733.29	115,682.27	112,191.78	104,669.27	101,403.31
LULUCF	-2,582.97	-2,793.47	-3,068.53	-3,197.24	-1,474.02	-3,129.32	-3,239.88	-3,260.71	-3,301.96	-3,246.83	-3,148.45	-3,236.67
Index per sector												
Energy	133.78	134.42	138.39	136.75	139.94	135.71	129.92	120.61	118.92	113.62	102.54	97.78
IPPU	129.44	130.70	137.40	113.47	117.34	115.68	99.63	103.87	91.92	99.23	106.66	110.17
Agriculture	87.78	88.18	86.09	85.34	86.52	84.51	85.02	87.82	85.79	85.37	86.25	85.84
Waste	83.12	82.41	83.06	85.62	82.20	82.03	77.42	82.48	79.33	76.34	77.58	78.23
Total ²⁾	125.70	126.30	129.77	126.09	128.75	125.26	119.06	113.27	110.36	107.03	99.85	96.73

¹⁾ Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

²⁾ *Land Use, Land Use Change and Forestry* is not included

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PART I: ANNUAL INVENTORY SUBMISSION

1. Introduction

1.1 *Background information on greenhouse gas inventories, climate change*

The impact of all human activities on the climate of earth has been recognized as the greatest global environmental challenge involving the whole international community. The mitigation of the effects of this problem requires responses from governments, economic sectors and all societal actors working together.

Naturally occurring greenhouse gases (GHG) include water vapour, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and ozone (O₃). In the last few years, a new category of greenhouse gases has emerged that includes hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF₆). These gases are man-made and are mainly used in a number of industrial activities in replacement of CFCs. Other naturally occurring gases, which do not contribute directly to the greenhouse effect, are carbon monoxide (CO), oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO₂).

1.1.1 Background information on climate change

United Nations Framework Convention on Climate Change

In response to the emerging evidence that climate change could have a major global impact, the United Nations Framework Convention on Climate Change (henceforth the Convention) was adopted on 9 May 1992 and was opened for signature in Rio de Janeiro in June 1992. Greece signed the Convention in Rio and ratified it in 1994 (Law 2205/94).

The ultimate objective of the Convention is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Convention recognizes that the developed countries should take the lead in combating climate change and calls these countries to:

- ↳ Adopt policies and measures to mitigate climate change.
- ↳ Return, individually or jointly, to 1990 levels of carbon dioxide and other greenhouse gas by the year 2000
- ↳ Provide technology transfer and financial resources to help developing countries so as to confront climate change impacts and to develop, ensuring at the same time the environmental protection through the restraint of GHG emissions.

Kyoto Protocol

Recognizing early the need for an effective instrument to provide confidence in addressing the climate change challenge, the Parties at the third meeting of the Conference of the Parties (COP) to the Convention, held in Kyoto (1-11 December 1997), finalised negotiations related to the establishment of such a legal instrument, the Kyoto Protocol on Climate Change (henceforth the Protocol). The Protocol provides a foundation upon which future action can be intensified. It establishes, for the first time, legally binding targets for the reduction of greenhouse gas emissions and it also confirms the capacity of the international community to cooperate in action to deal with a major global environmental problem.

The Protocol calls for legally binding commitments of the developed countries to reduce, individually or jointly, emissions of 6 greenhouse gases (CO₂, CH₄, N₂O, HFC, PFC and SF₆) by more than 5% in the period 2008 to 2012, below their 1990 level. The EU and its Member States agreed to a -8% reduction.

For the achievement of these targets, the Protocol provides for the use of the following:

- ✎ Adoption of national policies and measures,
- ✎ Establishment of an emissions trading regime,
- ✎ Establishment of the joint implementation mechanism,
- ✎ Establishment of a clean development mechanism and
- ✎ Protection and promotion of sinks to enhance CO₂ removals.

Detailed rules for the implementation of the Protocol were set out at the 7th Conference of the Parties (in Marrakesh) and are described in the Marrakesh Accords adopted in 2001.

The Protocol entered into force on 16 February 2005, after its ratification from 141 Parties including developed countries with a contribution of more than 55% to global CO₂ emissions in 1990.

At the first Conference of the Parties serving as the Meeting of the Parties to the Protocol (COP/CMP) held in Canada (December 2005) the rules for the implementation of the Protocol agreed at COP7 were adopted.

The same COP/CMP established a working group, called the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP), to discuss future commitments for industrialized countries under the Kyoto Protocol.

The Conference of the Parties (COP) in 2007, by its decision 1/CP.13 (the Bali Action Plan) launched a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, to be conducted

under a subsidiary body under the Convention, the Ad Hoc Working Group on Long-Term Cooperative Action under the Convention (AWG-LCA).

In Doha, Qatar, on 8 December 2012, the "Doha Amendment to the Kyoto Protocol" was adopted. The amendment includes:

- ✓ New commitments for Annex I Parties to the Kyoto Protocol who agreed to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020;
- ✓ A revised list of greenhouse gases (GHG) to be reported on by Parties in the second commitment period; and
- ✓ Amendments to several articles of the Kyoto Protocol which specifically referenced issues pertaining to the first commitment period and which needed to be updated for the second commitment period.

During the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the composition of Parties in the second commitment period is different from the first. The EU and its Member States agreed to a -20% reduction.

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1.1.2 Background information on greenhouse gas inventories

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent and reduce dangerous human-induced interference with the climate system. The ability of the international community to achieve this objective is dependent on an accurate knowledge of GHG emissions trends, and on our collective ability to alter these trends.

In accordance with Articles 4 and 12 of the Convention and the relevant decisions of the Conference of the Parties (COP), Annex I Parties to the Convention submit to the secretariat national greenhouse gas inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. These inventories are subject to an annual technical review process. In addition, Annex I Parties provide inventory data in summary form in their national communications and biennial reports under the Convention.

Annual inventories of greenhouse and other gases emissions form an essential element of each national environmental policy-making process. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the

progress of existing abatement measures for the reduction of greenhouse gases emissions and the fulfilment of the KP target.

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

The “UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Annex I Parties)” require each Annex I Party, by 15 April each year, to provide its annual GHG inventory covering emissions and removals of direct GHGs (carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃)) from five sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry (LULUCF); and waste), and for all years from the base year (or period) to two years before the inventory is due (e.g. the inventories due 15 April 2016 cover emissions and removals for all years from the base year to 2014).

Under the UNFCCC reporting guidelines on annual inventories for Annex I Parties, inventory submissions are in two parts:

1. Common reporting format (CRF) tables – a series of standardized data tables containing mainly quantitative information;
2. National Inventory Report (NIR) – a report containing transparent and detailed information on the inventory. It should include descriptions of the methodologies used in the estimations (including references and sources of information), the data sources, the institutional arrangements for the preparation of the inventory (including quality assurance and control procedures), and recalculations and changes compared with the previous inventory.

Good annual inventories should include transparent documentation and data to enable the reader to understand the underlying assumptions and calculations of the reported emission estimates. Annex I Parties should implement and maintain national inventory arrangements for the estimation of anthropogenic GHG emissions by sources and removals by sinks. The national inventory arrangements include all institutional, legal and procedural arrangements made within an Annex I Party for estimating emissions and removals of GHGs, and for reporting and archiving inventory information.

Annex I Parties that are Parties to the Kyoto Protocol are also required to report supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol, with the inventory submission due under the Convention, in accordance with paragraph 3(a) of decision 15/CMP.1.

In decision 24/CP.19 the COP requested that Annex I Parties should use the updated CRF Reporter software (developed by the secretariat) for the submission of their annual greenhouse gas inventories. Moreover, the UNFCCC reporting guidelines on annual inventories for Annex I Parties (decision 24/CP.19) require that Annex I Parties should use of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Greece, as an Annex I signatory Party to the Convention, has to comply with the above-mentioned reporting requirements. Parallel commitments also exist under the European Union Regulation No 525/2013 and its implementing acts, concerning a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change.

1.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Greece, as an Annex I Party that is also Party to the Kyoto Protocol is also required to report supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol, with the inventory submission due under the Convention, in accordance with paragraph 3(a) of decision 15/CMP.1. Part II of this report (Chapters 9-13) provides information on activities under Article 3, paragraph 3 (Afforestation, Reforestation, Deforestation) and the elected activity under Article 3, paragraph 4 (Forest Management), on accounting of Kyoto units, on changes in the national system and the national registry and information on the minimization of adverse impacts of climate change in accordance with Articles 3.14.

1.1.4 Structure of the report

The present NIR consists of 13 chapters and 5 annexes. **Chapter 1** contains (a) a presentation of the institutional, legal and procedural arrangements for inventory planning and preparation, (b) a brief description of basic methodological issues and (c) an overview of the completeness of the inventory.

Indirect CO₂ from the atmospheric oxidation of CH₄, CO and NMVOCs and indirect N₂O emissions from other than the agriculture and LULUCF sources have not been estimated and included in the inventory. Therefore, no Chapter related to “Indirect CO₂ and nitrous oxide emissions was included in the NIR.

Emissions trends (including other gases) per gas and per sector for the period 1990 – 2014 are discussed in **Chapter 2**, while comprehensive information regarding methodologies used for the estimation of GHG emissions per source category are presented in **Chapters 3 – 7**. In **Chapter 8** an overview of the recalculations made since the 2015 submission and the future improvements

planned is presented. The **Chapters 9-13** of part II of this report contain supplementary information required under article 7, paragraph 1. **Chapter 9** provides information on activities under Article 3, paragraph 3 (Afforestation, Reforestation, Deforestation) and the elected activity under Article 3, paragraph 4 (Forest Management), and **Chapters 10-13** provide information on accounting of Kyoto units, changes in national system, changes in national registry, minimization of adverse impacts in accordance with Article 3, paragraph 14, respectively.

As concerns the annexes, in **Annex I** the methodology for the determination of key categories is described, while in **Annexes II** and **III** the methodology for the estimate of carbon dioxide emissions from the energy sector is discussed (sectoral and reference approach respectively). The calculations made for the assessment of uncertainty are presented in **Annex IV**.

1.2 A description of the institutional arrangements for inventory preparation, including the legal and procedural arrangements for inventory planning, preparation and management

1.2.1 Overview of institutional, legal and procedural arrangements for compiling GHG inventory and supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

In article 5, paragraph 1 of the Protocol, it is specified that "Each Party included in Annex I shall have in place, no later than one year prior to the start of the first commitment period, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol". A national system includes all institutional, legal and procedural arrangements made within an Annex I Party of the Convention that is also a Party to the Protocol for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and for reporting and archiving inventory information.

The **Ministry of Environment and Energy, MEEN** is the governmental body responsible for the development and implementation of environmental policy in Greece, as well as for the provision of information concerning the state of the environment in Greece in compliance with relevant requirements defined in international conventions, protocols and agreements. Moreover, the MEEN is responsible for the co-ordination of all involved ministries, as well as any relevant public or private organization, in relation to the implementation of the provisions of the Kyoto Protocol, according to the Law 3017/2002 with which Greece ratified the Kyoto Protocol.

In this context, the MEEN has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Kyriakos Psychas, Address: Patission 147, Athens, Greece, e-mail: k.psychas@prv.ypeka.gr, tel.: +30210 8665938).

Figure 1.1 provides an overview of the organizational structure of the National Inventory System. The entities participating in it are:

- The **MEEN** designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays an active role in the inventory planning, preparation and management.
- The **National Technical University of Athens (NTUA) / School of Chemical Engineering**, which has the technical and scientific responsibility for the compilation of the annual inventory for all sectors except LULUCF sector. The inventory of LULUCF sector has been assigned, on a contract basis, to an independent consultant by MEEN.
- **Governmental ministries and agencies** through their appointed focal persons, ensure the data provision.

International or national associations, along with individual public or private industrial companies contribute to data providing and development of methodological issues as appropriate.

The legal framework defining the roles-responsibilities and the co-operation between the MEEN Climate team, the Inventory team and the designated contact points of the competent Ministries was formalized by circular 918/21-4-08 released by MEEN entitled “Structure and operation of the National Greenhouse Gases Inventory System- Roles and Responsibilities”. The above-mentioned circular includes a description of each entity’s responsibilities, concerning the inventory preparation, data providing or other relative information. This formal framework has improved the collaboration between the entities involved, assuring the timely collection and quality of the activity data required and solving data access restriction problems raised due to confidentiality issues.

According to the Presidential Decree No 189 dated 5th November 2009 the Ministry of Environment and, Energy and Climate Change retained the responsibilities regarding the Environment, and Physical Planning of the former Ministry for the Environment, Physical Planning and Public Works. Furthermore, the General Directorate of Energy and Natural Resources, previously belonging to the Ministry of Development as well as the General Directorate of Forest Development and Protection and Natural Resources, previously belonging to the Ministry of Rural Development and Food, were transferred to the Ministry of Environment, Energy and Climate Change. In 2015 the Ministry of Environment, Energy and Climate Change (the name of which for a short period was Ministry of Environment, Energy and Production Reconstruction) was named Ministry of Environment & Energy (MEEN).

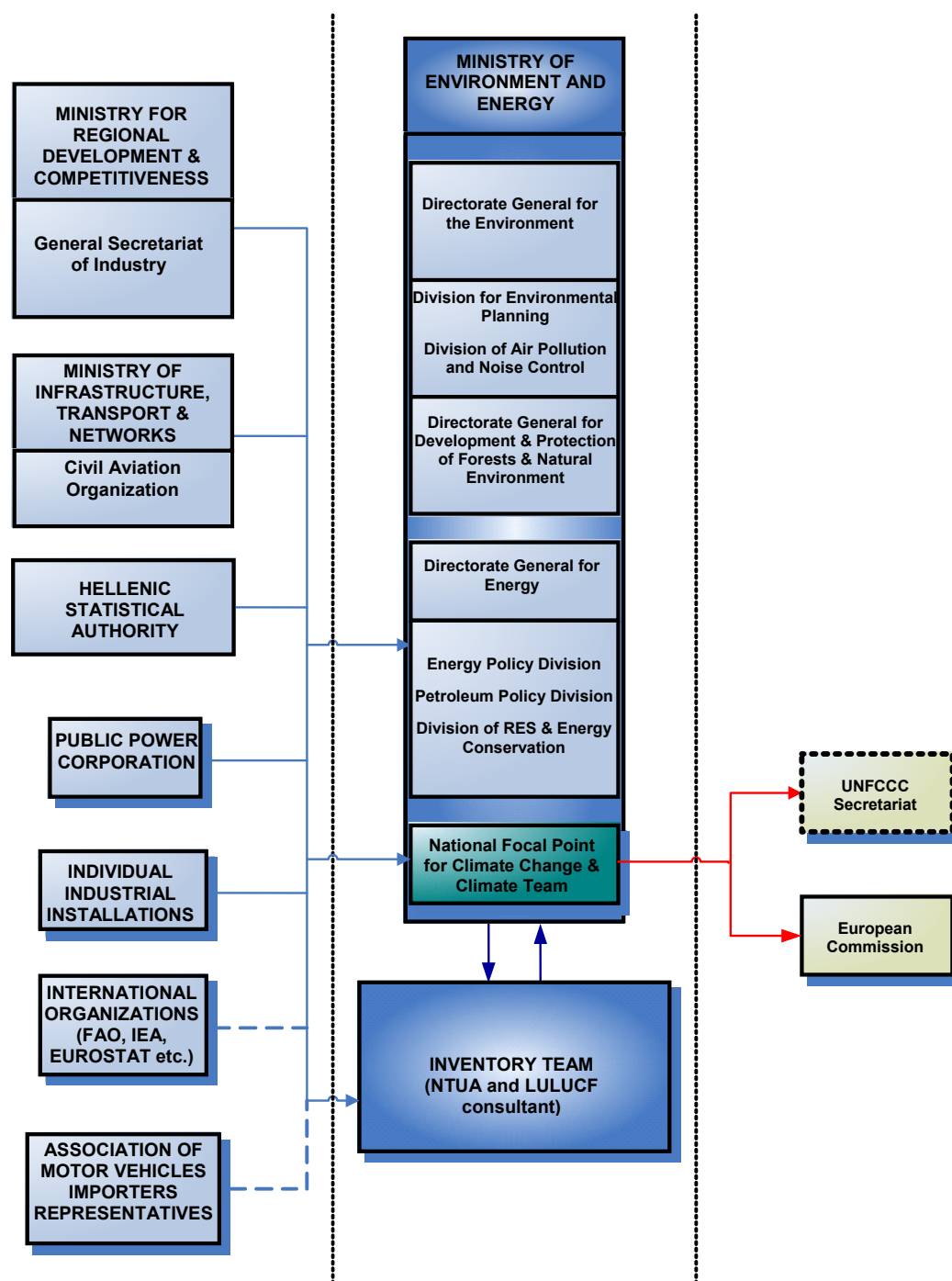


Figure 1.1 *Organizational Structure of the National Inventory System*

1.2.2 Roles and Responsibilities

1.2.2.1 Ministry of Environment and Energy

The Ministry of Environment and Energy, MEEN, has the overall responsibility, as the national entity, for the national GHG inventory. Among its responsibilities are the following:

- The co-ordination of all ministries and governmental agencies involved, as well as any relevant public or private organization. In this context, it oversees the operation of the National System and decides on the necessary arrangements to ensure compliance with relevant decisions of the COP and the COP/CMP.
- The official consideration and approval of the inventory prior to its submission.
- The response to any issues raised by the inventory review process under Article 8 of the Kyoto Protocol, in co-operation with the technical consultants (NTUA and LULUCF consultant), who have the technical and scientific responsibility for the inventory planning, preparation and management of the inventory, as mentioned above.
- The timely submission of the GHG inventory to the European Commission and to the UNFCCC Secretariat.
- The keeping of the Centralised Inventory File, which is delivered to the inventory team which has the technical responsibility for the inventory planning, preparation and management (currently NTUA and LULUCF consultant) at the beginning of each inventory cycle. The Centralised Inventory File is kept at the premises of the MEEN.
- The administration of the National Registry. Greece cooperates with the Member States of the European Union and with the supplementary transaction log and the registry of the European Community by maintaining the national registries in a consolidated system. The administration of the registry is assigned to the National Center for the Environment and Sustainable Development, which reports to the Ministry of Environment, Energy and Climate Change and operates under the authority of the latter.
- The supervision of Quality Assurance/Quality Control Plan (QA/QC)

As it appears from the above description, the role of the MEEN is not narrowed to the co-ordination of the entities involved in the inventory process and to facilitate the activity data transfer from the data providers to the Inventory Team (NTUA and LULUCF consultant). MEEN has an active role in monitoring and overseeing the inventory process through continuous communication and frequent scheduled and / or ad-hoc meetings with the Inventory Team (NTUA and LULUCF consultant) and the competent ministries or other agencies involved.

1.2.2.2 National Technical University of Athens (NTUA) School of Chemical Engineering and LULUCF consultant

The Ministry of Environment and Energy has assigned, on a contract basis, the National Technical University of Athens (NTUA) / School of Chemical Engineering as the national institution that has the technical and scientific responsibility for the planning, preparation and management of the annual national inventory for all sectors except LULUCF. With regard to the LULUCF sector the respective responsibilities have been assigned by the MEEN, to an independent consultant, on a contract basis. In this framework, NTUA and LULUCF consultant have the following responsibilities / tasks to fulfil for the GHG inventory preparation:

1. Data collection (activity data and emission factors) for all source categories that are Energy, Industrial Processes, Solvents and Other Product Use, Agriculture, Waste and LULUCF).
2. Reliability check of input data through
 - ✓ the comparison of the same or similar data from alternative data sources and
 - ✓ time-series assessment in order to identify changes that cannot be explained.
3. Selection of the appropriate methodologies according to the 2006 IPCC guidelines, preparation of GHG emissions estimates by applying the methodologies and models having been selected.
4. Data processing and archiving.
5. Assessment of the consistency of the methodologies applied, inventory improvement – recalculations.
6. Reliability check of results.
7. Key categories analysis.
8. Uncertainty assessment.
9. Preparation of Common Reporting Format (CRF) tables.
10. Preparation of National Inventory Report (NIR).
11. Reporting of the required information according to Regulation 525/2013 of the European Parliament and of the Council and its implementing acts.
12. Preparation and keeping of annual Centralised Inventory File. At the end of each cycle of the inventory preparation, all inventory related information is handled to the MEEN's employee responsible for keeping the Centralised Inventory File (member of the Climate Team), who in turn gives the latest version of all relevant files to the NTUA and LULUCF consultant at the beginning of the next inventory cycle.
13. Development of QA/QC procedures.
14. Implementing the QA/QC procedures under the supervision of MEEN.
15. Training the representatives of data providing agencies on inventory issues.

The NTUA and LULUCF consultant co-operates with a number of government agencies and other entities for the preparation of the inventory (see next section). It should be mentioned that this co-operation is not restricted to data collection but it also concerns methodological issues as appropriate. However, the technical consultants (NTUA and LULUCF consultant) are responsible for the final decision concerning methodological issues.

The names and contact details of the NTUA inventory team follows:

1. Prof. Ioannis Ziomas, Scientific responsible
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Heron Polytechniou 9, Zografos, 157 80 Athens, Greece.
E-mail: ziomas@chemeng.ntua.gr
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FAX: +30 210 772 3155
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7. Konstantina maggouta

Physicist, MSc
E-mail: kon_maggouta@yahoo.gr
Tel: +30 210 772 3149
FAX: +30 210 772 3155

It should be mentioned that, whenever necessary, the above mentioned NTUA's Inventory Team is ad hoc supported by experts either from the NTUA or other institutions.

With regard to the LULUCF consultant, the name and contact details are the following:

1. Iordanis Tzamtzis
Forester, MSc
E-mail: i.tzamtzis@accel.gr
Tel: +30 210 7242305
FAX: +30 210 7242305

1.2.2.3 Government Ministries/ Government agencies

The following government agencies and ministries, develop and maintain, within their terms of operation, data sets and emission methodology information necessary for the estimation of GHG emissions / removals. Most of these institutes have been used as sources of data since the first submission of greek GHG national inventory. However, new sources of information are being sought both for further inventory development and improvement (higher Tier methodology usage) and quality control issues.

The co-operation with the following government agencies and other entities for the preparation of the inventory is indispensable, as those agencies and entities develop and maintain statistical data necessary for the estimation of GHG emissions / removals.

Each of the following ministries/agencies, has appointed focal persons responsible for data provision, included in the above mentioned circular:

- The Ministry of Environment and Energy (Contact Persons: Vicky Sita, Macheras Ioannis, Panagiotis Mpalatsos) provides
 - annual data for energy consumption and production (more specifically: Energy policy division – Solid fuels and electricity; Petroleum policy division – Liquid and gaseous fuels; Division of RES and energy conservation – Renewable energy sources).
 - data for solid waste management (Department of Solid Waste Management) data for wastewater treatment (Central Water Agency)

- activity data and emissions for the installations included in the Emissions Trading system (Directorate of Climate Change and Air Quality)
 - data for f-gases use (Directorate of Climate Change and Air Quality)
 - data for emissions / removals from LULUCF activities (UNFCCC and KP scope) (General Directorate for the Development and Protection of Forests and Agricultural Environment).
- The Hellenic Statistical Authority (Contact persons: Ioanna Papanagnou, Vrontou Elissavet, and Konstantina Katartzi) represents the main source of information for the estimation of emissions / removals from most of the IPCC source / sink categories.
- The Ministry of Economy, Competitiveness and Shipping (Contact person: Xarikleia Piperopoulou, General Secretariat of Industry) provides industry data
- The Ministry of Rural Development and Food provides information and data (through the Hellenic Statistical Authority which processes primary data collected by the Ministry) for the main indices and parameters of rural economy (e.g. animal population, cultivated areas, crops production, etc.).
- The Ministry of Infrastructure, Transport and Networks (Contact person: Tselikas Panagiotis) provides information and data for the vehicle fleet and its technical characteristics. The Civil Aviation Organization (Contact person: Kokkinos Anastasios), supervised by the same Ministry provides information on Landing and Take-off cycles for both domestic and international aviation.

Data are also obtained from International Organizations as the United Nations Food and Agricultural Organization (FAO) from which data on the annual consumption of fertilizers are collected, the EUROSTAT, the International Iron and Steel Institute, the International Energy Association. These data are supplementary to the data collected from the aforementioned data providers.

Furthermore, other government organisations, associations, and individual public and private industrial companies contribute to data providing and development of methodological issues as appropriate. For example, data is provided from the National Organization for Medicines, while data from the Association of Motor Vehicles Importers Representatives or the Hellenic Association of Fertilizer professionals and traders are supplementary to the official data and are used in cases where official data are temporarily not available. Individual industrial companies / installations, either public or private, as Power Public Corporation, cement plants, etc, constitute an additional data source for the GHG inventory preparation. However, these data are used as supplementary to the official data (e.g. for QC).

1.3 Inventory planning and preparation

1.3.1 GHG inventory, data collection, processing and storage

The preparation of the Greek GHG emissions inventory is based on the application of the 2006 IPCC Guidelines.

The compilation of the inventory is completed in three main stages (*Figure 1.2*), while the timetable for the completion of those stages in the annual inventory cycle is presented in *Figure 1.3*.

Stage 1: The first stage consists of data collection and check for all source/sink categories. The main data sources used are the Hellenic Statistical Authority, the national energy balance, the government ministries/agencies involved and large private enterprises, along with the verified reports from installations under the EU ETS.

Quality control of activity data include the comparison of the same or similar data from alternative data sources (e.g. Hellenic Statistical Authority and ETS reports) as well as time-series assessment in order to identify changes that cannot be explained. In cases where problems and/or inconsistencies are identified, the agency's representative, responsible for data providing, is called to explain the inconsistency and/or help solving the problem.

Stage 2: Once the reliability of input data is checked and certified, emissions/removals per source/sink category are estimated. Emissions estimates are then transformed to the format required by the CRF Reporter. This stage also includes the evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the 2006 IPCC Guidelines.

Quality control checks, when at this stage, are related to time-series assessment as well as to the identification and correction of any errors / gaps while estimating emissions / removals and filling in the CRF Reporter.

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within technical consultants) check. The official approval procedure follows for one month period of interactions between the Inventory Team (NTUA and LULUCF consultant) and the Climate Team (MEEN), starting on the 1st of February of the year of submission. During this period, the Inventory Team has to revise the report according to the observations and recommendations of the Climate Team. On the basis of this interaction process, the final version of the report is compiled. The General Director for the Environment of MEEN, who supervises the National System, approves the inventory and then the MEEN submits the NIR to the European Commission and to the UNFCCC Secretariat.

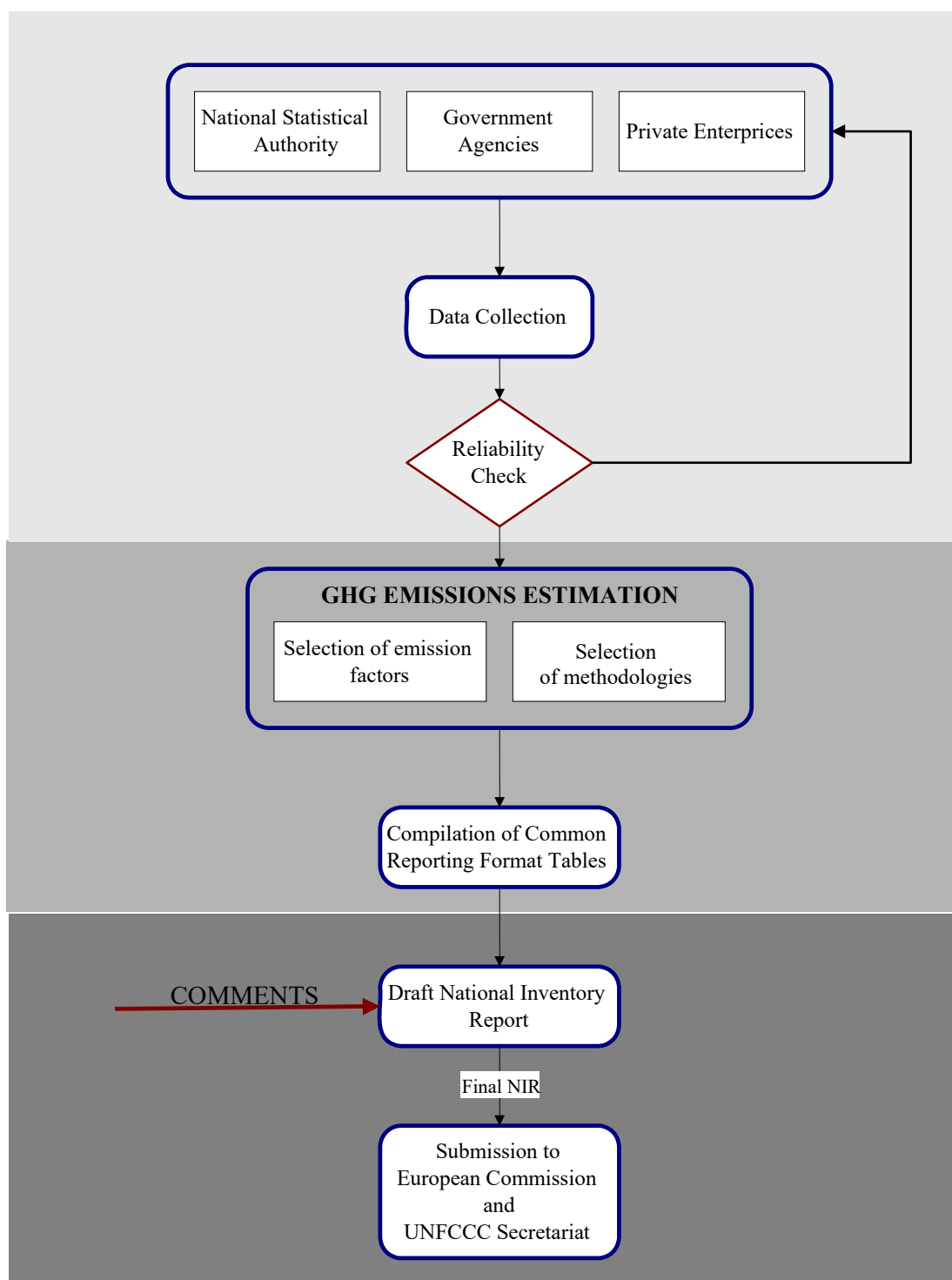


Figure 1.2 *GHG emissions inventory preparation process in Greece*

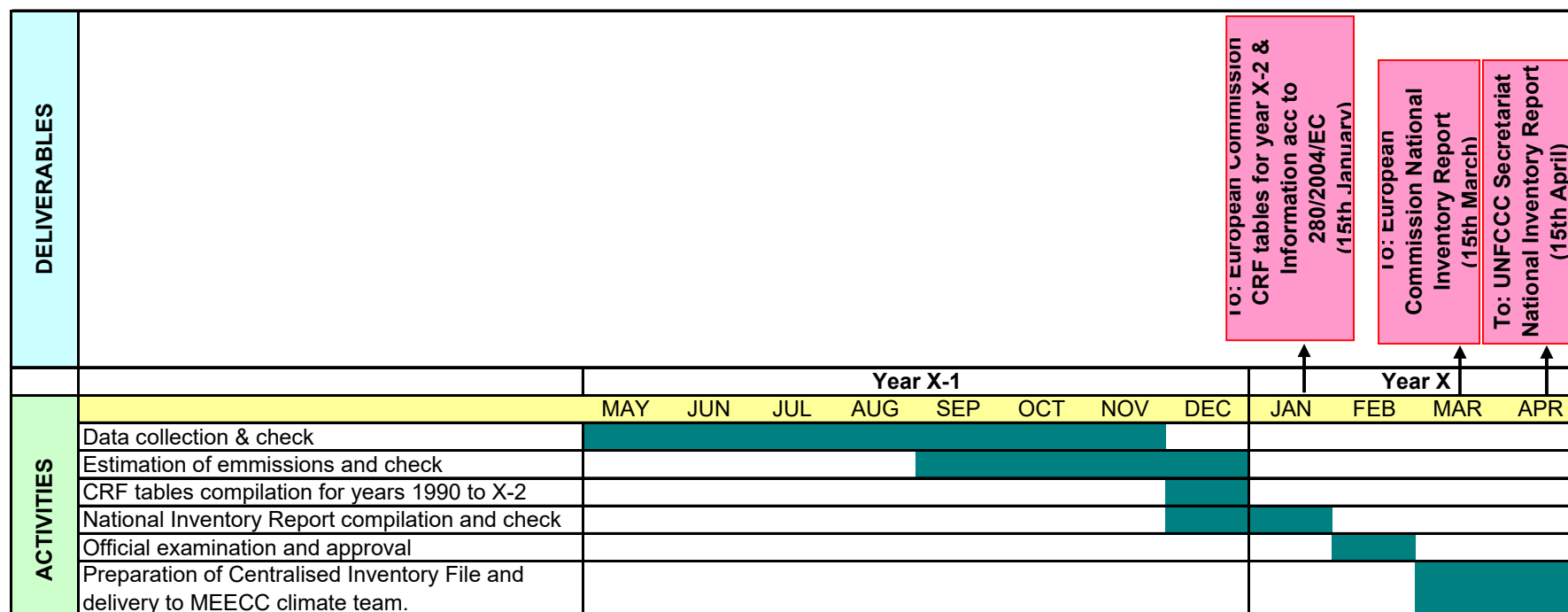


Figure 1.3 *Timetable for the preparation and submission of GHG emissions/removals inventory in Greece*

As shown in the timetable, the government ministries and agencies and the individual private or public industrial companies referred previously should have collected and delivered to the MEEN Climate Team and the technical consultants / Inventory Team (NTUA and LULUCF consultant) the respective activity data needed for the inventory (for year X-2) and any changes in activity data for the period 1990 to year X-2, within the time period of May to November of year X-1 (X is the submission year of CRF tables and NIR referred to X-2 GHG emissions inventory).

The information that is related to the annual GHG emissions inventory (activity data, emission factors, analytic results, compilation in the required analysis level of the CRF tables) is stored in MS Excel spreadsheets. Moreover, the final results (NIR and CRF tables) are available in the MEEN web site (<http://www.ypeka.gr/Default.aspx?tabid=470&language=el-GR>).

In addition, and within the context of the Quality Assurance/Quality Control system developed, two master files have been organized aiming at the systematic and safe archiving of inventory information: the Input Data File and the Centralised Inventory File.

- The Input Data File contains (in electronic format and/or hard copy) all input data and parameters that are necessary for the estimation of GHG emissions/removals. Data are stored in files by sector and reference year.
- The Centralised Inventory File includes all information relevant to the GHG emissions/removals inventory. At the end of each cycle of the inventory preparation, all inventory related information is handled by the NTUA and the LULUCF consultant to the person responsible for keeping the Centralised Inventory File (member of the Climate Team) in MEEN, who in turn provides the latest version of all relevant files (calculation files and NIR) to the Inventory Team at the beginning of the next inventory cycle.

More specifically the information stored in the Centralised Inventory Files includes:

- A list of the reports, the input data files and the calculation/estimation files.
- The members of the Inventory Team.
- Final versions, in electronic format and hard copy, of the NIR.
- CRF tables in electronic format and a hard copy of the CRF tables for the last year covered by each submission.
- XML file and database of CRF reporter
- Calculation files, including the uncertainty estimation files.
- Expert review reports.
- Any comments from the public review of the inventory.
- Documentation derived from the implementation of the QA/QC procedures.

1.3.2 Quality assurance/quality control (QA/QC) procedures and extensive review of GHG inventory

Information pertaining to this section can be found in section 1.6.

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory and KP-LULUCF inventory

1.4.1.1 Emission factors

The estimation of GHG emissions / removals per source / sink category is based on the methods described in the 2006 IPCC Guidelines, and 2013 Revised Supplementary Methods and the Good Practice Guidance Arising from the Kyoto Protocol. The emission factors used derive from the above-mentioned methodological sources and special attention was paid in selecting the emission factors that better describe practices in Greece. Furthermore, emission factors were obtained from plant specific information contained in EU ETS reports. An overview of the methods applied for the calculation of emissions / removals is presented in *Table 1.1*.

The key categories analysis (see Paragraph 1.5) constitutes the basic tool for methodological choice and for the prioritisation of the necessary improvements. In addition, the results of the various review processes (at national and international level) represent key input information for the identification of possible improvements. It should be mentioned however, that data availability as well as availability of resources (both human and financial) also have to be considered.

- ✎ Data availability could become a significant restrictive parameter when selecting an estimation methodology. The accuracy and the consistency of the emissions estimated depend on the availability of the data needed for the correct application of the selected methodology.
- ✎ Availability of resources needs also to be considered as the searching for and the collection of the necessary data in order to apply a detailed methodology for a source category should not affect the completeness and the on-time preparation of an inventory submission.

Table 1.1 *Overview of methods applied for the calculation of GHG emissions / removals*

	CO ₂		CH ₄		N ₂ O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
1. Energy								
A. Fuel combustion								
1. Energy industries	T2	CS, PS	T1	D	T1	D		
2. Manufacturing industries and Construction	T2	CS, PS	T1	D	T1	D		
3. Transport	T1,T2	D, CS	CR,M,T1,T2	CR,D,M	CR,M,T1,T2	CR,D,M		
4. Other sectors	T2	CS,D	T1	D	T1	D		
B. Fugitive emissions from fuels								
1. Solid fuels	NA	NA	T1	D	NA	NA		
2. Oil and Natural gas	T1	D	T1	D	T1	D		
2. Industrial processes								
A. Mineral products	CS,T1	CS, D, OTH, PS	NA	NA	NA	NA		
B. Chemical industry	T1, T1a	CS	T1, NA	D, NA	D	D		
C. Metal production	CS, T1	CS, PS	CR	CR	NA	NA	T3	PS
E. Production of halocarbons and SF ₆							T1, NA	D, NA
F. Consumption of halocarbons and SF ₆							NA, T2, CS	NA, D, CS
3. Solvents and other products use	CR	CR			OTH	OTH		
4. Agriculture								
A. Enteric fermentation			T1,T2	CS,D				
B. Manure management			T1,T2	CS,D	D	D		
C. Rice cultivation			D	D				
D. Agricultural soils			NA	NA	D,T1,T1a,T1b	CS,D		

	CO ₂		CH ₄		N ₂ O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
F. Field burning of agricultural residues			D	D	D	D		
5. Land Use, Land Use Change and Forestry								
A. Forest land	NA,OTH,T1,T2	CS,D,NA,OTH	NA,T1	D,NA	NA,T1	D,NA		
B. Cropland	NA,T1,T2	CS,D,NA	NA	NA	NA,T1	D,NA		
C. Grassland	NA,T1	CS,D,NA	NA	NA	NA	NA		
D. Wetlands	NA	NA	NA	NA	NA	NA		
E. Settlements	NA,T1,T2	CS,D,NA	NA	NA	NA	NA		
F. Other Land	NA,T1,T2	CS,D,NA	NA	NA	NA	NA		
G. HWP	T2	D	NA	NA	NA	NA		
6. Waste								
A. Solid waste disposal on land	NA	NA	T2	D, CS				
B. Wastewater handling			CS,D	D, CS	D, CR	D, CS		
C. Waste incineration	D	D, CS	D	CS	D	CS		
KP-LULUCF								
KP.A.1. Afforestation - Reforestation	OTH	OTH	T1	D	T1	D		
KP.A.2. Deforestation	T1,T2	CS,D	NA	NA	T1	D		
KP.B.1. Forest Management	T2	CS,D	T1	D	T1	D		

CR = CORINAIR, CS = Country Specific, PS = Plant Specific

NE = Not Estimated, NA= Not Applicable, NO= Not Observed, OTH= Other

T1, T1a, T1b, T2, T2a, T3b = IPCC T1, T1a, T1b, T2, T2a, T3b methodology respectively

D = Default IPCC methodology and emission factor

IE = Included Elsewhere

M = Copert IV model

1.4.1.2 Activity data

Data collection, processing and check constitute the activity with the longest duration in the annual inventory cycle. The duration of this activity is related to the amount of the necessary data and the number of the entities involved. The on-time and successful completion of this activity has a major effect on the timeliness preparation and submission of the inventory as well as on its accuracy, completeness and consistency.

Table 1.2 gives an overview of the main data sets used for the estimation of GHG emissions / removals. Data from international organizations and databases are supplementary to the data collected from the above data providers.

It should be noted that information and data collected (through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC) in the framework of the formulation of the National Allocation Plan (NAP) for the period 2005 – 2007, according to the EU Directive 2003/87/EC (and its transposition to the national Law, JMD 2004) along with the data from the verified reports from installations under the EU ETS for years 2005-2014 constituted a significant source of information and an additional quality control check.

Table 1.2 *Data sources and data sets per IPCC sector, source category*

SECTOR		STATISTICAL DATA	DATA SOURCES
1.A1	Electricity generation	Fuel consumption	<ul style="list-style-type: none"> Public Power Corporation Ministry of Environment and Energy ETS verified reports
1.A2	Manufacturing industry and construction	Fuel consumption	<ul style="list-style-type: none"> Ministry of Environment and Energy ETS verified reports
1.A3	Transport	Number of vehicles	<ul style="list-style-type: none"> Ministry of Infrastructure, Transport and Networks Hellenic Statistical Authority Association of Greek Auto Importers
		Aircraft landing and take off cycles	<ul style="list-style-type: none"> Civil Aviation Organization
1.A4	Residential / Tertiary sector / Agriculture	Fuel consumption	<ul style="list-style-type: none"> Ministry of Environment and Energy
1.B	Fugitive emissions from fuels	Amount of fuels Transmission/distribution pipelines length	<ul style="list-style-type: none"> Ministry of Environment and Energy
2	IPPU	Industrial production and Amount of solvents/other products use	<ul style="list-style-type: none"> Hellenic Statistical Authority Industrial units ETS verified reports Market surveys National Association of Refrigerating and Cooling Technicians Hellenic Aerosol Association Public Power Corporation National Organization of Medicines Private companies
3	Agriculture	Cultivated areas Agricultural production Livestock population Fertilizer use	<ul style="list-style-type: none"> Hellenic Statistical Authority Ministry of Rural Development and Food UN Food and Agricultural Organisation Pan-Hellenic Association of Professional Fertilizers Producers & Dealers
4	Land Use, Land Use Change and Forestry / KP-LULUCF	Area and wood stocks of managed forests Forest and grassland area affected by wildfires Afforestation and Deforestation areas Cultivated areas and areas of other land uses	<ul style="list-style-type: none"> Ministry of Environment and Energy Hellenic Statistical Authority
5	Waste	Quantities - composition of solid waste generated Recycling Population Industrial production	<ul style="list-style-type: none"> Ministry of Environment and Energy Association of Communities and Municipalities in the Attica Region (ACMAR) Hellenic Statistical Authority UN Food and Agricultural Organisation

1.4.1.3 Global warming potential

Emissions from anthropogenic activities affect the concentration and distribution of greenhouse gases in the atmosphere. These changes can potentially produce a radiative forcing of the Earth's

surface and lower atmosphere, by changing either the reflection or absorption of solar radiation or the emissions and absorption of long-wave radiation.

A simple measure of the relative radiative effects of the emissions of various greenhouse gases is the Global Warming Potential (GWP) index. This index is defined as the cumulative radiative forcing between the present and some chosen time-horizon caused by a unit mass of gas emitted now, expressed relative to that for some reference gas. The values for GWP for some of the most potent greenhouse gases are given in *Table 1.3*.

Corresponding values of GWP for other gases (NO_x, CO, NMVOC) are not given by the IPCC (nor by other sources for this purpose), since at present it is impossible to calculate the indirect results of these gases, as the scientific knowledge on their chemical reactions taking place in the atmosphere is not sufficient.

Table 1.3 **Global Warming Potential (in t of CO₂ eq) for the 100-year horizon**

Gas	GWP
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	25
Nitrous oxide (N ₂ O)	298
Hydrofluorocarbons (HFC)	
HFC-23	Please refer to 24/CP.19
HFC-32	
HFC-125	
HFC-134a	
HFC-143a	
HFC-152a	
HFC-227ea	
HFC-236fa	
HFC-4310mee	
Perfluorocarbons (PFC)	
CF ₄	
C ₂ F ₆	
C ₄ F ₁₀	
C ₆ F ₁₄	
Sulphur hexafluoride (SF ₆)	

1.5 Brief description of key categories

1.5.1 GHG inventory

The 2006 IPCC Guidelines define procedures (in the form of decision trees) for the choice of estimation methods within the context of the IPCC Guidelines. Decision trees formalize the choice of the estimation method most suited to national circumstances considering at the same time the need for accuracy and the available resources (both financial and human). Generally, inventory uncertainty is lower when emissions are estimated using the most rigorous methods, but due to finite resources, this may not be feasible for every source category. Therefore it is good practice to identify those source categories (key source categories) that have the greatest contribution to overall inventory uncertainty in order to make the most efficient use of available resources.

In that context, a *key source category* is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions (level assessment) or/and to the trend of emissions (trend assessment). As far as possible, key source categories should receive special consideration in terms of two important inventory aspects:

1. The use of source category-specific good practice methods is preferable, unless resources are unavailable.
2. The key source categories should receive additional attention with respect to quality assurance (QA) and quality control (QC).

As a result of the adoption of the LULUCF Good Practice Guidance (Decision 13/CP.9) the concept of key sources has been expanded in order to cover LULUCF emissions by sources and removals by sinks. Therefore the term key category is used in order to include both sources and sinks.

The determination of the key categories for the Greek inventory system is based on the application of the Tier 1 methodology (see Annex I for an analytic presentation of calculations) described in the 2006 IPCC Guidelines.

Tier 1 methodology for the identification of key categories assesses the impacts of various source categories on the level and the trend of the national emissions inventory. Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms.

It should be mentioned that:

- ✎ Source category uncertainty estimates are not taken into consideration.
- ✎ Base year estimates were calculated considering 1990 as base year.

The key categories for the Greek inventory system (without *LULUCF*) and for the year 2014 are presented in **Table 1.4**.

Twelve key source categories are found in the energy sector and seven in the IPPU sector in 2014 (without *LULUCF*).

Table 1.4 *Key categories for the Greek inventory system without LULUCF for 2014*

Source categories	Gas	Criteria
Energy		
Energy industries – Liquid fuels	CO ₂	Level, Trend
Energy industries– Solid fuels	CO ₂	Level
Energy industries – Gaseous fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO ₂	Trend
Manufacturing Industries & Construction – Liquid fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Gaseous fuels	CO ₂	Level, Trend
Road Transportation	CO ₂	Level, Trend
Domestic Navigation	CO ₂	Level, Trend
Domestic Aviation	CO ₂	Level, Trend
Coal Mining (surface)	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Ferroalloys	CO ₂	Level
Nitric acid production	N ₂ O	Trend
Ammonia production	CO ₂	Trend
Other	CO ₂	Trend
Other Process Uses of Carbonates	CO ₂	Trend
Product Uses as Substitutes for ODS	F-gases	Level, Trend
Agriculture		
Enteric fermentation – Non dairy cattle	CH ₄	Level
Enteric fermentation – Sheep	CH ₄	Level
Enteric fermentation – Other	CH ₄	Level
Manure management	N ₂ O	Level
Agricultural soils – Direct emissions	N ₂ O	Level, Trend
Agricultural soils – Indirect emissions	N ₂ O	Level, Trend
Waste		
Solid waste disposal on land	CH ₄	Level, Trend
Wastewater Treatment and Discharge	CH ₄	Level, Trend

The methodology applied for the determination of the key categories with *LULUCF* is similar to the one presented above. The key categories identified for the year 2014 are presented in **Table 1.5** (see Annex I for an analytic presentation of calculations). The comparison of the results of the analysis with and without *LULUCF* reveals no major differences in the source categories identified

(apart from the categories from the LULUCF sector). In the analysis including LULUCF twelve categories from the Energy Sector and seven from the IPPU Sector have been identified as key.

Table 1.5 *Key categories for the Greek inventory system with LULUCF for 2014*

Source categories	Gas	Criteria
Energy		
Energy industries – Liquid fuels	CO ₂	Level, Trend
Energy industries– Solid fuels	CO ₂	Level, Trend
Energy industries – Gaseous fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO ₂	Trend
Manufacturing Industries & Construction – Liquid fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Gaseous fuels	CO ₂	Level, Trend
Transport – Road transportation	CO ₂	Level, Trend
Transport – Navigation	CO ₂	Level, Trend
Transport – Domestic Aviation	CO ₂	Level, Trend
Coal Mining (surface)	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Ferroalloys	CO ₂	Level
Nitric acid production	N ₂ O	Trend
Ammonia production	CO ₂	Trend
Other	CO ₂	Trend
Other Process Uses of Carbonates	CO ₂	Trend
Product Uses as Substitutes for ODS	F-gases	Level, Trend
Agriculture		
Enteric fermentation – Non dairy cattle	CH ₄	Level
Enteric fermentation – Sheep	CH ₄	Level
Enteric fermentation – Other	CH ₄	Level
Enteric fermentation – Dairy cattle	CH ₄	Level
Manure management	N ₂ O	Level
Agricultural soils – Direct emissions	N ₂ O	Level, Trend
Agricultural soils – Indirect emissions	N ₂ O	Level, Trend
Waste		
Solid waste disposal on land	CH ₄	Level, Trend
Wastewater handling	CH ₄	Level, Trend
LULUCF		
Forest land remaining forest land	CO ₂	Level, Trend
Cropland remaining cropland	CO ₂	Trend
Conversion to Grassland	CO ₂	Level, Trend
Harvested Wood Products	CO ₂	Trend

There are some differences (inclusions and exclusions of sub-categories) throughout the time series, usually due to the fluctuation of the emissions (this is mostly the case in the industrial

processes sector and is justified by the fact that in many cases there is a limited number of plants for each sub-category and the fluctuation of one plant's emissions cannot be easily counterbalanced by the production of the rest).

1.5.2 KP-LULUCF inventory

In accordance with the IPCC Guidelines, the assessment of key categories under article 3.3 and 3.4 of Kyoto Protocol was based on the assessment made for the UNFCCC inventory. In the cases where there is a clear correspondence between the UNFCCC categories and the Kyoto Protocol Activities (i.e. Forest land remaining Forest land/managed and Forest Management), a Kyoto Protocol activity was considered as key when the associated category was identified as key in the UNFCCC inventory.

The Kyoto Protocol activity of Deforestation encompasses the UNFCCC subcategories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 (Forest land converted to other land uses). The sum of these subcategories is much smaller than the smallest UNFCCC key category. Moreover, none of the categories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 has been identified as key, and hence Deforestation is not identified as a key category.

Table 1.6 *Key categories under Kyoto Protocol art. 3.3 and 3.4*

Key category	Gas	Criteria	Associated key category in UNFCCC inventory
KP-LULUCF			
Forest Management	CO ₂	Level, Trend	Forest Land remaining Forest Land/managed

1.6 Information on the QA/QC plan including verification and treatment of confidentiality issues where relevant

1.6.1 QA/QC procedures and verification activities

The development and the implementation of an inventory Quality Assurance / Quality Control (QA/QC) plan represents a key tool for meeting the objectives of National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7.

With the Protocol's application, the pressure upon national GHG emissions inventories increases and therefore quality management is essential in order to comply with the requirements of (a) producing transparent, consistent, comparable, complete and accurate emissions estimates, (b) establishing a reliable central archiving system concerning all necessary information for GHG emissions inventories development and (c) compiling national reports according to the provisions of the adopted decisions.

In this framework, a QA/QC system is being implemented since April 2004. For the implementation of the QA/QC system the NTUA and LULUCF consultant are responsible in close co-operation with the MEEN. The system is based on the ISO 9001:2000 standard and its quality objectives, as stated in the quality management handbook, are the following:

1. Compliance with the 2006 IPCC guidelines and the UNFCCC reporting guidelines while estimating and reporting emissions/removals.
2. Continuous improvement of GHG emissions/removals estimates.
3. Timely submission of necessary information in compliance with relevant requirements defined in international conventions, protocols and agreements.

The accomplishment of the above-mentioned objectives can only be ensured by the implementation, from all the members of the Inventory Team (see **Figure 1.4** for the flow chart of activities concerning emissions inventory), of the QA/QC procedures included in the plan for:

- ↳ data collection and processing,
- ↳ applying methods consistent with 2006 IPCC Guidelines for calculating / recalculating emissions or removals, and 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol
- ↳ making quantitative estimates of inventory uncertainty,
- ↳ archiving information and record keeping and
- ↳ compiling national inventory reports.

The QA/QC system developed covers the following processes (see **Table 1.7** for the list of procedures within each process and **Figure 1.5** for the relationship between the processes and the activities of the inventory team):

- ↪ **QA/QC system management**, comprising all activities that are necessary for the management and control of the inventory agency in order to ensure the accomplishment of the above-mentioned quality objectives.
- ↪ **Quality control**, that is directly related to the estimation of emissions. The process includes activities related to (a) data inquiry, collection and documentation, (b) methodological choice in accordance with the 2006 IPCC Guidelines, (c) quality control checks for data from secondary sources and (d) record keeping.
- ↪ **Archiving inventory information**, comprising activities related to centralised archiving of inventory information and the compilation of the national inventory report.
- ↪ **Quality assurance**, comprising activities related to the different levels of review processes including the review of input data from experts, if necessary, and comments from the public
- ↪ **Estimation of uncertainties**, defining procedures for estimating and documenting uncertainty estimates per source / sink category and for the whole inventory.
- ↪ **Inventory improvement**, that is related to the preparation and the justification of any recalculations made.

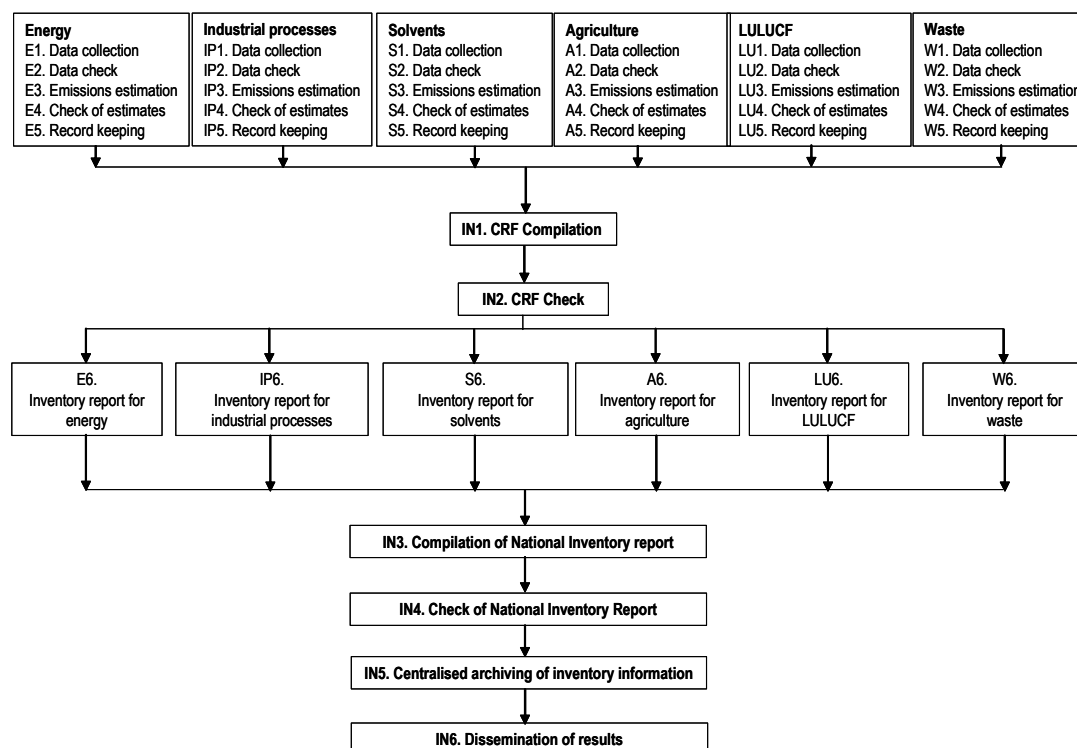


Figure 1.4 *Flow chart activities concerning the GHG emissions inventory*

Table 1.7 *Quality assurance / quality control procedures for the Greek GHG emissions inventory*

Process	Procedure code	Procedures
Quality management	QM 01	System review
	QM 02	System improvement
	QM 03	Training
	QM 04	Record keeping
	QM 05	Internal reviews
	QM 06	Non compliance – Corrective and preventive actions
	QM 07	Supplies
	QM 08	Quality management system
	QM 09	Documents control
	QM 10	Internal communication
Quality control	QC 01	Data collection
	QC 02	Estimation of emissions / removals
	QC 03	Data quality control check
	QC 04	Input data record keeping
Archiving of inventory information	AI 01	Centralised archiving of inventory information
	AI 02	Compilation of reports
Quality assurance	QA 01	Expert review of input data and parameters
	QA 02	Expert review of GHG emissions / removals inventory
	QA 03	Review from public
Estimation of uncertainties	EU 01	Uncertainty analysis
Inventory improvement	II 01	Recalculations management

All the procedures described in the QA/QC manual are followed by both the MEEN and the NTUA and LULUCF consultant. As described in the chapters of the NIR entitled “Source-specific QA/QC and verification”, source-specific Tier 2 QC procedures are applied in the majority of source categories for quality control and verification purposes.

Furthermore, annual internal audits take place by MEEN/NTUA/LULUCF consultant between January and March of each year and audits by independent local experts are planned and implemented.

In 2013, a Bilateral QA exercise between the Spanish and the Greek Inventory teams was performed. The Spanish inventory team reviewed the Agriculture, Waste and IP (F-gases) sectors of the Greek inventory. On the other hand, the Greek inventory team reviewed the industrial combustion, industrial processes and waste sectors of the Spanish inventory

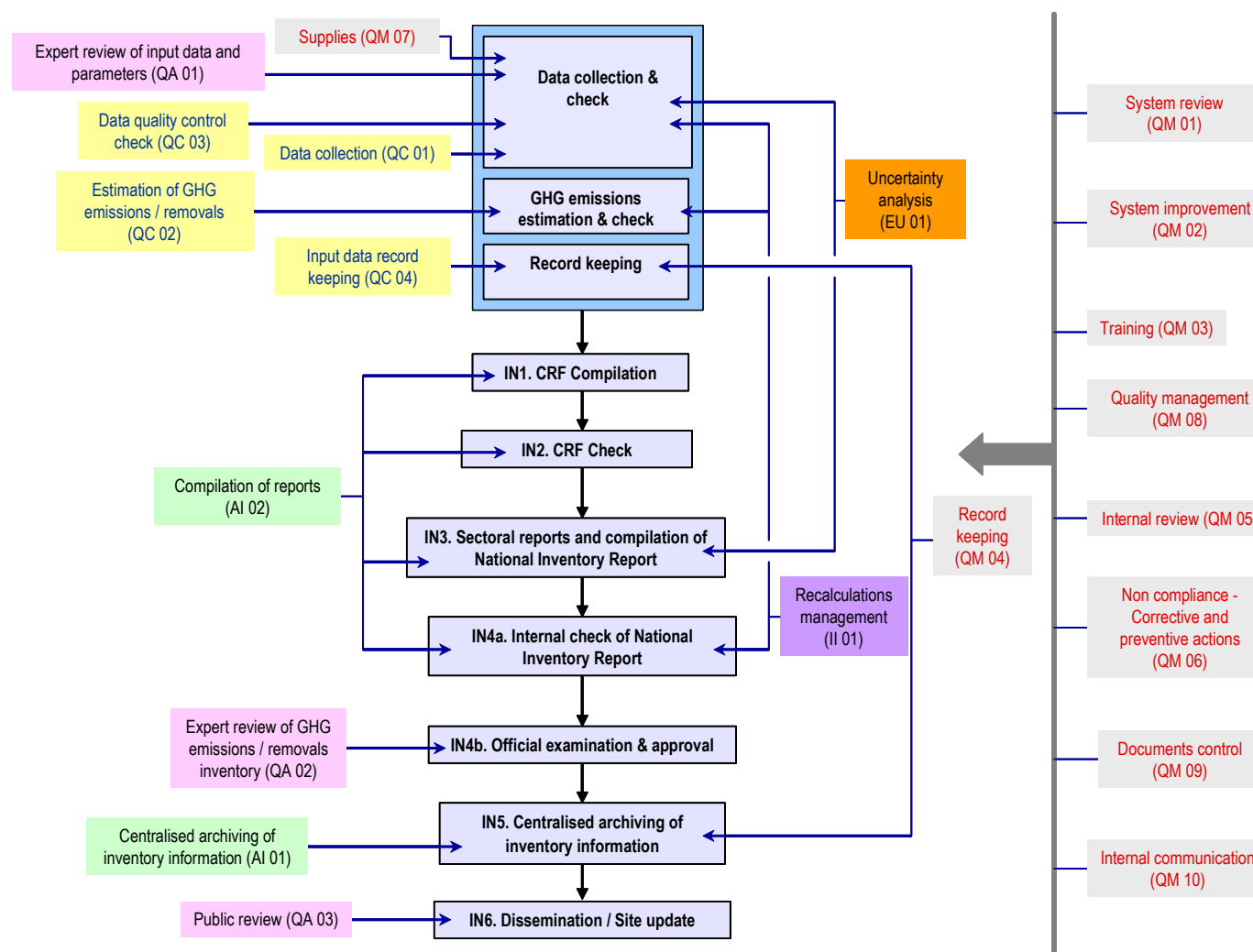


Figure 1.5 *QA/QC processes and procedures and inventory related activities*

1.6.2 Treatment of confidentiality issues

Confidentiality issues concern mainly the Industrial Processes sector in cases where the activity data relate directly to the production activity of one plant. This is the case in a number of categories of the industrial processes sector.

The provision of data that are concerned as confidential is quite difficult, since these data are not published in the national statistics.

In the past, there were also procedures of confidential data exchange between the inventory team and the Hellenic Statistics Authority (El.Stat). More specifically, the cooperation established under this system contributed to the confidentiality waiver that was decided by the relevant committee of the Service in 2008. The received data have been entered in Greece's QA/QC input file and are constantly used as primary data or in QA/QC checks (see also Chapter 4: Industrial Processes). Moreover, whenever a confidentiality issue arises, the inventory system is working in close cooperation with the Prodcom Section of the El. Stat. throughout all the stages of the inventory preparation and during the reviews if necessary. It should be also mentioned that in any case, the El. Stat. provides the inventory team with all the information regarding the plant's id, information that has also been considered as confidential in the past. This enables the resolve of any sub-category completeness issues by directly addressing the plant.

In the recent years, the most efficient way for collecting such information is by communicating directly to the respective plants, building a very good cooperation between the plants and the inventory team and ensuring that the published data are the most updated.

Finally, in a number of cases activity data are reported as confidential in the inventory files. This happens in cases when the inventory team has not received an official approval by the corresponding industry in order to publish direct activity data. It should be noted, however, that in any case the activity data are kept in the Input File of the inventory and are made available at any request during the review processes. For example, this has been the case for ferroalloys productions, when the only plant operating in Greece has not granted permission to publish the reported production data.

This has also been the case for aluminium production in the past. However, since the 2010 submission and based on the respective recommendation by the 2010 ERT, the aluminium production as provided by international and national sources (Greek Mining Enterprises Association, US Geological Survey) is reported. It should be noted that this production differs slightly from the one reported by the plant itself in accuracy and also due to the fact that in some cases provisional estimations may have been used by the other sources.

1.7 General uncertainty evaluation

1.7.1 GHG inventory

In order to evaluate the accuracy of an emissions inventory, an uncertainty analysis has to be carried out for both annual estimates of emissions and emissions trends over time.

The estimated uncertainty of emissions from individual sources (e.g. power plants, motor vehicles) is either a function of instrument characteristics, calibration and sampling frequency of direct measurements, or (more often) a combination of the uncertainties in the emission factors for typical sources and the corresponding activity data.

✎ Emission factors reported in the literature usually derive from measurements at specific installations, the characteristics of which are judged to be typical for a set of similar installations. The validity of this assumption given the national circumstances represents the crucial factor determining uncertainty.

✎ Activity data are more closely linked to economic activity than are emission factors. Therefore, there are often well established incentives requirements for accurate accounting. As a result activity data tend to have lower uncertainties and lower correlation between years. Data availability at the level of analysis required for the estimation of GHG emissions / removals as well as the definitions used by the statistical agencies represent some of the parameters affecting the uncertainty of activity data.

Detailed explanation regarding the choice of the uncertainty values on the activity data and emission factors estimations is presented in Annex IV.

The uncertainty analysis for the Greek GHG inventory is based on Tier 1 methodology described in the 2006 IPCC Guidelines, with 1990 as base year for CO₂, CH₄, N₂O and F-gases emissions.

✎ For the estimation of uncertainties per gas, a combination of the information provided by the IPCC and critical evaluation of information from indigenous sources was applied.

✎ The uncertainty analysis was carried out both without and with the *LULUCF* sector.

Table 1.8 presents the uncertainty estimates by source category and by gas (without *LULUCF*), while the detailed calculations are presented in Annex IV.

The uncertainty estimates for GHG emissions per gas in 2014, were estimated at:

2.6% for CO₂ emissions

36.2% for CH₄ emissions

106.8% for N₂O emissions and

167.5% for the F-gases emissions.

Table 1.8 *Uncertainty estimates per source category and gas (without LULUCF)*

Source categories	Gas	Uncertainty (%)
1.A Fuel Combustion Activities-Liquid	CO ₂	4.2%
1.A Fuel Combustion Activities-Solid		4.2%
1.A Fuel Combustion Activities-Gas		3.6%
1.A Fuel Combustion Activities-Other fossil fuels		4.2%
1.B.2 Oil and Natural Gas		300.0%
2.A.1 Cement Production		2.8%
2.A.2 Lime Production		7.8%
2.A.3 Glass production		5.8%
2.A.4 Other process uses of carbonates		11.2%
2.B.1 Ammonia Production		6.7%
2.B.8 Petrochemical and Carbon Black Production		7.1%
2.B.10 Other-Hydrogen production		4.2%
2.C.1 Iron and Steel Production		7.1%
2.C.2 Ferroalloys		9.9%
2.C.3 Aluminium Production		2.8%
2.C.5 Lead production		20.1%
2.C.6 Zinc production		20.1%
2.D.1 Lubricant Use		7.1%
2.D.2 Paraffin Wax Use		7.1%
2.G.4 Other product manufacture and use		7.1%
3.H Urea application		53.9%
5. Incineration and open burning of waste		64.0%
Total CO₂		2.6%
1.A.1 Energy Industry-Liquid	CH ₄	100.0%
1.A.1 Energy Industry-Solid		100.0%
1.A.1 Energy Industry-Gas		100.0%
1.A.1 Energy Industry-Biomass		100.0%
1.A.2 Industries and Construction-Liquid		100.0%
1.A.2 Industries and Construction-Solid		100.0%
1.A.2 Industries and Construction-Gas		100.0%
1.A.2 Industries and Construction-Other fossil fuels		100.0%
1.A.2 Industries and Construction-Biomass		100.0%
a. Domestic aviation		100.1%
b. Road Transportation		40.2%
c. Railways		100.1%
d. Domestic Navigation		100.1%
e. Other Transportation		100.1%
1.A.4 Other Sectors-Liquid		100.0%
1.A.4 Other Sectors-Solid		100.0%
1.A.4 Other Sectors-Gas		100.0%
1.A.4 Other Sectors-Biomass		100.0%

Table 1.8(cont.) Uncertainty estimates per source category and gas (without LULUCF)

Source categories	Gas	Uncertainty (%)
1B Coal Mining	CH ₄	300.0%
1.B.2 Oil and Natural Gas		300.0%
2.B.8 Petrochemical and Carbon Black Production		7.1%
2.C.1 Iron and Steel Production		6.4%
3.A Enteric Fermentation		50.2%
3.B Manure Management		30.4%
3.C Rice Cultivation		40.0%
3.F Field burning of agricultural residues		28.3%
5.A.1 Managed waste disposal sites		42.4%
5.A.1 Unmanaged waste disposal sites		42.4%
5.B.1 Biological treatment of solid waste-Composting		104.4%
5. Incineration and open burning of waste		111.8%
5.D.1 Domestic Wastewater Treatment and Discharge		42.4%
5.D.2 Industrial Wastewater Treatment and Discharge		42.4%
Total CH₄		36.2%
1.A.1 Energy Industry-Liquid	N ₂ O	300.0%
1.A.1 Energy Industry-Solid		300.0%
1.A.1 Energy Industry-Gas		300.0%
1.A.1 Energy Industry-Biomass		300.0%
1.A.2 Industries and Construction-Liquid		300.0%
1.A.2 Industries and Construction-Solid		300.0%
1.A.2 Industries and Construction-Gas		300.0%
1.A.2 Industries and Construction-Other fossil fuels		300.0%
1.A.2 Industries and Construction-Biomass		300.0%
a. Domestic aviation		300.0%
b. Road Transportation		50.2%
c. Railways		300.0%
d. Domestic Navigation		300.0%
e. Other Transportation		300.0%
1.A.4 Other Sectors-Liquid		300.0%
1.A.4 Other Sectors-Solid		300.0%
1.A.4 Other Sectors-Gas		300.0%
1.A.4 Other Sectors-Biomass		300.0%
1.B.2 Oil and Natural Gas		300.0%
2.B.2 Nitric acid production		3.6%
2.G.3 N ₂ O from Product Uses		7.1%
3.B Manure Management		100.1%
3.D Direct N ₂ O Emissions from Agricultural Soils		201.0%
3.D Indirect N ₂ O Emissions from Managed Soils		53.9%
3.F Field burning of agricultural residues		28.3%
5.B.1 Biological treatment of solid waste-Composting		104.4%
5. Incineration and open burning of waste		111.8%
5.D.1 Domestic Wastewater Treatment and Discharge		42.4%
5.D.2 Industrial Wastewater Treatment and Discharge		104.4%
Total N₂O		106.8%

2.B.9 Fluorochemical production		70.7%
2.F.1 Refrigeration and Air-Conditioning Equipment		180.3%
2.F.2 Foam Blowing		64.0%
2.F.3 Fire Extinguishers		60.8%
2.F.4 Aerosols	F-gases	15.8%
2.C.3 Aluminium Production		6.7%
2.F.1 Refrigeration and Air-Conditioning Equipment		180.3%
2.C.4. Magnesium production		53.9%
2.G.1 Electrical Equipment		53.9%
Total F-gases		167.5
Total uncertainty (%)		11.8

In general, the uncertainties associated with CO₂ are very low, while the least accurate estimations are those for N₂O and F-gases. This difference is mainly due to the uncertainty in emissions factors. For example, in the sector of marine transport the emission factor for CO₂ depends only on the type of fuel, while CH₄ and N₂O factors depend heavily on the technology of the engine used. As a result, the uncertainty in emissions factors for marine transport is 5% for CO₂ and an order of magnitude for CH₄ and N₂O.

Total uncertainty is 11.8% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 11.3%. To be mentioned that the uncertainty analysis is based on the 100% of emissions.

The results of the uncertainty analysis for the *LULUCF* sector are presented in **Table 1.9**. The uncertainty estimates for GHG emissions per gas, with *LULUCF*, in 2014, were estimated at (the detailed calculations are presented in Annex IV):

- ↳ 2.9% for CO₂ emissions,
- ↳ 36.2% for CH₄ emissions,
- ↳ 106.8% for N₂O emissions and
- ↳ 167.5% for the F-gases emissions.

Total uncertainty is 12.2%, while the uncertainty that carried over into the GHG emissions trend is 11.5%.

Table 1.9 *Uncertainty analysis for the LULUCF sector*

Source / Sink categories	Gas	Uncertainty (%)
Forest Land remaining Forest Land	CO ₂	33
Conversion to Forest Land	CO ₂	113
Cropland remaining Cropland	CO ₂	53
Conversion to Cropland	CO ₂	51
Grassland remaining grassland	CO ₂	51
Conversion to Grassland	CO ₂	51
Land converted to Wetlands	CO ₂	51
Conversion to Settlements	CO ₂	51
Conversion to Other Land	CO ₂	51

Harvested Wood Products	CO ₂	51
Forest Land remaining Forest Land	CH ₄	71
Land converted to Forest Land	CH ₄	71
Grassland remaining Grassland	CH ₄	71
Forest Land remaining Forest Land	N ₂ O	71
Land converted to Forest Land	N ₂ O	71
Conversion to Cropland	N ₂ O	71
Grassland remaining Grassland	N ₂ O	71

1.7.2 KP-LULUCF inventory

Since there is a clear correspondence between the Kyoto Protocol activities ‘Afforestation / Reforestation’ and ‘Forest Management’, and the UNFCCC categories ‘Conversion to Forest land’ and ‘Forest land remaining Forest land/managed’, uncertainty levels of the net emissions/removals are the same for both inventories. The uncertainty of emissions from units of land under ‘Deforestation’ is estimated to be 51%.

Table 1.10 *Uncertainty analysis for the KP-LULUCF activities*

Art. 3.3 & 3.4 Activities	Gas	Uncertainty (%)
Afforestation / Reforestation	CO ₂	113
Deforestation	CO ₂	51
Forest Management	CO ₂	33
Forest Management	CH ₄	71
Forest Management	N ₂ O	71

1.8 General assessment of the completeness

1.8.1 GHG inventory

In the present inventory report, which supersedes all previous ones, estimates of GHG emissions in Greece for the years 1990-2014 are presented. Emissions estimates included in the CRF tables submitted and discussed in the present report, cover the whole territory of Greece. All major sources are reported including emissions estimates for indirect greenhouse gases and SO₂.

Completeness gaps in the present inventory submission that will be discussed in more details in the relevant chapters include:

- ✎ CO₂ emissions from *organic chemicals production* and *asphalt roofing-road paving with asphalt* are not estimated due to lack of emission factors in the IPCC guidelines.

2. Trends in greenhouse gas emissions

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO₂, CH₄, N₂O, HFC, PFC and SF₆) for the period 1990 - 2014 are presented in **Table 2.1** (in kt CO₂ eq). The GWP values used for the conversion of emissions estimates into the common unit of carbon dioxide equivalent are those presented in **Table 1.3**.

It is noted that according to the IPCC Guidelines, emissions estimates for international marine and aviation bunkers were not included in the national totals, however they are reported separately as memo items.

Base year GHG emissions for Greece (1990 for CO₂, CH₄, and N₂O - 1995 for F-gases) were estimated at 107.7 Mt CO₂ eq. Given that *LULUCF* was a net sink of GHG emissions in 1990 (and for the rest of the reporting period) the relevant emissions / removals are not considered in estimating base year emissions for Greece.

In 2014, GHG emissions (without *LULUCF*) amounted to 101.4 Mt CO₂ eq showing a decrease of 5.82% compared to base year emissions and of 3.27% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the decrease would be 4.27 % (from 102.55 Mt CO₂ eq in 1990 to 98.17 Mt CO₂ eq in 2014).

Carbon dioxide emissions accounted for 78.53% of total GHG emissions in 2014 (without *LULUCF*) and decreased by approximately 4.53% from 1990. Methane emissions accounted for 11.04% of total GHG emissions in 2014 and decreased by 11.49% from 1990, while nitrous oxide emissions accounted for 4.62% of the total GHG emissions in 2014 and decreased by 36.70% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 5.68% of total GHG emissions in 2014 were increased by 39.63% from 1995 (base year for F-gases).

Table 2.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2002*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
A. GHG emissions per gas (excluding LULUCF)													
CO ₂	83,403.72	83,390.35	84,949.03	84,263.01	86,425.86	86,980.65	89,134.43	93,839.87	98,663.19	97,979.78	103,019.66	105,407.31	105,051.47
CH ₄	12,644.74	12,624.31	12,709.99	12,700.94	12,823.74	12,944.66	13,099.87	12,976.79	13,194.14	13,165.01	12,934.08	11,881.96	11,872.45
N ₂ O	7,402.64	7,269.55	7,129.88	6,564.38	6,480.19	6,669.81	6,846.91	6,686.39	6,621.56	6,604.32	6,346.05	6,207.73	6,172.36
HFC	1,182.82	1,400.08	1,149.07	2,032.44	2,712.11	4,157.38	4,820.17	5,166.49	5,767.51	6,721.15	5,261.83	4,781.39	5,090.07
PFC	190.26	191.19	187.74	112.94	70.31	62.85	53.73	125.64	155.48	105.31	122.26	84.10	88.29
SF ₆	2.93	3.02	3.11	3.20	3.29	3.42	3.51	3.56	3.60	3.69	3.81	3.88	4.06
Total	104,827.11	104,878.50	106,128.82	105,676.90	108,515.50	110,818.77	113,958.62	118,798.72	124,405.49	124,579.27	127,687.69	128,366.36	128,278.69
B. GHG emissions/removals from LULUCF													
CO ₂	-2,346.12	-2,510.94	-2,556.15	-2,940.54	-2,682.27	-2,941.80	-2,640.29	-1,833.77	-1,986.24	-2,637.76	-2,107.42	-2,377.62	-2,881.78
CH ₄	62.23	30.95	91.44	81.62	76.10	43.13	26.09	57.32	156.06	11.89	205.70	27.70	3.78
N ₂ O	5.10	2.54	7.50	6.69	6.24	3.54	2.15	4.71	12.80	0.98	16.87	2.28	0.32
Total	-2,278.78	-2,477.46	-2,457.21	-2,852.22	-2,599.92	-2,895.13	-2,612.06	-1,771.74	-1,817.38	-2,624.89	-1,884.85	-2,347.64	-2,877.68
C. GHG Emissions from International Transport													
CO ₂	10,479.79	9,480.49	10,665.72	12,221.26	13,272.17	13,883.18	12,418.33	12,364.54	13,642.22	12,710.50	13,890.86	13,387.52	12,225.58
CH ₄	16.79	15.28	17.35	20.37	21.52	22.79	20.30	20.40	23.06	20.45	23.78	23.45	21.00
N ₂ O	259.88	252.98	311.33	344.47	381.81	442.84	366.17	363.89	369.45	344.99	368.54	316.98	286.43
Total	10,756.46	9,748.75	10,994.41	12,586.10	13,675.51	14,348.81	12,804.79	12,748.83	14,034.74	13,075.94	14,283.18	13,727.95	12,533.01

Table 2.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2003-2014*

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
A. GHG emissions per gas (excluding LULUCF)												
CO ₂	109,126.57	109,571.06	113,219.82	111,777.74	114,127.55	110,255.77	103,969.8	97,035.08	94,102.94	90,710.57	82,910.63	79,628.27
CH ₄	11,768.35	11,754.69	11,758.80	11,851.05	11,653.11	11,606.06	11,449.02	11,647.41	11,484.39	11,354.56	11,260.27	11,191.26
N ₂ O	6,050.25	6,054.53	5,882.95	5,730.83	5,825.36	5,610.97	5,325.96	5,526.83	5,317.62	4,912.06	4,670.44	4,686.09
HFC	4,733.36	4,927.91	5,077.45	2,722.45	3,245.14	3,710.35	3,964.12	4,388.67	4,661.66	5,061.78	5,650.22	5,758.13
PFC	89.28	87.86	91.51	87.21	103.04	118.95	91.35	129.44	110.53	147.77	172.56	134.63
SF ₆	4.06	4.26	6.16	7.98	9.46	7.18	5.02	5.86	5.13	5.05	5.15	4.92
Total	131,771.86	132,400.31	136,036.69	132,177.27	134,963.67	131,309.28	124,805.3	118,733.29	115,682.27	112,191.78	104,669.27	101,403.31
B. GHG emissions/removals from LULUCF												
CO ₂	-2,588.73	-2,808.08	-3,078.07	-3,219.66	-1,818.25	-3,175.96	-3,289.33	-3,278.29	-3,321.17	-3,293.86	-3,165.77	-3,246.86
CH ₄	5.31	13.48	8.80	20.71	318.14	43.09	45.69	16.23	17.74	43.46	15.99	9.39
N ₂ O	0.45	1.12	0.74	1.71	26.09	3.55	3.76	1.35	1.48	3.58	1.33	0.80
Total	-2,582.97	-2,793.47	-3,068.53	-3,197.24	-1,474.02	-3,129.32	-3,239.88	-3,260.71	-3,301.96	-3,246.83	-3,148.45	-3,236.67
C. GHG Emissions from International Transport												
CO ₂	13,173.30	13,340.43	11,511.49	12,712.18	12,969.70	12,872.75	10,961.76	10,796.79	11,144.45	9,854.93	9,568.31	8,878.27
CH ₄	21.74	22.02	19.77	21.39	21.96	21.55	18.24	18.89	19.41	15.93	15.08	13.20
N ₂ O	277.10	269.94	224.41	239.28	230.03	220.57	197.93	204.67	194.63	171.44	172.64	168.11
Total	13,472.14	13,632.39	11,755.67	12,972.85	13,221.69	13,114.87	11,177.93	11,020.35	11,358.48	10,042.30	9,756.03	9,059.59

2.2 Description and interpretation of emission trends by category

GHG emissions trends by sector for the period 1990 - 2014 are presented in *Table 2.2*.

Emissions from *Energy* in 2014 (*Figure 2.1*) accounted for 77.90% of total GHG emissions (without LULUCF) and decreased by approximately 2.22% compared to 1990 levels.

The living standards improvement, due to the economic growth, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from Energy for the period 1990 – 2007. For the period 2008 - 2014, the emissions have a decreasing trend.

The living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO₂ emissions per electricity produced have decreased mainly as a result of the introduction of the natural gas and RES into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 was not followed by a similar increase of emissions because of the penetration of natural gas and the high availability of hydropower.

The decreasing trend of emissions of energy of the years 2008-2014 is attributed mainly to the economic recession that the country is facing, but also to the effect of mitigation actions (i.e. RES, energy efficiency measures, road infrastructure and public transportation improvements, etc).

The majority of GHG emissions (61.1%) in 2014 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 23.4%, 7.3% and 6.6% respectively. The rest 1.6% of total GHG emissions from Energy derived from fugitive emissions from fuels. Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an increase of 21.0%, followed by energy industries with a 6.2% increase compared to 1990, respectively. Emissions from manufacturing industries and construction emissions and other sectors (i.e. residential, tertiary and agriculture sectors) had decreased by around 41.8% and 41.3%, respectively, compared to 1990. The decrease in the other sectors is noticeable during the recent years. Finally, fugitive emissions from fuels decreased by 0.8% for the period 1990 – 2014..

Emissions from *Industrial Processes and Product use* in 2014 accounted for 9.93% of the total emissions (excluding LULUCF) and increased by 10.17% compared to 1990 levels. In 2014 mineral products production has continued the decreasing trend of the previous years, following the decrease of all the subcategories of the sector, mainly due to the effects of the economic recession. There is an increase in emissions since 2011 (44.59%), which followed the intense decrease of 2011. Emissions from chemical industry have decreased by 79.66% since 1990. Emissions from metal industry slightly increased with regards to 2011 by 1.76%, due to the increased production of aluminium and nickel.

Emissions from *Agriculture* that accounted for 7.75% of total emissions in 2014 (without *LULUCF*), decreased by approximately 14.16% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N₂O emissions from agricultural soils, because of the reduction in the use of synthetic nitrogen fertilizers. The decrease in the use of synthetic nitrogen fertilizers is attributed to the increase of organic farming, the high price of fertilizers and the impact of initiatives to promote good practice in fertilizer use. The changes of the rest determining parameters of GHG emissions from the sector (e.g. animal population, crops production etc.) have a minor effect on GHG emissions trend.

Emissions from the *Waste* Sector (4.42% of the total emissions, without *LULUCF*), decreased by approximately 21.77% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions. However, the increase of recycling along with the exploitation of the biogas produced limits the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2014. The sink capacity of the *LULUCF* sector fluctuates between 1.47 Mt CO₂ eq. and 3.30 Mt CO₂ eq., showing an increasing trend. This is the result of the decrease of the sink capacity of the Cropland category on the one hand, and the increase of the sink capacity of the Forest Land category on the other.

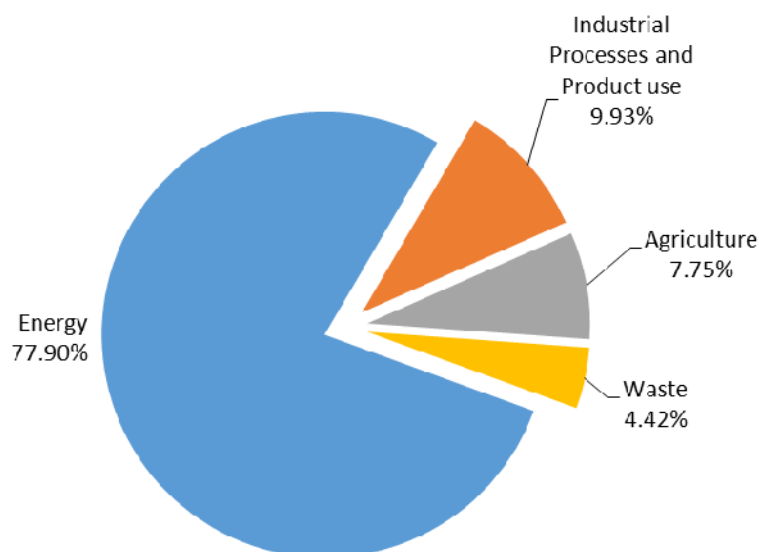


Figure 2.1 *Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2014*

Table 2.2a *Total GHG emissions (in kt CO₂ eq) by sector for the period 1990-2002*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Energy	76,914.70	77,063.80	79,075.96	78,713.57	80,938.49	81,003.18	83,221.30	87,755.24	92,483.28	91,945.60	96,742.40	99,182.55	99,008.53
IPPU	11,226.96	11,163.40	10,577.36	11,028.32	11,636.59	13,569.65	14,338.11	14,835.60	15,552.78	16,389.35	15,176.38	14,575.50	14,768.63
Agriculture	10,185.94	10,209.49	9,943.55	9,387.34	9,231.21	9,565.43	9,632.26	9,548.06	9,532.25	9,528.41	9,229.33	9,132.64	9,155.18
Waste	6,499.52	6,441.81	6,531.95	6,547.67	6,709.21	6,680.50	6,766.95	6,659.83	6,837.18	6,715.90	6,539.59	5,475.67	5,346.35
Total ¹⁾	104,827.11	104,878.50	106,128.82	105,676.90	108,515.50	110,818.77	113,958.62	118,798.72	124,405.49	124,579.27	127,687.69	128,366.36	128,278.69
LULUCF	-2,278.78	-2,477.46	-2,457.21	-2,852.22	-2,599.92	-2,895.13	-2,612.06	-1,771.74	-1,817.38	-2,624.89	-1,884.85	-2,347.64	-2,877.68
Index per sector													
Energy	100.00	100.19	102.81	102.34	105.23	105.32	108.20	114.09	120.24	119.54	125.78	128.95	128.73
IPPU	100.00	99.43	94.21	98.23	103.65	120.87	127.71	132.14	138.53	145.98	135.18	129.83	131.55
Agriculture	100.00	100.23	97.62	92.16	90.63	93.91	94.56	93.74	93.58	93.54	90.61	89.66	89.88
Waste	100.00	99.11	100.50	100.74	103.23	102.78	104.11	102.47	105.20	103.33	100.62	84.25	82.26
Total ²⁾	100.00	100.05	101.24	100.81	103.52	105.72	108.71	113.33	118.68	118.84	121.81	122.46	122.37

¹⁾ Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

²⁾ *Land Use, Land Use Change and Forestry* is not included

Table 2.2b *Total GHG emissions (in kt CO₂ eq) by sector for the period 2003-2014*

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Energy	102,896.09	103,389.50	106,442.89	105,180.57	107,634.15	104,382.40	99,928.86	92,765.39	91,467.72	87,394.22	78,867.41	75,206.62
IPPU	14,532.25	14,673.33	15,425.62	12,739.51	13,173.76	12,987.40	11,185.04	11,661.84	10,320.16	11,140.31	11,974.28	12,368.83
Agriculture	8,940.86	8,981.46	8,769.53	8,692.46	8,812.99	8,607.75	8,659.70	8,945.17	8,738.11	8,695.63	8,785.14	8,743.10
Waste	5,402.65	5,356.02	5,398.65	5,564.75	5,342.77	5,331.73	5,031.65	5,360.89	5,156.27	4,961.62	5,042.45	5,084.76
Total ¹⁾	131,771.86	132,400.31	136,036.69	132,177.27	134,963.67	131,309.28	124,805.25	118,733.29	115,682.27	112,191.78	104,669.27	101,403.31
LULUCF	-2,582.97	-2,793.47	-3,068.53	-3,197.24	-1,474.02	-3,129.32	-3,239.88	-3,260.71	-3,301.96	-3,246.83	-3,148.45	-3,236.67
Index per sector												
Energy	133.78	134.42	138.39	136.75	139.94	135.71	129.92	120.61	118.92	113.62	102.54	97.78
IPPU	129.44	130.70	137.40	113.47	117.34	115.68	99.63	103.87	91.92	99.23	106.66	110.17
Agriculture	87.78	88.18	86.09	85.34	86.52	84.51	85.02	87.82	85.79	85.37	86.25	85.84
Waste	83.12	82.41	83.06	85.62	82.20	82.03	77.42	82.48	79.33	76.34	77.58	78.23
Total ²⁾	125.70	126.30	129.77	126.09	128.75	125.26	119.06	113.27	110.36	107.03	99.85	96.73

¹⁾ Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

²⁾ *Land Use, Land Use Change and Forestry* is not included

2.3 Description and interpretation of emission trends by gas

2.3.1 Carbon dioxide

The trend of carbon dioxide emissions from 1990 to 2014 by source category is presented in **Table 2.3**. Total CO₂ emissions increased from 83.4 Mt in 1990 to 79.63 Mt in 2014 (without LULUCF). The decrease of 4.53% from 1990 to 2014 is mainly attributed to economic crisis. Other reasons are the increased share of natural gas in energy mix and RES technologies.

CO₂ emissions from *Energy* increased, from 74.69 Mt in 1990 to 73.30 Mt in 2014, presenting a total decrease of 1.87% from 1990 to 2014. Carbon dioxide emissions from *Industrial processes and product use* in 2014 decreased by 27.14% compared to 1990 levels. Finally, emissions from *Waste* in 2009 show a continuous increase from 1990. (**Figure 2.2**).

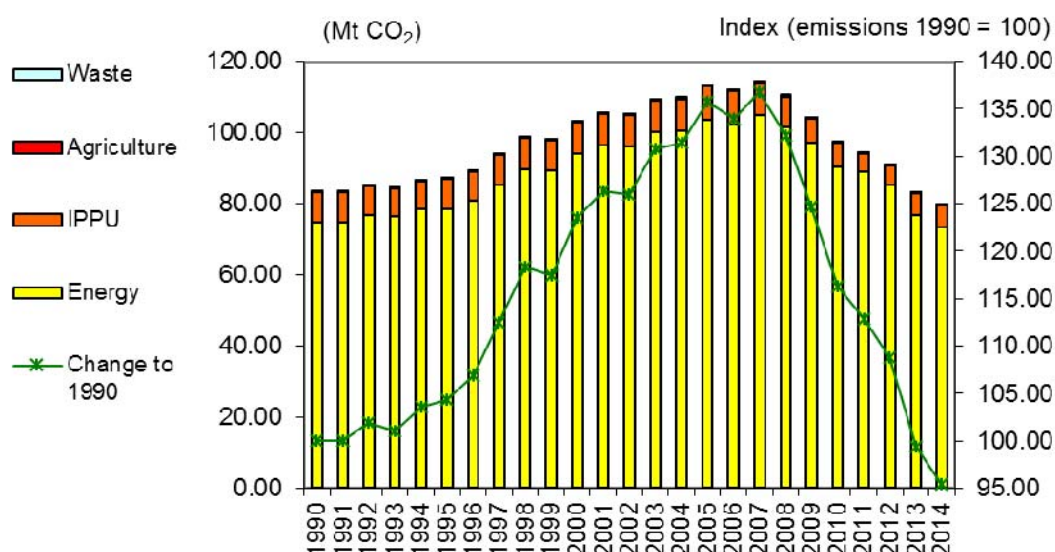


Figure 2.2 CO₂ emissions by sector (in Mt) for the years 1990 – 2014 (without LULUCF)

Table 2.3a *CO₂ emissions / removals by sector for the period 1990-2002 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total (with LULUCF)	81,057.60	80,879.41	82,392.87	81,322.47	83,743.59	84,038.84	86,494.13	92,006.10	96,676.96	95,342.02	100,912.25	103,029.69	102,169.68
Total (without LULUCF)	83,403.72	83,390.35	84,949.03	84,263.01	86,425.86	86,980.65	89,134.43	93,839.87	98,663.19	97,979.78	103,019.66	105,407.31	105,051.47
Energy	74,692.89	74,777.69	76,712.41	76,350.95	78,522.74	78,575.00	80,733.85	85,246.03	89,833.75	89,246.07	94,077.78	96,431.04	96,173.16
A. Fuel combustion	74,650.19	74,734.53	76,676.12	76,321.48	78,496.96	78,552.45	80,708.90	85,223.38	89,818.14	89,245.22	94,063.82	96,421.21	96,163.52
1. Energy industries	43,093.70	41,932.61	44,212.55	44,111.98	46,089.07	44,857.20	44,037.52	47,473.14	49,995.24	50,294.82	54,739.01	55,254.97	54,678.66
2. Man. Industry and Construction	9,338.49	9,387.80	9,044.66	8,760.33	8,610.16	9,481.90	10,087.60	10,194.95	10,152.18	9,139.77	9,847.74	9,971.73	9,426.05
3. Transport	14,152.49	14,965.13	15,334.40	15,505.85	15,798.92	16,135.88	16,587.98	17,291.90	19,056.90	19,372.81	18,427.46	19,290.09	19,613.85
4. Other sectors	8,065.52	8,449.00	8,084.51	7,943.33	7,998.81	8,077.46	9,995.79	10,263.39	10,613.82	10,437.82	11,049.60	11,904.42	12,444.96
B. Fugitive emissions	42.70	43.16	36.30	29.47	25.77	22.55	24.96	22.65	15.61	0.85	13.97	9.83	9.63
IPPU	8,650.20	8,554.31	8,180.83	7,868.10	7,862.15	8,360.40	8,354.33	8,549.88	8,785.34	8,691.74	8,903.19	8,939.01	8,841.78
A. Mineral Industry	6,775.43	6,696.57	6,775.95	6,730.23	6,702.72	7,186.10	7,176.80	7,255.63	7,294.80	7,285.27	7,492.72	7,549.59	7,312.47
B. Chemical Industry	680.65	649.65	248.00	170.01	30.43	32.03	33.38	116.18	382.22	353.33	281.96	135.77	165.68
C. Metal Industry	1,012.05	1,049.91	999.29	814.52	979.88	1,006.91	1,014.44	1,040.53	986.22	918.40	1,000.97	1,111.55	1,239.96
LULUCF	-2,346.12	-2,510.94	-2,556.15	-2,940.54	-2,682.27	-2,941.80	-2,640.29	-1,833.77	-1,986.24	-2,637.76	-2,107.42	-2,377.62	-2,881.78
Waste	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.48
International transport ¹⁾	10,479.79	9,480.49	10,665.72	12,221.26	13,272.17	13,883.18	12,418.33	12,364.54	13,642.22	12,710.50	13,890.86	13,387.52	12,225.58
Aviation	2,439.00	2,103.14	2,194.20	2,335.46	2,771.76	2,599.12	2,489.26	2,407.68	2,526.96	2,837.73	2,489.34	2,313.49	2,313.55
Marine	8,040.79	7,377.35	8,471.51	9,885.80	10,500.41	11,284.06	9,929.06	9,956.87	11,115.26	9,872.77	11,401.52	11,074.04	9,912.03

1) Emissions from International transport are not included in national totals.

Table 2.3b *CO2 emissions / removals by sector for the period 2003-2014 (in kt)*

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total (with LULUCF)	106,537.84	106,762.99	110,141.75	108,558.09	112,309.31	107,079.81	100,680.45	93,756.79	90,781.77	87,416.71	79,744.86	76,381.41
Total (without LULUCF)	109,126.57	109,571.06	113,219.82	111,777.74	114,127.55	110,255.77	103,969.78	97,035.08	94,102.94	90,710.57	82,910.63	79,628.27
Energy	100,081.90	100,550.62	103,604.60	102,394.09	104,842.63	101,624.39	97,315.80	90,421.29	89,133.33	85,196.59	76,899.78	73,297.28
A. Fuel combustion	100,074.88	100,543.77	103,599.00	102,388.47	104,838.06	101,620.84	97,311.36	90,415.32	89,128.09	85,191.64	76,895.71	73,293.53
1. Energy industries	55,921.54	57,238.34	58,058.17	55,895.54	59,371.47	58,019.05	54,480.47	52,036.60	53,838.38	54,507.26	49,205.02	45,784.63
2. Man. industry and Construction	9,102.77	8,618.35	10,134.37	10,369.07	9,959.13	9,325.77	7,436.78	6,813.24	4,917.03	5,457.78	5,229.16	5,397.33
3. Transport	20,694.87	21,127.34	21,192.35	22,018.93	22,778.26	21,822.97	24,719.39	21,990.79	19,569.69	15,969.52	17,558.42	17,300.80
4. Other sectors	14,355.70	13,559.75	14,214.11	14,104.93	12,729.20	12,453.05	10,674.72	9,574.70	10,802.99	9,257.07	4,903.11	4,810.77
B. Fugitive emissions	7.03	6.85	5.59	5.62	4.57	3.55	4.44	5.97	5.24	4.95	4.07	3.75
IPPU	9,008.62	8,983.06	9,581.38	9,351.32	9,248.16	8,599.05	6,625.46	6,580.30	4,940.78	5,485.76	5,981.72	6,302.11
A. Mineral Industry	7,348.96	7,357.02	7,926.76	7,635.81	7,471.57	6,957.92	5,321.32	4,920.64	3,108.57	3,738.18	4,283.01	4,494.59
B. Chemical Industry	286.61	304.52	296.92	313.93	317.94	338.06	453.25	632.88	584.38	502.02	516.91	569.38
C. Metal Industry	1,239.99	1,182.25	1,215.54	1,233.61	1,301.47	1,167.74	732.64	909.45	1,137.50	1,139.16	1,072.63	1,124.76
LULUCF	-2,588.73	-2,808.08	-3,078.07	-3,219.66	-1,818.25	-3,175.96	-3,289.33	-3,278.29	-3,321.17	-3,293.86	-3,165.77	-3,246.86
Waste	0.85	1.05	1.93	2.41	3.13	3.68	3.60	3.14	2.99	3.23	3.12	3.11
International transport ¹⁾	13,173.30	13,340.43	11,511.49	12,712.18	12,969.70	12,872.75	10,961.76	10,796.79	11,144.45	9,854.93	9,568.31	8,878.27
Aviation	3,011.38	3,095.58	2,376.88	2,850.96	2,913.77	3,029.92	2,606.08	2,084.93	2,268.30	2,514.03	2,472.00	2,829.92
Marine	10,161.92	10,244.85	9,134.61	9,861.22	10,055.93	9,842.83	8,355.68	8,711.86	8,876.15	7,340.89	7,096.31	6,048.35

¹⁾ Emissions from International transport are not included in national totals.

2.3.2 Methane

The trend of methane emissions from 1990 to 2014 by source category is presented in **Table 2.4** and in **Figure 2.3**. Emissions present an abrupt decrease in 2001 mainly due to Waste Sector, while in 2014 emissions are slightly lower than 2013.

Waste represents the largest anthropogenic source of methane emissions in Greece accounting for 42.35% of total methane emissions in 2014 (without *LULUCF*). Methane emissions from Waste decreased by 23.8% since 1990 and are mainly attributed to Solid Waste Disposal on Land and Wastewater Handling.

Methane emissions from *Agriculture* in 2014 increased by 0.53% compared to 1990 levels. Methane emissions from *Agriculture*, with enteric fermentation being the main source category in the sector, in 2014 accounted for 45.08% of total methane emissions. Methane emissions from the *Energy sector* (mainly fugitive emissions from coal mining and production, processing, and distribution of liquid fuels and natural gas) account for almost the remaining 12.56% of the total methane emissions. Finally, the contribution of CH₄ emissions from *Iron and Steel Production* can be considered negligible (0.002%).

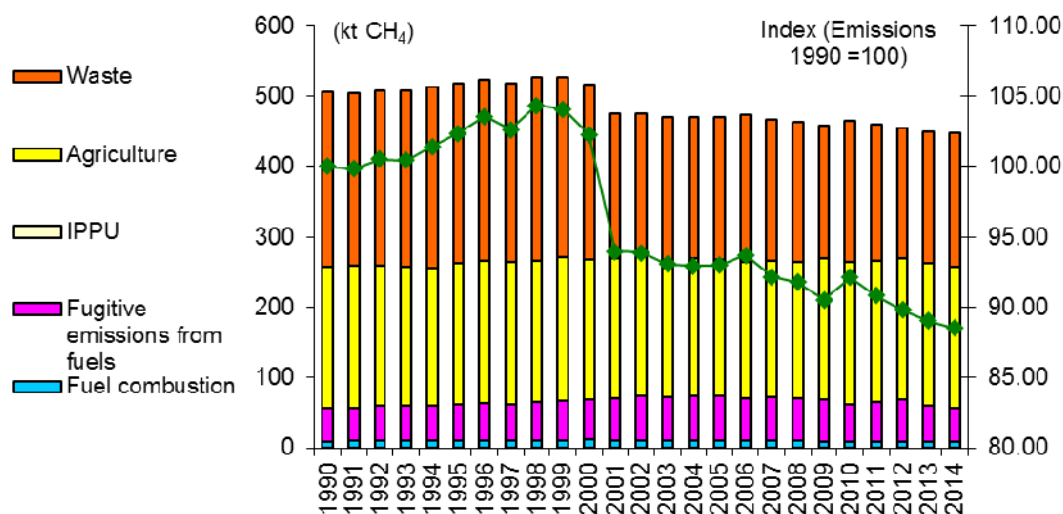


Figure 2.3 *CH₄ emissions by sector (in kt) for the period 1990 – 2014 (without LULUCF)*

Table 2.4a *CH₄ emissions by source category for the period 1990-2002 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total (with LULUCF)	508.28	506.21	512.06	511.30	515.99	519.51	525.04	521.36	534.01	527.08	525.59	476.39	475.05
Total (without LULUCF)	505.79	504.97	508.40	508.04	512.95	517.79	523.99	519.07	527.77	526.60	517.36	475.28	474.90
Energy	56.21	57.51	60.19	59.34	60.43	61.24	63.31	62.49	64.88	66.53	69.48	71.18	73.90
A. Fuel combustion	9.56	10.21	10.96	10.58	10.16	10.15	10.24	10.13	10.18	10.86	11.56	11.22	10.24
1. Energy industries	0.57	0.57	0.58	0.59	0.60	0.61	0.60	0.63	0.65	0.66	0.73	0.72	0.72
2. Manufacturing industry and Construction	0.48	0.47	0.47	0.45	0.44	0.46	0.50	0.50	0.49	0.47	0.52	0.52	0.53
3. Transport	4.42	4.47	4.42	4.47	4.46	4.51	4.53	4.61	4.77	4.90	4.93	5.06	4.99
4. Other sectors	4.09	4.71	5.50	5.07	4.66	4.58	4.62	4.39	4.27	4.83	5.37	4.92	4.00
B. Fugitive emissions from fuels	46.66	47.30	49.23	48.77	50.27	51.09	53.06	52.37	54.69	55.67	57.93	59.96	63.67
1. Solid fuels	45.20	45.90	47.95	47.75	49.36	50.22	52.07	51.25	53.03	54.05	55.65	57.79	61.38
2. Oil and natural gas	1.46	1.40	1.28	1.02	0.90	0.86	0.99	1.11	1.66	1.62	2.28	2.18	2.29
IPPU	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.03	0.02	0.01	0.02
Agriculture	200.73	201.07	198.37	198.28	195.88	201.16	201.89	202.29	201.64	204.14	199.15	197.72	199.65
A. Enteric fermentation	160.69	160.92	158.51	157.14	154.26	158.95	159.28	159.36	159.37	162.73	158.59	157.49	159.08
B. Manure management	35.38	35.28	35.36	35.59	35.26	35.47	35.38	35.59	35.60	35.34	35.10	34.49	34.62
C. Rice cultivation	3.29	2.95	2.94	4.05	4.74	5.22	5.72	5.82	5.25	4.67	3.98	4.22	4.48
F. Field burning of agricultural residues	1.37	1.91	1.56	1.49	1.63	1.52	1.50	1.52	1.42	1.40	1.48	1.51	1.46
LULUCF	2.49	1.24	3.66	3.26	3.04	1.73	1.04	2.29	6.24	0.48	8.23	1.11	0.15
Waste	248.80	246.33	249.78	250.36	256.59	255.33	258.74	254.23	261.19	255.91	248.70	206.36	201.33
A. Solid waste disposal on land	89.75	92.52	95.50	98.62	101.96	105.53	109.27	113.24	117.36	121.59	126.61	109.92	114.92
B. Wastewater treatment and discharge	159.04	153.81	154.29	151.74	154.63	149.80	149.47	140.86	143.70	134.19	121.97	96.45	86.41
C. Waste Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
International Transport ¹⁾	0.67	0.61	0.69	0.81	0.86	0.91	0.81	0.82	0.92	0.82	0.95	0.94	0.84
Aviation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Marine	0.66	0.60	0.68	0.80	0.85	0.90	0.80	0.80	0.91	0.81	0.94	0.92	0.83
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¹⁾ Emissions from International Transport are not included in national totals

Table 2.4b *CH₄ emissions by source category for the period 2003-2014 (in kt)*

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total (with LULUCF)	470.95	470.73	470.70	474.87	478.85	465.97	459.79	466.55	460.09	455.92	451.05	448.03
Total (without LULUCF)	470.73	470.19	470.35	474.04	466.12	464.24	457.96	465.90	459.38	454.18	450.41	447.65
Energy	72.10	74.31	73.38	69.84	71.70	70.91	69.61	62.60	65.02	67.99	59.63	56.24
A. Fuel combustion	10.12	10.60	10.03	10.36	10.15	9.80	9.45	9.43	9.23	8.74	8.62	8.42
1. Energy industries	0.75	0.74	0.77	0.77	0.82	0.82	0.72	0.66	0.67	0.67	0.63	0.59
2. Manufacturing industry and Construction	0.46	0.46	0.56	0.53	0.52	0.55	0.48	0.46	0.45	0.36	0.26	0.31
3. Transport	4.96	5.00	4.83	4.76	4.56	4.26	4.07	4.30	3.74	2.81	3.34	3.23
4. Other sectors	3.96	4.40	3.88	4.29	4.25	4.17	4.19	4.01	4.36	4.91	4.39	4.29
B. Fugitive emissions from fuels	61.98	63.71	63.35	59.48	61.55	61.11	60.16	53.18	55.79	59.25	51.01	47.82
1. Solid fuels	59.49	61.01	60.45	56.20	57.89	57.24	56.52	49.23	51.10	54.83	46.97	44.29
2. Oil and natural gas	2.50	2.70	2.91	3.29	3.66	3.87	3.64	3.95	4.70	4.41	4.04	3.53
IPPU	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Agriculture	195.37	194.40	193.95	195.00	194.31	193.26	200.19	202.36	201.74	201.48	202.86	201.79
A. Enteric fermentation	155.27	154.21	153.61	155.60	154.60	153.71	159.78	162.02	161.61	161.36	162.66	161.63
B. Manure management	34.23	34.13	34.19	33.54	33.34	32.89	33.24	33.19	32.93	32.90	32.96	32.89
C. Rice cultivation	4.52	4.55	4.62	4.46	5.00	5.00	5.60	5.60	5.60	5.60	5.60	5.60
F. Field burning of agricultural residues	1.36	1.51	1.53	1.40	1.37	1.65	1.57	1.55	1.60	1.63	1.64	1.67
LULUCF	0.21	0.54	0.35	0.83	12.73	1.72	1.83	0.65	0.71	1.74	0.64	0.38
Waste	203.24	201.45	203.00	209.17	200.10	200.05	188.13	200.92	192.60	184.70	187.91	189.60
A. Solid waste disposal on land	123.19	125.42	133.74	139.38	137.05	141.24	131.20	138.99	130.41	122.44	125.59	127.29
B. Wastewater treatment and discharge	80.06	76.02	69.19	69.47	62.70	58.45	56.83	61.40	61.53	61.46	61.52	61.51
C. Waste Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

International Transport ¹⁾	0.87	0.88	0.79	0.86	0.88	0.86	0.73	0.76	0.78	0.64	0.60	0.53
Aviation	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02
Marine	0.86	0.87	0.78	0.84	0.86	0.85	0.72	0.74	0.76	0.62	0.59	0.51

¹⁾ Emissions from International Transport are not included in national totals

2.3.3 Nitrous oxide

The trend of nitrous oxide emissions from 1990 to 2014 by source category is presented in **Table 2.5** and in **Figure 2.4**.

Agriculture represents the largest anthropogenic source of nitrous oxide emissions in Greece (78.37% approximately of the total nitrous oxide emissions in 2014, without *LULUCF*). Emissions from this sector decreased by 28.09% since 1990, mainly because of new agricultural practices applied, affecting the use of synthetic nitrogen fertilizers.

Nitrous oxide is also produced from the reaction between nitrogen and oxygen during fossil fuel combustion. Nitrous oxide emissions from fossil fuels combustion (accounting for 10.74% of total nitrous oxide emissions in 2014) decreased by 38.35% from 1990.

Production of nitric acid is the major source of N_2O emissions from *Industrial processes and product use* and accounts for 3.60% of total N_2O emissions in 2014. Nitrous oxide emissions from this source decreased by 85.93% from 1990, due to the reduction of nitric acid production in Greece. However, it should be mentioned that the high decrease between 2011 and 2012, which was attributed to the economic recession, is 26.91%. N_2O emissions from *Waste* in 2014 (7.29% of total emissions without *LULUCF*) increased by 22.26% compared to 1990 levels.

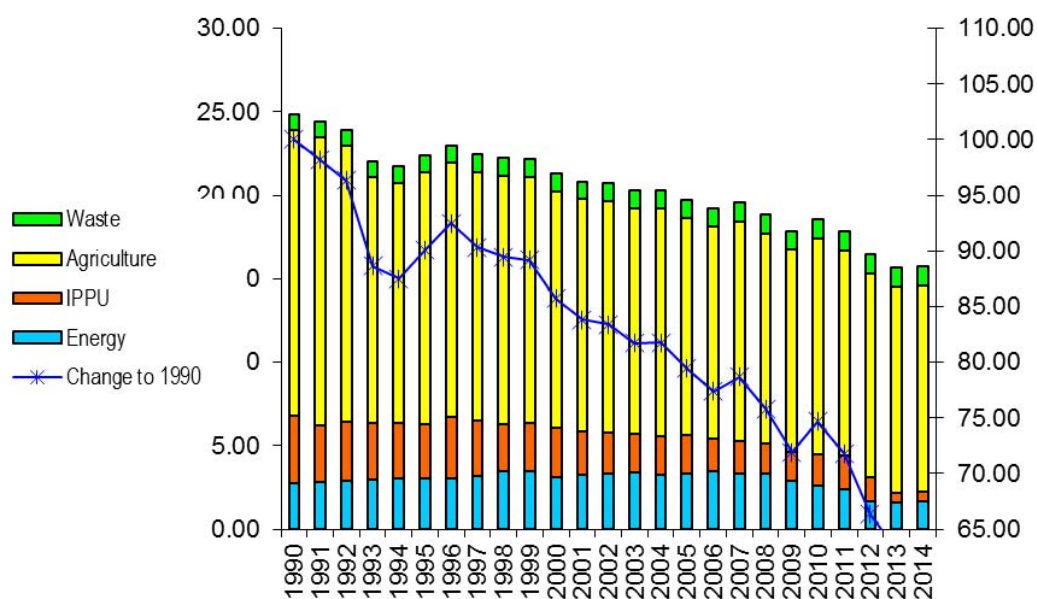


Figure 2.4 *N₂O emissions by sector (in kt) for the period 1990 – 2014 (without LULUCF)*

Table 2.5a *N₂O emissions by source category for the period 1990-2002 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total (with LULUCF)	24.86	24.40	23.95	22.05	21.77	22.39	22.98	22.45	22.26	22.17	21.35	20.84	20.71
Total (without LULUCF)	24.84	24.39	23.93	22.03	21.75	22.38	22.98	22.44	22.22	22.16	21.30	20.83	20.71
Energy	2.74	2.85	2.88	2.95	3.04	3.01	3.04	3.18	3.45	3.48	3.11	3.26	3.31
A. Fuel combustion	2.74	2.85	2.88	2.95	3.04	3.01	3.04	3.18	3.45	3.48	3.11	3.26	3.31
1. Energy industries	0.49	0.47	0.50	0.50	0.52	0.50	0.49	0.53	0.56	0.55	0.59	0.60	0.59
2. Man. industry and Construction	0.18	0.19	0.19	0.18	0.19	0.21	0.24	0.25	0.24	0.22	0.25	0.26	0.25
3. Transport	0.92	0.97	1.03	1.13	1.21	1.25	1.23	1.33	1.58	1.62	1.17	1.30	1.30
4. Other sectors	1.16	1.22	1.16	1.14	1.12	1.05	1.08	1.07	1.07	1.08	1.10	1.11	1.18
B. Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPPU	4.02	3.40	3.54	3.39	3.31	3.30	3.71	3.32	2.82	2.91	2.97	2.57	2.50
Agriculture	17.14	17.20	16.54	14.72	14.41	15.07	15.23	14.92	14.92	14.71	14.13	13.94	13.85
B. Manure management	1.02	1.03	1.02	1.01	1.01	1.03	1.03	1.04	1.05	1.09	1.03	1.00	1.05
D. Agricultural soils	16.08	16.12	15.48	13.67	13.36	14.01	14.16	13.85	13.84	13.59	13.07	12.89	12.77
F. Field burning of agr.. residues	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
LULUCF	0.02	0.01	0.03	0.02	0.02	0.01	0.01	0.02	0.04	0.00	0.06	0.01	0.00
Waste	0.94	0.95	0.96	0.97	0.99	1.00	1.00	1.02	1.03	1.07	1.08	1.06	1.05
International transport ¹⁾	0.87	0.85	1.04	1.16	1.28	1.49	1.23	1.22	1.24	1.16	1.24	1.06	0.96
Aviation	0.08	0.07	0.07	0.07	0.09	0.08	0.08	0.08	0.08	0.09	0.08	0.07	0.07
Marine	0.79	0.78	0.98	1.08	1.19	1.40	1.15	1.14	1.16	1.07	1.16	0.99	0.89

²⁾ Emissions from International transport are not included in national totals

Table 2.5b *N₂O emissions by source category for the period 2003-2014 (in kt)*

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total (with LULUCF)	20.30	20.32	19.74	19.24	19.64	18.84	17.88	18.55	17.85	16.50	15.68	15.73
Total (without LULUCF)	20.30	20.32	19.74	19.23	19.55	18.83	17.87	18.55	17.84	16.48	15.67	15.73
Energy	3.39	3.29	3.37	3.49	3.35	3.31	2.93	2.61	2.38	1.67	1.60	1.69
A. Fuel combustion	3.39	3.29	3.37	3.49	3.35	3.31	2.93	2.61	2.38	1.67	1.60	1.69
1. Energy industries	0.60	0.61	0.62	0.58	0.60	0.59	0.57	0.53	0.54	0.55	0.49	0.46
2. Man. industry and Construction	0.23	0.24	0.31	0.32	0.31	0.33	0.30	0.26	0.19	0.20	0.18	0.24
3. Transport	1.28	1.33	1.32	1.42	1.38	1.36	1.22	1.07	0.84	0.68	0.68	0.72
4. Other sectors	1.28	1.12	1.12	1.18	1.06	1.03	0.84	0.75	0.81	0.24	0.25	0.27
B. Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPPU	2.34	2.25	2.24	1.91	1.90	1.85	1.67	1.87	2.02	1.48	0.55	0.57
Agriculture	13.49	13.71	13.05	12.71	13.16	12.58	12.18	12.94	12.31	12.19	12.37	12.32
B. Manure management	1.01	1.02	1.04	1.05	1.02	1.02	1.08	1.09	1.10	1.09	1.10	1.09
D. Agricultural soils	12.45	12.65	11.97	11.63	12.10	11.52	11.07	11.81	11.17	11.06	11.23	11.19
F. Field burning of agr. residues	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
LULUCF	0.00	0.00	0.00	0.01	0.09	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Waste	1.08	1.07	1.08	1.12	1.13	1.10	1.09	1.12	1.14	1.14	1.15	1.15
International transport ¹⁾	0.93	0.91	0.75	0.80	0.77	0.74	0.66	0.69	0.65	0.58	0.58	0.56
Aviation	0.10	0.10	0.08	0.09	0.09	0.10	0.08	0.07	0.07	0.08	0.07	0.11
Marine	0.83	0.81	0.68	0.71	0.68	0.64	0.58	0.62	0.58	0.50	0.51	0.46

²⁾ Emissions from International transport are not included in national totals

2.3.4 Halocarbons and sulphur hexafluoride

HFCs and PFCs are chemical substances, the production of which aims mainly to the substitution of ozone depleting substances (see Montreal Protocol – 1987). HFC and PFC are not harmful to the stratospheric ozone layer and thus their emissions are not controlled by the above-mentioned Protocol. However, many of these substances, as well as SF₆, are powerful greenhouse gases; in addition, apart from being characterized by a high Global Warming Potential (GWP), these gases have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere. Especially sulphur hexafluoride is the most potent greenhouse gas according to the IPCC evaluation.

Emission estimates of these gases presented in *Table 2.6* originate from:

- 1) The production of HCFC-22 (emissions of HFC-23) and aluminium production (emissions of CF₄ and C₂F₆). HFC-23 emissions have been increasing steadily up to 1999 due to an equivalent increase in the production of HCFC-22, while PFC emissions from aluminium have dropped due to the control/reduction of the "anode effect" during the production process, since 1990 (with the exception of the period 1997 – 2000). Emissions in the years 2008-2014 show fluctuations that are mainly attributed to the production levels. HFC-23 emissions are reported as not occurring since 2006, due to the closure of the plant producing HCFC-22.
- 2) Manufacturing, operation and maintenance of refrigeration and air conditioning equipment. f-gases emissions increased significantly since 1995 (base year), mainly due to the increase of air conditioning equipment in the residential sector, the increasing trend of emissions from the commercial refrigeration and the introduction of new passenger cars with air-conditioning systems, but also due to substitution of CFCs, following the implementation of the Montreal Protocol, leading to an increase in the number of equipment operating with f-gases
- 3) Use of f-gases (mainly HFC-134a) in aerosol products. The main application regards the use of HFC-134a in metered dose inhalers, as provided by the National Organization of Medicines and plants of the sector. The increment in the MDIs emissions is important in the recent years, mainly due to the inclusion of new MDIs brands in the recent years. Other aerosol applications regard the use of HFC-134a by one company in Greece, according to data received by the Hellenic Aerosol Association.
- 4) Use of HFC-134a and HFC-152a in foam blowing since 2001, as reported by the four plants of the sector. Emissions show a peak in 2006, resulting from the use of f-gases by three of the plants in that particular year.
- 5) The use of SF₆ in the electricity transmission and distribution system of the Public Power Corporation of Greece. Emissions mainly derive from the use of SF₆ in the transmission system, as the equipment used by the distribution system and by the medium voltage Greek clients refers to sealed pressure systems, minimizing the possibility of SF₆ leakages.
- 6) Finally, the emissions from fire extinguishers, which follow a continuous increasing trend in the inventory years.

Table 2.6 *Actual F-gases emissions for the period 1990-2014 (in kt CO₂ eq)*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
HFC	1,182.821	400.081	149.072	032.442	712.114	157.384	820.175	166.495	767.516	721.155	261.834	781.395	090.07
HFC-23	1,182.821	400.081	149.072	032.342	711.954	114.994	738.965	016.145	529.616	377.164	761.244	071.514	102.40
HFC-32						0.03	0.22	0.73	1.45	2.45	4.78	9.23	15.15
HFC-125						6.10	12.12	24.10	39.46	57.46	90.44	137.29	198.05
HFC-134a				0.10	0.16	27.34	52.43	95.30	149.77	215.02	305.89	427.11	547.39
HFC-152a												2.78	51.22
HFC-143a						8.92	16.44	30.21	47.21	65.88	95.11	127.57	168.30
HFC-227ea										3.17	4.37	5.89	7.57
PFC	190.26	191.19	187.74	112.94	70.31	62.85	53.73	125.64	155.48	105.31	122.26	84.10	88.29
SF₆	2.93	3.02	3.11	3.20	3.29	3.42	3.51	3.56	3.60	3.69	3.81	3.88	4.06
Total	1,376.001	594.291	339.932	148.582	785.714	223.654	877.415	295.685	926.606	830.155	387.904	869.375	182.41

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
HFC	4,733.36	4,927.91	5,077.45	2,722.45	3,245.14	3,710.35	3,964.12	4,388.67	4,661.66	5,061.78	5,650.225	758.13
HFC-23	3,444.78	3,317.29	2,832.99	114.65	171.78	186.46	190.76	221.65	196.32	220.06	222.78	180.55
HFC-32	24.38	36.24	48.77	63.42	79.69	95.41	110.41	133.11	164.13	206.95	279.77	306.06
HFC-125	280.48	381.28	529.08	639.15	804.19	946.15	1,070.21	1,283.25	1,495.19	1,791.55	2,194.69	2,373.39
HFC-134a	677.57	825.17	1,166.96	1,343.16	1,525.19	1,741.52	1,809.97	1,864.24	1,884.16	1,847.38	1,960.28	1,877.90
HFC-152a	81.63	88.67	105.66	133.60	141.14	152.37	155.26	159.96	162.36	167.08	158.40	159.04
HFC-143a	214.72	266.35	377.70	409.08	500.06	561.97	597.83	693.47	723.09	790.29	793.33	818.00
HFC-227ea	9.80	12.91	16.29	19.40	23.08	26.47	29.69	32.99	36.40	38.47	40.97	43.19
PFC	89.28	87.86	91.51	87.21	103.04	118.95	91.35	129.44	110.53	147.77	172.56	134.63
SF₆	4.06	4.26	6.16	7.98	9.46	7.18	5.02	5.86	5.13	5.05	5.15	4.92
Total	4,826.69	5,020.03	5,175.12	2,817.64	3,357.65	3,836.48	4,060.49	4,523.97	4,777.31	5,214.60	5,827.935	897.68

2.4 Description and interpretation of emission trends for KP-LULUCF inventory in aggregate and by activity, and by gas

Since 1990, land areas afforested were 33,25 ha, land areas deforested were 5,19 ha and land areas under forest management were 1,234,49 ha. In 2014 net removals from ARD activities were 89.70 kt CO₂ eq and from Forest Management activities 2468.18 Kt CO₂ eq.

Since there is a clear correspondence between the Kyoto Protocol activities "Afforestation / Reforestation" and "Forest Management", and the UNFCCC categories "Conversion to Forest land" and "Forest land remaining Forest land/managed", the description and interpretation of emission / removal trends for the associated UNFCCC categories can be found in Chapter 6.

The Kyoto Protocol activity of Deforestation encompasses the UNFCCC subcategories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 (Forest land converted to other land uses). In figure 2.5 emissions from these subcategories during the period 1990-2014 are summed up in order to illustrate the effect of deforestation.

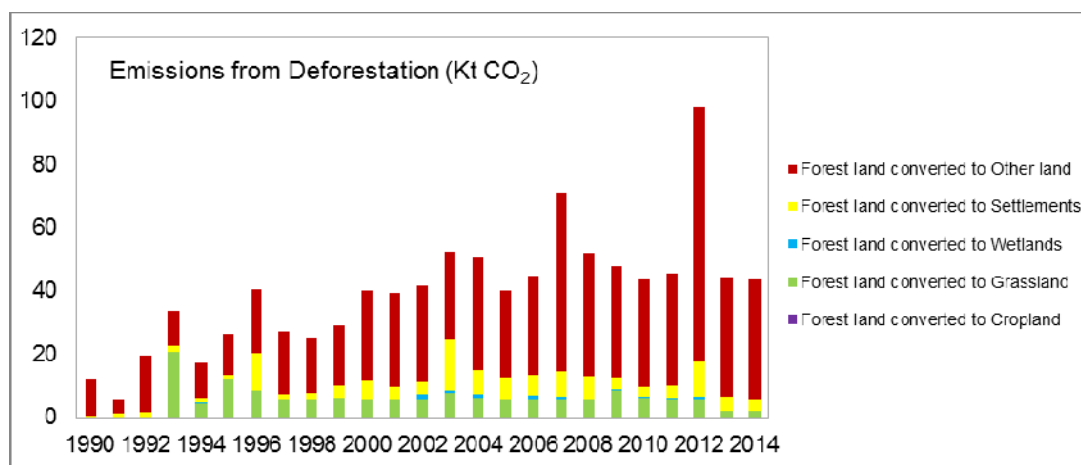


Figure 2.5 *CO₂ emissions (in kt) from deforestation for the period 1990 – 2014*

3. Energy (CRF sector 1)

3.1 Overview of sector

In this chapter, estimations for greenhouse gas emissions from the energy sector are presented and the methodological approach followed per source category is described.

According to the 2006 IPCC Guidelines, this sector includes two general source categories: fuel combustion activities and fugitive emissions from fuels.

In the present report and for presentation purposes, fuel combustion activities are further divided in two main categories, on the basis of the characteristics of the methodology applied for the calculation of emissions:

- ↳ Stationary combustion, including energy industries, manufacturing industries and construction and the other sectors (agriculture, residential and commercial / institutional sectors).
- ↳ Transport, including internal civil aviation, road transport, railways and internal navigation.

3.1.1 Emissions trends

The energy sector relies on fossil fuel combustion for meeting the bulk of energy requirements in Greece. As shown in **Figure 3.1**, gross inland consumption in 2014 amounted to approximately 945 PJ. The consumption of solid fuels and oil products accounts for 78.2% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar, wind energy and geothermal) are 3.0% and 5.6% respectively. Finally, the share of natural gas in gross inland consumption is 9.8%, while the rest of gross inland consumption is covered by electricity (net imports – exports). In 2014, gross inland consumption increased by approximately 3.8% compared to 1990, presenting a 0.2% average annual rate of increase. It should be mentioned that up to 1996 supply of natural gas was exclusively minor quantities from domestic primary production. In essence, the introduction of natural gas in the Greek energy system started in 1997 and since then its consumption has been continuously increasing. Furthermore, since 2007 to 2014 a decrease in gross inland consumption is observed, presenting a about 5.1% average annual rate of decrease.

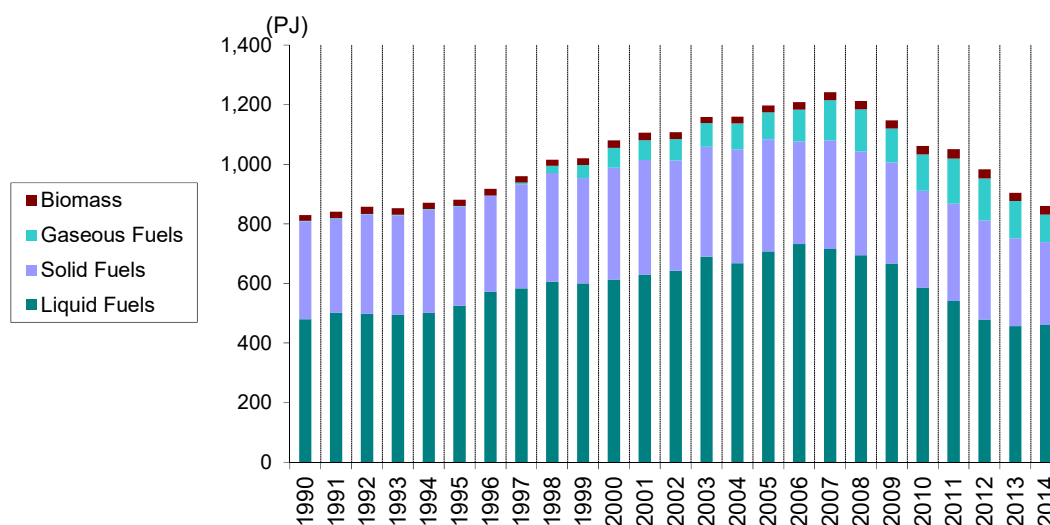


Figure 3.1 Gross inland consumption (in PJ) by energy type for the period 1990 - 2014

GHG emissions from *Energy* in 2014 decreased by 2.2% compared to 1990 (**Figure 3.2**). The highest increase on an annual basis (compared to the previous year) was recorded in 1997 (emissions increased by 5.5%), due to the significant increase in electricity demand as a result of particular weather conditions (very high summer temperatures), while the highest decrease on an annual basis was recorded in 2010 and 2013 (mainly due to the effect of economic crisis).

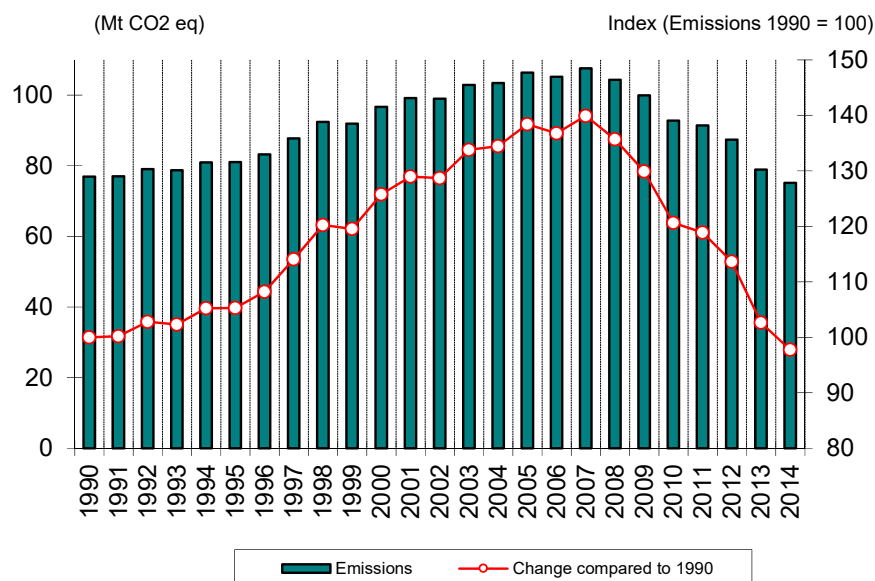


Figure 3.2 Total GHG emissions from Energy (in Mt CO2 eq) for the period 1990 – 2014

The evolution of GHG emissions from *Energy* can be distinguished into five periods that are related to economic development and the penetration of natural gas. At first (1990 – 1995) GHG emissions increased with an average annual rate of 1.0% while Gross Domestic Product (GDP)

increased with an annual rate of 1.7%. Then and up to 2000, GHG emissions increased with an annual rate of 3.7% which is higher than the rate of increase of GDP for the same period (3.4%). The average annual rate of emissions increase for the period 2000 – 2005 was 2.0% while GDP increased with a higher rate (approximately 4%). For the period 2005-2008, a stabilization of the emission levels is observed, although the GDP increased with an annual rate of 3.3%. Finally, a reduction of emissions is observed by 28.0% in 2014 compared to 2008, mainly due to the economic recession, and biomass use in the residential sector, but also due to measures such as the increase of RES and NG share of the energy mixture, along with energy efficiency improvement actions.

Energy is mainly responsible for carbon dioxide emissions, while it contributes also to methane and nitrous oxide emissions. Emissions from energy per greenhouse gas are presented in **Table 3.1**.

The majority of GHG emissions (61.1%) in 2014 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 23.4%, 7.3% and 6.6% respectively. The rest 1.6% of total GHG emissions from *Energy* derived from fugitive emissions from fuels.

Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an increase of 21.0%, followed by energy industries with a 6.2% increase compared to 1990, respectively. Emissions from manufacturing industries and construction emissions and other sectors (i.e. residential, tertiary and agriculture sectors) had decreased by around 41.8% and 41.3%, respectively, compared to 1990. The decrease in the other sectors is noticeable during the recent years. Finally, fugitive emissions from fuels decreased by 0.8% for the period 1990 – 2014.

Table 3.1 *GHG emissions from Energy by source category and gas for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂ emissions (in Mt)																									
A. Fuel Combustion																									
Energy Industries	43.09	41.93	44.21	44.11	46.09	44.86	44.04	47.47	50.00	50.29	54.74	55.25	54.68	55.92	57.24	58.06	55.90	59.37	58.02	54.48	52.04	53.84	54.51	49.21	45.78
Industry	9.34	9.39	9.04	8.76	8.61	9.48	10.09	10.19	10.15	9.14	9.85	9.97	9.43	9.10	8.62	10.13	10.37	9.96	9.33	7.44	6.81	4.92	5.46	5.23	5.40
Transport	14.15	14.97	15.33	15.51	15.80	16.14	16.59	17.29	19.06	19.37	18.43	19.29	19.61	20.69	21.13	21.19	22.02	22.78	21.82	24.72	21.99	19.57	15.97	17.56	17.30
Other Sectors	8.07	8.45	8.08	7.94	8.00	8.08	10.00	10.26	10.61	10.44	11.05	11.90	12.44	14.36	13.56	14.21	14.10	12.73	12.45	10.67	9.57	10.80	9.26	4.90	4.81
B. Fugitive Emissions from Fuels																									
Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
CH ₄ emissions (in kt)																									
A. Fuel Combustion																									
Energy Industries	0.57	0.57	0.58	0.59	0.60	0.61	0.60	0.63	0.65	0.66	0.73	0.72	0.72	0.75	0.74	0.77	0.77	0.82	0.82	0.72	0.66	0.67	0.67	0.63	0.59
Industry	0.48	0.47	0.47	0.45	0.44	0.46	0.50	0.50	0.49	0.47	0.52	0.52	0.53	0.46	0.46	0.56	0.53	0.52	0.55	0.48	0.46	0.45	0.36	0.26	0.31
Transport	4.42	4.47	4.42	4.47	4.46	4.51	4.53	4.61	4.77	4.90	4.93	5.06	4.99	4.96	5.00	4.83	4.76	4.56	4.26	4.07	4.30	3.74	2.81	3.34	3.23
Other Sectors	4.09	4.71	5.50	5.07	4.66	4.58	4.62	4.39	4.27	4.83	5.37	4.92	4.00	3.96	4.40	3.88	4.29	4.25	4.17	4.19	4.01	4.36	4.91	4.39	4.29
B. Fugitive Emissions from Fuels																									
Solid Fuels	45.20	45.90	47.95	47.75	49.36	50.22	52.07	51.25	53.03	54.05	55.65	57.79	61.38	59.49	61.01	60.45	56.20	57.89	57.24	56.52	49.23	51.10	54.83	46.97	44.29
Oil and Natural Gas	1.46	1.40	1.28	1.02	0.90	0.86	0.99	1.11	1.66	1.62	2.28	2.18	2.29	2.50	2.70	2.91	3.29	3.66	3.87	3.64	3.95	4.70	4.41	4.04	3.53
N ₂ O emissions (in kt)																									
A. Fuel Combustion (in kt)																									
Energy Industries	0.49	0.47	0.50	0.50	0.52	0.50	0.49	0.53	0.56	0.55	0.59	0.60	0.59	0.60	0.61	0.62	0.58	0.60	0.59	0.57	0.53	0.54	0.55	0.49	0.46
Industry	0.18	0.19	0.19	0.18	0.19	0.21	0.24	0.25	0.24	0.22	0.25	0.26	0.25	0.23	0.24	0.31	0.32	0.31	0.33	0.30	0.26	0.19	0.20	0.18	0.24
Transport	0.92	0.97	1.03	1.13	1.21	1.25	1.23	1.33	1.58	1.62	1.17	1.30	1.30	1.28	1.33	1.32	1.42	1.38	1.36	1.22	1.07	0.84	0.68	0.68	0.72
Other Sectors	1.16	1.22	1.16	1.14	1.12	1.05	1.08	1.07	1.07	1.08	1.10	1.11	1.18	1.28	1.12	1.12	1.18	1.06	1.03	0.84	0.75	0.81	0.24	0.25	0.27
B. Fugitive Emissions from Fuels (in t)																									
Solid Fuels	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
Oil and Natural Gas	0.59	0.60	0.50	0.41	0.38	0.33	0.36	0.33	0.22	0.01	0.19	0.13	0.13	0.09	0.09	0.08	0.07	0.06	0.05	0.06	0.09	0.07	0.07	0.05	0.05

NA: Not Applicable, NO: Not Occurring

3.1.2 Methodology

The calculation of GHG emissions from fuel combustion activities is based on the 2006 IPCC Guidelines.

The methodology applied for the calculation of emissions by source category for 2014 is briefly presented in *Table 3.2*.

Table 3.2 *Methodology for the estimation of emissions from energy*

CRF	IPCC categories	CO ₂		CH ₄		N ₂ O	
		Method	Emission factor	Method	Emission factor	Method	Emission factor
1A	Fuel combustion						
1A1	Energy industries						
1A1a	Public electricity and heat production	T2	CS, PS	T1	D	T1	D
1A1b	Petroleum refining	T2	PS	T1	D	T1	D
1A1c	Solid fuel manufacturing and other energy industries	T2	PS	T1	D	T1	D
1A2	Manufacturing industries and Construction	T2	CS, PS	T1	D	T1	D
1A3	Transport						
1A3a	Aviation	T2	D	T2	D	T2	D
1A3b	Road transport	T2	CS	M	M, D	M	M, D
1A3c	Railways	T2	CS	T1	CR	T1	CR
1A3d	Navigation	T2	CS	T1	CR	T1	CR
1A3e	Pipeline transport	T1	CS	T1	D	T1	D
1A4	Other sectors						
1A4a	Commercial / Institutional	T2	CS, D	T1	D	T1	D
1A4b	Residential	T2	CS, D	T1	D	T1	D
1A4c	Agriculture / Forestry / Fisheries	T2	CS, D	T1	D	T1	D
1B	Fugitive emissions from fuels						
1B1	Solid fuels	NA	NA	T1	D	NA	NA
1B2	Oil and Natural gas	T1	D	T1	D	T1	D
	International transport						
	Aviation	T2	D	T2	D	T2	D
	Marine	T2	CS	T1	CR	T1	CR

CR=Corinair. CS= Country specific emission factor. PS= Plant Specific. T2a = IPCC Tier 2a. T1= IPCC Tier 1. D = IPCC Default. M= Copert IV model

The energy data used for the calculation of emissions derived from the national energy balance and the reports of installations under the EU ETS. The Ministry of Transport and the Hellenic Statistical Authority are the main sources of information regarding road transport, while data on civil aviation come from the Civil Aviation Organization and Eurocontrol.

Key categories

The key categories identified in the energy sector are presented in **Table 3.3** (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations). These sources are responsible for about 80% of total national GHG emissions in 2014 (without *LULUCF*).

Table 3.3 *Key categories from Energy*

IPCC source categories	Gas	Criteria
Energy industries – Liquid fuels	CO ₂	Level, Trend
Energy industries– Solid fuels	CO ₂	Level, Trend
Energy industries – Gaseous fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO ₂	Trend
Manufacturing Industries & Construction – Liquid fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Gaseous fuels	CO ₂	Level, Trend
Transport – Road transport	CO ₂	Level, Trend
Transport – Navigation	CO ₂	Level, Trend
Transport – Civil Aviation	CO ₂	Level, Trend
Coal mining and handling	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV. In general, the uncertainty of emissions estimates for the energy sector is relatively small (**Table 1.9**). In **Table IV.1 and IV.2** the uncertainty of activity data and emission factors is illustrated.

3.1.3 Completeness

Table 3.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the energy sector.

Table 3.4 *Energy – Completeness of emissions inventory*

ENERGY	Greenhouse gases						Other gases			
	CO ₂	CH ₄	N ₂ O	HFC	PFC	SF ₆	NO _x	CO	NM VOC	SO ₂
Energy industries										
Public electricity and heat production	☒	☒	☒				☒	☒	☒	☒
Petroleum refining	☒	☒	☒				☒	☒	☒	☒
Manufacturing of solid fuels and other energy industries	☒	☒	☒				☒	☒	☒	
Manufacturing industries and Construction										
Iron and steel	☒	☒	☒				☒	☒	☒	☒
Non ferrous metals	☒	☒	☒				☒	☒	☒	☒
Chemicals	☒	☒	☒				☒	☒	☒	☒
Paper, pulp and print	☒	☒	☒				☒	☒	☒	☒
Food processing, Beverages and Tobacco	☒	☒	☒				☒	☒	☒	☒
Other industries	☒	☒	☒				☒	☒	☒	☒
Transport										
Aviation	☒	☒	☒				☒	☒	☒	☒
Road transport	☒	☒	☒				☒	☒	☒	☒
Railways	☒	☒	☒				☒	☒	☒	☒
Navigation	☒	☒	☒				☒	☒	☒	☒
Pipeline transport	☒	☒	☒				☒	☒	☒	☒
Other sectors										
Commercial / Institutional	☒	☒	☒				☒	☒	☒	☒
Residential	☒	☒	☒				☒	☒	☒	☒
Agriculture / Forestry / Fisheries	☒	☒	☒				☒	☒	☒	☒
Fugitive emissions from fuels										
Solid fuels	IE/NO	☒	NA/NO				NA	NA	NA	
Oil	☒	☒	☒				☒	☒	☒	☒
Natural gas	☒	☒	☒						NE	NE
International transport ¹⁾										
Aviation	☒	☒	☒				☒	☒	☒	☒
Marine	☒	☒	☒				☒	☒	☒	☒

¹⁾ Emissions from international transport are not included in national totals

IE: Include Elsewhere

NE: Not Estimated

NA: Not Applicable

3.2 Fuel Combustion (CRF Source Category 1.A)

3.2.1 Comparison of the sectoral approach with the reference approach

According to the 2006 IPCC Guidelines and UNFCCC reporting GLs, carbon dioxide emissions from the energy sector should be calculated using both the reference and the sectoral approach (see Sections 3.2 – 3.3). The reference approach (see **Annex III** for an analytical presentation of the methodology) is based on detailed data on primary energy consumption, which lead to the calculation of apparent consumption and to the consequent calculation of CO₂ emissions, while the sectoral approach is based on a detailed disaggregation of energy consumption by sector, fuel and technology for the calculation of CO₂ emissions.

The application of the reference approach can be considered as a quality control procedure, as the deviation of estimations should not be significant (deviations in the order of $\pm 2\%$) or else explanations should be provided. The estimation of carbon dioxide emissions according to the two methodologies is presented in *Table 3.5*.

Table 3.5 *CO₂ emissions (in kt) according to the reference and the sectoral approach for the period 1990 – 2014*

Year	Reference approach	Sectoral approach	Deviation %
1990	74,738.10	74,650.19	0.12
1991	75,141.30	74,734.53	0.54
1992	77,681.52	76,676.12	1.31
1993	76,786.66	76,321.48	0.61
1994	79,560.15	78,496.96	1.35
1995	79,041.92	78,552.45	0.62
1996	79,738.18	80,708.90	-1.20
1997	83,802.99	85,223.38	-1.67
1998	88,096.11	89,818.14	-1.92
1999	87,603.20	89,245.22	-1.84
2000	92,032.05	94,063.82	-2.16
2001	95,074.83	96,421.21	-1.40
2002	95,022.86	96,163.52	-1.19
2003	96,656.17	100,074.88	-3.42
2004	98,295.63	100,543.77	-2.24
2005	100,311.46	103,599.00	-3.17
2006	97,063.88	102,388.47	-5.20
2007	98,330.37	104,838.06	-6.21
2008	97,496.69	101,620.84	-4.06
2009	94,415.94	97,311.36	-2.98
2010	87,601.98	90,415.32	-3.11
2011	85,859.60	89,128.09	-3.67
2012	86,245.32	85,191.64	1.24

2013	73,740.43	76,895.71	-4.10
2014	71,760.03	73,293.53	-2.09

As shown in the table above, the estimated deviation (which ranges from –6.21% to 1.35%), while the deviation of most years is within the threshold defined by the 2006 IPCC Guidelines. The existing differences result mainly from:

1. **Statistical differences in fuel consumption.** The sectoral approach uses the actual consumption of the different fuels, while the reference approach uses their apparent consumption. Theoretically, both consumption estimates should be equal, but there is usually a difference between them (statistical differences) due to the collection of information from different sources. The reference approach does not provide for the calculation of these differences. The deviation in the calculation of the consumption of liquid fuels (*Table 3.6*) is mainly attributed to the statistical differences.
2. **Losses from transformation, transport and distribution.** During the refining of crude oil and the transmission/distribution of natural gas losses may occur, due to possible leaks in the refining systems, the transmission/distribution pipelines etc. These losses are not taken into account in the reference approach.
3. **Emission factors.** In the reference approach, CO₂ emissions from liquid fuel consumption are mainly estimated assuming "combustion" of crude oil. On the contrary, the sectoral approach calculates emissions using the actual consumption per liquid fuel and appropriate emission factors. Additionally, the emission factor as well as the calorific value of solid fuels (lignite) is differentiated by sector, resulting in deviations in the calculated energy consumption.

The amount "Apparent energy consumption (excluding non-energy use and feedstocks)" of the CRF Table 1A(c) was calculated from the apparent energy consumption calculated through the reference approach excluding the fuel amounts that were not included in the total energy consumption calculated through the sectoral approach. Therefore, it was calculated by subtracting the following fuel consumption per fuel:

- Liquid fuels: bitumen, which was consumed in the construction industry, and petcoke, which was consumed in the non-ferrous industry and accounted in the Industrial Processes sector.
- Solid fuels: coal and lignite, which were consumed in the non-ferrous industry and were accounted in the Industrial Processes sector.
- Gaseous fuels: natural gas, which was used as feedstock for the production of ammonia and hydrogen and accounted in the Industrial Processes sector.

Table 3.6 *Deviations during the calculation of energy consumption (apparent and actual) for the period 1990 – 2014 (%)*

Year	Liquid fuels	Solid fuels	Gaseous fuels
1990	2.88	0.56	0.00
1991	3.99	0.14	-0.63
1992	5.83	0.96	-0.84
1993	3.14	0.87	-0.88
1994	5.06	0.96	-0.09
1995	0.95	3.59	0.00
1996	0.31	0.85	0.00
1997	-0.75	0.63	1.05
1998	-1.32	0.62	0.15
1999	-0.91	0.38	-0.06
2000	-0.58	-0.85	0.80
2001	0.28	-0.08	1.42
2002	0.67	0.24	0.03
2003	-2.91	-0.80	0.09
2004	0.25	-1.62	-0.20
2005	-2.03	-0.80	2.03
2006	-6.22	-0.45	2.04
2007	-9.57	0.10	0.40
2008	-4.12	-1.83	-1.71
2009	-3.52	0.56	1.82
2010	-4.82	0.84	2.10
2011	-6.55	0.12	2.48
2012	5.18	-0.19	2.62
2013	-5.92	-0.11	0.56
2014	-3.16	-0.25	0.42

3.2.2 International bunker fuels

GHG emissions from international aviation and marine bunkers are calculated with the same methodologies as described for internal aviation and navigation. The fuel consumption data used are taken from the national energy balance, as declared by oil trading companies. Finally, the allocation of LTOs between domestic and international aviation was based, up to 2011, on data provided by the Civil Aviation Organisation (Table 3.7). For 2012, 2013 and 2014, the corresponding EUROCONTROL calculation data were used, as they were considered more reliable than CAO data.

For marine bunkers, after a research made with the Laboratory of Fuels of the National Technical University of Athens, country specific carbon content was applied (as it was already done for the whole timeseries).

GHG emissions from international bunkers (Table 3.8a,b,c) decreased by about 25% since 1990 for marine bunkers and increased by 16% for international aviation.

Table 3.7 *Allocation of LTOs to domestic and international aviation for the period 1990-2014*

Year	Domestic	International
1990	60535	61803
1991	52653	59037
1992	57949	71603
1993	63750	74699
1994	63783	80487
1995	67626	78556,5
1996	72558	76995
1997	82440	83806
1998	83851	87857
1999	100264	98049
2000	111481	102174
2001	99765	98332
2002	85721	94421
2003	97974	99913
2004	106108	103818
2005	100336	101246
2006	105927	108783
2007	111424	116176
2008	107182	113275
2009	120063	108790
2010	108102	106330
2011	94687	110427

Year	Domestic	International
2012	95044	104735
2013	87392	107841
2013	87392	107841
2014	91453	123532

Table 3.8(a) *GHG emissions in the transportation sector per category. for the period 1990 – 1999*

Memo items 1) – International bunkers										
Emissions (kt CO ₂ eq)										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
International aviation	2463	2124	2216	2359	2799	2625	2514	2432	2552	2866
International marine	8285	7616	8767	10215	10863	11708	10278	10304	11470	10198

¹⁾ Emissions from international transport are not included in national emissions

Table 3.8(b) *GHG emissions in the transportation sector per category. for the period 2000 – 2009*

Memo items 1) – International bunkers										
Emissions (kt CO ₂ eq)										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
International aviation	2514	2336	2337	3041	3126	2400	2879	2943	3060	2632
International marine	11756	11381	10187	10423	10499	9349	10087	10273	10050	8541

¹⁾ Emissions from international transport are not included in national emissions

Table 3.8(c) *GHG emissions in the transportation sector per category. for 2010-2014*

Memo items 1) – International bunkers Emissions (kt CO ₂ eq)					
	2010	2011	2012	2013	2014
International aviation	2106	2291	2539	2494	2862
International marine	8909	9063	7433	7262	6198

¹⁾ Emissions from international transport are not included in national emissions

3.2.3 Feedstocks and non-energy use of fuels

Non-energy fuel use concerns the consumption of fuels as raw materials (e.g. in chemical industry, metal production) for the production of other products, or the use of fuels for non-energy purposes (e.g. bitumen). Part of the carbon content of fuels is stored in final products and is not oxidized into carbon dioxide for a certain time period. The fraction of the carbon contained in final products and the time period for which carbon is stored in them, depend on the type of fuel used and of the products produced.

The oxidation of the carbon stored in final products occurs either during the use of the product (e.g. solvents) or during their decomposition (e.g. through combustion). It should be noted that emissions during production processes (e.g. ammonia and hydrogen production) should be reported under the sector of IPPU, while emissions from burning of products should be reported under the waste sector or energy sector (as long as energy exploitation takes place).

Non-energy use of fuels in Greece refers to the consumption of:

- ↳ naphtha, natural gas, and lignite (for the period 1990 – 1991) in chemical industry,
- ↳ petroleum coke in the production of non-ferrous metals,
- ↳ lubricants in transport (including off-road transportation),
- ↳ bitumen in construction and
- ↳ other petroleum products in the industrial and residential sectors

The calculation of carbon dioxide emissions from non-energy use of fuels is based on the relevant consumption by fuel type (**Table 3.9**) and the fraction of the carbon stored by fuel type (**Table 3.10**), according to the following equation:

$$E = \sum_f FC_f \cdot CC_f \cdot (1 - CS_f)$$

where, E represents carbon emissions, f is the index of fuel type, FC_f is non-energy consumption of fuel f , CC_f is the carbon content of fuel f and CS_f is the fraction of carbon stored from the non-energy use of fuel f .

Data on the non-energy consumption of fuels derive from the national energy balance. However, plant specific data derived from verified ETS reports and information provided by specific greek industries resulted to the improvement of reallocation of non-energy use fuels from the energy to the industrial processes sector:

- ↳ The non-energy use of natural gas for ammonia production has been reallocated to industrial processes sector since the 2012 submission, by using data from ETS reports and plant specific information. Non-energy use of lignite is accounted in the industrial processes sector and refers only to ammonia production (in one installation for 1990 and 1991) and as a result the

fraction of carbon stored is equal to 0. The operation of this installation ended at 1998 while it did not produce ammonia for the period 1992 – 1998.

- ↳ The non-energy use of natural gas for hydrogen production is included in the industrial processes sector, by using data from ETS reports and information from Public Gas Corporation.
- ↳ CO₂ emissions from the use of fuels as reduction agents in the iron and steel industry, are only reported under the industrial processes sector.
- ↳ Solid fuels consumption in the ferroalloys production industry is included (in the national energy balance) in the solid fuels consumption of the non-ferrous metals sector. However, by using data from ETS reports and plant specific information, emissions from solid fuels for ferroalloys production are reallocated to the industrial processes sector, as from 2010 submission.
- ↳ The non-energy use of petroleum coke (see Table 3.9) refers exclusively to the primary aluminium production. Given that the relevant emissions are reported under the industrial processes sector, petroleum coke consumption is not taken into account in the energy sector.

Since this submission, following 2006 IPCC GLs, all fuels with non-energy use were reallocated to the IPPU sector (e.g. other petroleum products, lubricants, etc). On the basis of the above-mentioned clarifications, the possibility to double-count or underestimate CO₂ emissions from the non-energy use of fuels is minor.

Table 3.9 Non-energy fuel use (in PJ) for the period 1990 – 2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Naphtha	2.6	3.1	2.3	2.3	1.5	3.2	3.9	2.2	0.6	1.0	2.1	1.7	0.9	2.6	4.5	3.6	6.0	6.5	4.0	4.3	4.9	1.6	2.9	0.7	0.1
Lubricants	5.3	3.5	3.5	3.4	3.5	3.0	2.7	3.2	2.1	2.6	2.3	3.2	2.2	2.6	2.8	3.2	4.9	4.1	2.8	1.8	1.6	1.5	1.4	1.5	1.9
Bitumen	8.2	9.0	9.4	10.0	10.2	12.0	12.2	12.3	13.9	14.2	16.3	16.6	17.3	14.8	16.6	11.1	14.6	12.2	18.9	15.0	10.8	4.6	3.3	4.4	6.3
Natural gas	4.0	3.9	3.7	2.4	NO	NO	NO	1.5	6.4	6.3	5.0	2.5	3.0	5.2	5.5	5.4	5.7	5.7	7.9	8.2	11.3	10.5	9.0	9.3	10.7
Lignite (ammonia)	3.2	3.1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal	2.3	2.4	2.3	1.8	3.0	2.8	3.2	2.4	2.1	1.7	1.9	3.8	4.4	4.4	3.8	3.4	2.4	3.5	3.5	2.8	4.9	5.5	6.9	5.6	4.7
Lignite	2.6	2.7	3.4	4.9	3.8	3.9	4.9	4.1	4.0	2.6	4.1	1.7	1.3	1.7	1.9	2.1	3.3	2.7	2.4	0.2	0.2	0.4	NO	0.6	1.6
Petcoke	1.9	2.2	2.3	1.8	1.7	1.5	1.6	1.6	1.6	1.9	1.9	2.0	3.7	2.0	2.0	2.0	2.0	2.3	1.6	1.5	2.2	1.7	1.9	1.9	1.0
Other	2.4	0.4	1.2	0.5	1.2	1.0	0.8	0.9	1.2	0.4	2.9	3.7	4.7	7.5	5.8	6.8	5.5	4.6	4.4	5.5	12.4	11.6	6.9	6.6	6.4

Table 3.10 Carbon stored (%) by fuel

	Naphtha	Lubricants	Bitumen	Natural gas	Lignite	Petroleum coke	Paraffin waxes	Other oil products
Carbon stored	75%	50%	100%	0%	0%	NA	50%	50%

NA: Not Applicable

The fuel consumption from non-energy fuel use per liquid, solid and gaseous fuels are presented in **Table 3.11**.

Table 3.11 *Fuel consumption from non-energy fuel use per liquid, solid and gaseous fuels for the period 1990 - 2014*

Year	Liquid fuels (TJ)	Solid fuels (TJ)	Gaseous fuels (TJ)
1990	20,357.00	8,131.04	4,046.40
1991	18,181.30	8,181.52	3,866.40
1992	18,699.20	5,696.77	3,676.50
1993	18,018.40	6,722.83	2,369.70
1994	17,952.10	6,735.01	NO
1995	20,646.40	6,667.81	NO
1996	21,182.20	8,073.92	NO
1997	20,214.80	6,424.60	1,509.38
1998	19,380.90	6,135.35	6,370.17
1999	20,041.40	4,329.56	6,256.32
2000	25,443.30	6,008.80	5,005.86
2001	27,190.50	5,536.50	2,451.96
2002	28,835.60	5,697.04	2,991.96
2003	29,524.30	6,084.31	5,174.74
2004	31,795.30	5,680.86	5,495.72
2005	26,776.70	5,473.88	5,362.96
2006	32,877.20	5,615.87	5,670.10
2007	29,720.50	6,137.37	5,740.69
2008	31,647.10	5,955.54	7,940.89
2009	28,045.50	3,049.62	8,164.41
2010	31,985.40	5,082.52	11,330.34
2011	20,992.00	5,931.27	10,473.94
2012	16,322.60	6,885.65	8,982.89
2013	15,139.40	6,159.23	9,296.33
2014	15,677.48	6,350.31	10,705.33

3.2.4 Stationary combustion (CRF Source Category 1.A except 1.A.3)

3.2.4.1 Source category description

As it was already mentioned, stationary combustion includes energy industries, manufacturing industries and construction and the other sectors (agriculture, residential and commercial/institutional sectors).

The consumption of fossil fuels in these sectors accounts for 70% - 77% of total fossil fuel consumption in Greece for the period 1990 – 2014 (**Figure 3.3**).

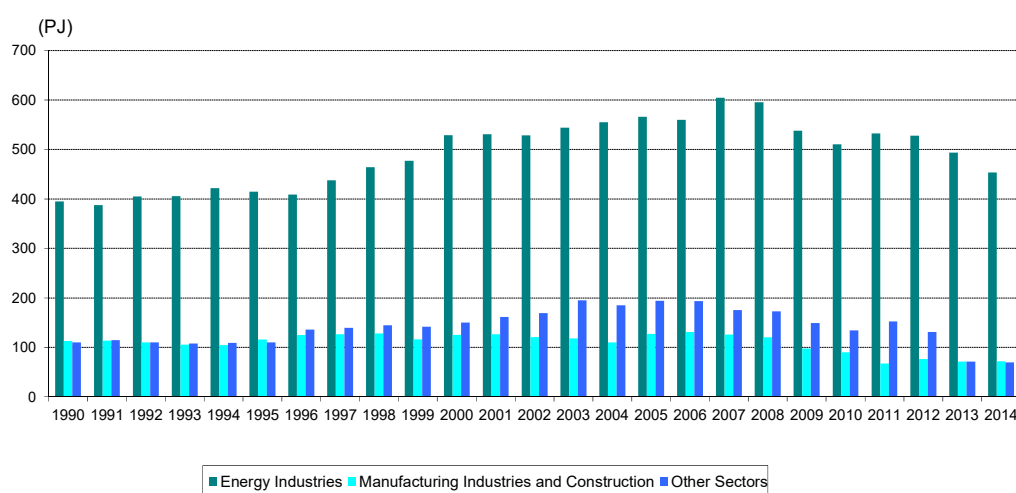


Figure 3.3 Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2014

The consumption of fossil fuels in 2014 decreased by approximately 3.6% compared to 1990.

- ↳ Fuel consumption in energy industries accounts for 66% (average value for the period 1990 – 2014) of fuel consumption in stationary combustion. The average annual rate of increase for the period 1990 – 2014 is estimated at 0.7%, resulting in an increase of 14.8% in 2014 compared to 1990 levels. It is noted, however, that this increase took place mostly after 1996, due to the significant increase of electricity consumption attributed to the improvement of living standards and weather conditions. During the years 2008 – 2014 the fuel consumption in energy industries had a decreasing trend with an average annual rate of 3.9% (with the exception of year 2011).
- ↳ The consumption of fossil fuels in industry presented significant variations on an annual basis that are related to the trend of the industrial production in Greece. Overall, fuel consumption in 2014 decreased by 36.2% compared to 1990 levels.
- ↳ Fossil fuels consumption in Other sectors decreased by 36.6% from 1990 to 2014.

GHG emissions from stationary combustion in general follow the trend of fossil fuels consumption. Therefore, GHG emissions in 2014 (56.41 Mt CO₂ eq) decreased by 7.8% compared to 1990 (61.17 Mt CO₂ eq) (**Figure 3.4**). The years 2008-2014, a decreasing trend of emissions is observed with average annual rate of 5.2%. This decreasing trend is attributed to the penetration of natural gas and RES technologies to the energy mix, the increased use of biomass during the recent years (residential sector), but also, to the economic recession that the country is facing.

It is noted that emissions from stationary combustion account for around 60% of total national emissions (without *LULUCF*) for the period 1990 – 2014, while **eight key categories** are included in this sector (**CO₂ emissions from solid, liquid and gaseous fuels combustion of Energy industries and Manufacturing industries; and CO₂ emissions from liquid and gaseous fuels combustion from Other sectors.**

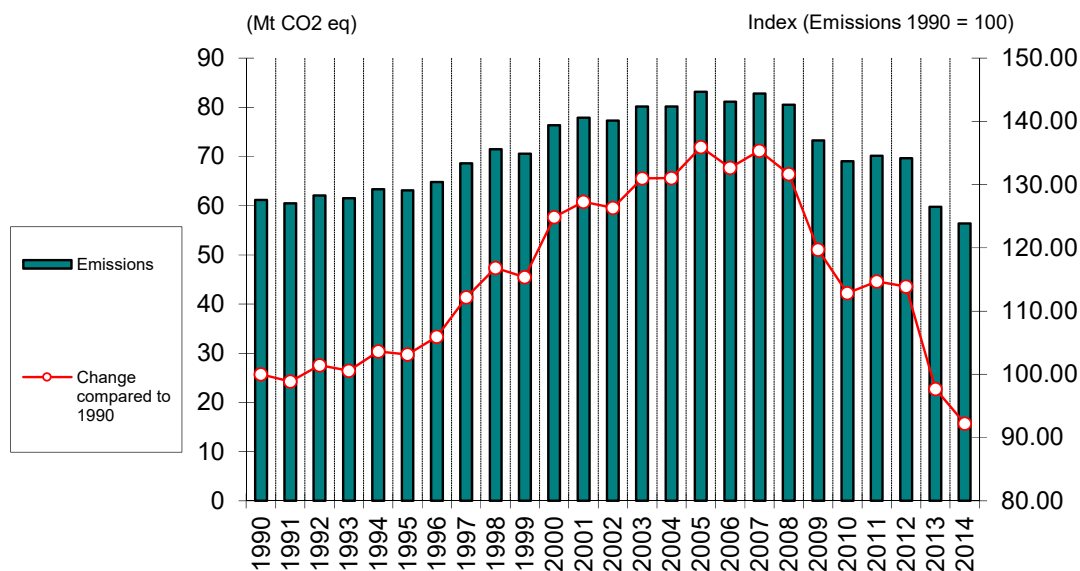


Figure 3.4 *GHG emissions (in Mt CO₂ eq) from stationary combustion for the period 1990 – 2014*

Emissions from stationary combustion per gas and source category are presented in **Table 3.12**.

Carbon dioxide represents the major GHG from stationary combustion with a share in total emissions from stationary combustion being 99.3% in 2014. Overall, CO₂ emissions in 2014 decreased by 7.5% compared to 1990 levels. N₂O emissions in 2014 account for 0.5% of emissions from stationary combustion, decreased by 46.7% compared to 1990. CH₄ emissions account for the rest 0.2% of total emissions of the sector and increased by 1.1% from 1990 to 2014.

Table 3.12 *GHG emissions per gas and source category from stationary combustion for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GHG emissions per gas																									
CO ₂ (in Mt)	60.50	59.77	61.34	60.82	62.70	62.42	64.12	67.93	70.76	69.87	75.64	77.13	76.55	79.38	79.42	82.41	80.37	82.06	79.80	72.59	68.42	69.56	69.22	59.34	55.99
CH ₄ (in kt)	5.13	5.74	6.54	6.11	5.70	5.65	5.72	5.52	5.41	5.96	6.63	6.16	5.24	5.16	5.60	5.20	5.60	5.59	5.54	5.39	5.12	5.48	5.94	5.28	5.19
N ₂ O (in kt)	1.82	1.88	1.85	1.82	1.83	1.76	1.81	1.85	1.87	1.85	1.94	1.96	2.01	2.11	1.96	2.04	2.07	1.97	1.95	1.71	1.54	1.54	0.99	0.92	0.97
GHG emissions per source category (in Mt CO ₂ eq)																									
Energy industries	43.25	42.09	44.38	44.27	46.26	45.02	44.20	47.65	50.18	50.47	54.93	55.45	54.87	56.12	57.44	58.26	56.09	59.57	58.21	54.67	52.21	54.02	54.69	49.37	45.94
Man. Ndustry and cons	9.40	9.46	9.11	8.83	8.68	9.55	10.17	10.28	10.24	9.22	9.94	10.06	9.51	9.18	8.70	10.24	10.48	10.06	9.44	7.54	6.90	4.99	5.53	5.29	5.48
Other sectors	8.51	8.93	8.57	8.41	8.45	8.51	10.43	10.69	11.04	10.88	11.51	12.36	12.90	14.84	14.00	14.65	14.56	13.15	12.86	11.03	9.90	11.15	9.45	5.09	5.00
TOTAL (Mt CO ₂ eq)	61.17	60.47	62.06	61.51	63.39	63.08	64.80	68.62	71.45	70.57	76.38	77.87	77.28	80.14	80.14	83.15	81.13	82.79	80.52	73.24	69.01	70.16	69.66	59.74	56.41

Energy industries constitute the major contributor (81.4% in 2014) in the overall GHG emissions from stationary combustion, followed by manufacturing industry and construction. Emissions from other sectors decreased by 41.3% in 2014 compared to 1990, due to economic recession, switch to biomass and natural gas and energy efficiency measures. The decreasing trend was noticeable during the last years.

3.2.4.2 Methodological issues

The calculation of GHG emissions from stationary combustion was based on the 2006 IPCC Guidelines. CH₄ and N₂O emission factors are differentiated by technology and fuel, while CO₂ emission factors are differentiated only by fuel. The determination of emission factors was based on data derived from verified ETS reports and 2006 IPCC guidelines, as described in this paragraph.

CO₂ emissions from stationary combustion are estimated on the basis of fuel consumption and fuel characteristics, according to the following equation:

$$E_{CO_2} = \sum_f FC_f \cdot NCV_f \cdot CC_f \cdot OX_f \cdot \frac{44}{12}$$

where, E_{CO_2} is CO₂ emissions, f is an index referring to the fuel consumed, FC_f is the consumption of fuel- f , CC_f is the carbon content of fuel- f , NCV_f is the net calorific value of fuel- f and OX_f is the oxidation factor of fuel- f .

The national energy balance and the verified ETS reports are the main sources of information regarding fuel consumption by sector and activity. The basic characteristics of fuels used in the Greek energy system and the estimated CO₂ emission factors are presented in **Table 3.13**.

Concerning the data presented in the Table 3.13, the following should be mentioned

- ↳ The 2006 IPCC Guidelines constitute an important source of information regarding carbon content, fraction of carbon oxidised and therefore the calculated EF by fuel type. However, as indicated in Table 3.13 for the cases of refinery gas, LPG, petcoke, steamcoal, lignite, domestic and imported natural gas plant, country and/or plant specific data have been processed for the calculation of the respective EFs. CS EFs for gasoline, diesel and HFO are also used.
- ↳ Information on the net calorific value (NCV) per fuel is mainly provided by the national energy balance, compiled by the Ministry of Environment and Energy (Energy Policy Division). This information is also submitted by the Ministry annually to both the IEA and the EUROSTAT. For the fuels: refinery gas, petcoke, steam coal and lignite NCV values were obtained from plant specific data, as indicated in Table 3.13. Gasoline's, HFO's and diesel's NCV are CS.

- ↳ The carbon content of domestic natural gas derives from data of the company involved on the exploitation of domestic crude oil and natural gas fields. The carbon content of the domestic natural gas is higher than the one of the imported natural gas and as a result the corresponding CO₂ emission factor is higher.

Table 3.13 *Carbon dioxide emission factors (in t CO₂ / TJ), net calorific value (in TJ / kt) and other parameters by fuel type (2014)*

Fuel type	Net calorific value (TJ/kt)	Carbon content. CC (tC/TJ)	Oxidation factor. OF (%)	EF (tCO ₂ /TJ)
Liquid fuels				
Refinery gas	19.29 ¹	17.44	100	63.95 ¹
LPG	47.30	17.21	100	63.10 ² , 63.30 ³
Gasoline	42.79	19.98	100	73.26
Kerosene	43.8	19.61	100	71.90
Diesel oil	42.80	20.12	100	73.78
Heavy fuel oil	40.14	21.38	100	78.40
Naphtha	45.01	20.0	100	72.60
Petroleum coke	32.33 ⁴ , 32.32 ⁵	27.18, 25.63	100	99.65 ⁴ , 93.97 ⁵
Other oil products	40.20	20.0	100	73.30
Solid fuels				
Steam coal	28.87 ⁶	25.53	100	93.61 ⁶
Lignite				
Electricity generation	5.337	34.29	98.0	123.224
Other sectors	8.205	27.05	100	99.18
Oven and gas coke	29.31	29.5	100	106.00
BKB / Patent fuel	14.20	25.8	100	92.71
Gaseous fuels				
Natural gas – Domestic		15.95 - 16.22	100	56.95 ⁷
Natural gas – Imports		15.15, 15.18	100	55.55 ⁸ , 55.67 ⁹
Gas works gas		12.11	100	44.4

Notes to Table 3.13:

1 Mean value. It depends on refineries' feedstock characteristics and processes applied. It is derived from PS data contained in the verified EU ETS emission reports of refineries. Especially for the case of HBG and LBG refinery gases from flexicoker units, the EFs are 2.6963 and 0.5122 tCO₂/t, respectively, and the NCVs 48.25 and 4.62 TJ/kt, respectively.

2 For use in sectors other than refineries.

3 Only for petroleum refining category. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

4 Mean value. Petcoke consumed in refineries. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

5 Mean value. Petcoke consumed in manufacturing industries (i.e. cement, lime and ceramics plants). It is derived from PS data contained in the verified EU ETS emission reports.

6 Derived from PS data of verified EU ETS emission reports.

7 The emission factor was calculated to comprise emissions from a) the combustion of domestic gas from two different reservoirs, b) the combustion of gas by the company that extracts the domestic natural gas which derived from the Public Gas Corporation distribution network (imported gas) and c) the processing of sour gas.

8 Mean value for electricity production based on PS data derived from verified EU ETS emission reports.

9 Mean value based on chemical composition data of NG provided by DESFA (Hellenic Gas Transmission System Operator S.A.).

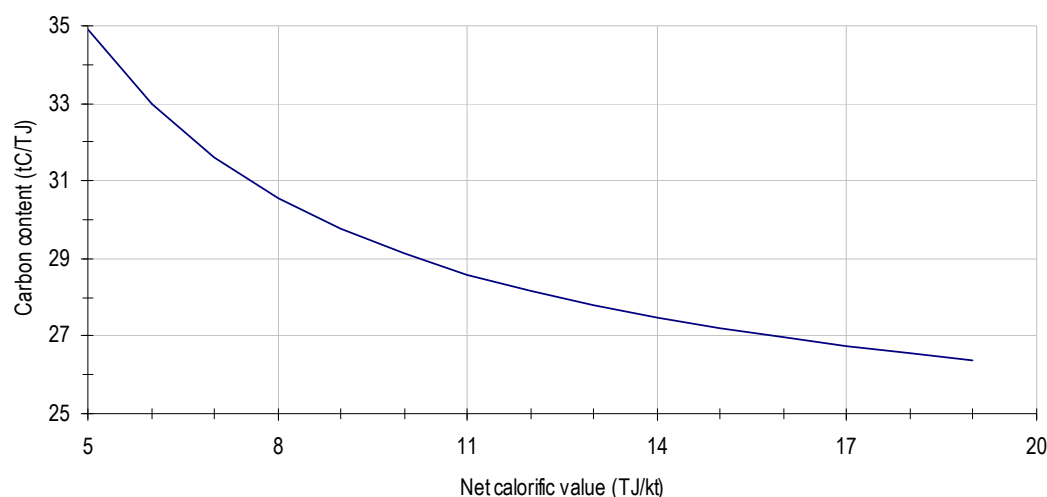
- ↳ Calorific values for gas works gas (in use until 1997) and natural gas do not appear in the table above, because the relative consumption in the energy balance is given directly in energy units (TJ).
- ↳ Domestic natural gas is produced from two reservoirs (2014):
 1. the South Kavala reservoir, which has a NCV of 11313 kcal/Nm³ and a carbon content of 15.95 tC/TJ.
 2. the Prinos reservoir, which has a NCV of 12192 kcal/Nm³ and a carbon content of 16.22 tC/TJ.
- ↳ The calorific value of lignite is differentiated annually, as it is related to the characteristics of mining fields, and therefore it is presented separately in **Table 3.14**.

Table 3.14 Net calorific value of lignite by sector (in TJ / kt) for the period 1990 - 2014

Year	Electricity generation	Industry	Other sectors
1990	5.711	8.399	5.740
1991	5.447	8.323	5.481
1992	5.225	9.504	5.288
1993	5.355	11.074	5.443
1994	5.355	11.317	5.418

1995	5.179	11.300	5.451
1996	4.915	11.204	5.037
1997	5.384	11.300	5.485
1998	5.506	11.380	5.589
1999	5.366	11.110	5.421
2000	5.346	10.902	5.388
2001	5.296	10.006	5.296
2002	5.087	8.620	5.296
2003	5.043	10.886	5.002
2004	5.182	9.807	5.109
2005	5.240	10.471	5.200
2006	5.240	10.471	5.280
2007	5.297	10.235	5.297
2008	5.179	8.025	5.179
2009	5.141	7.435	5.275
2010	5.497	8.025	5.419
2011	5.388	8.479	5.356
2012	5.337	8.501	5.350
2013	5.388	8.205	5.224
2014	5.337	8.205	5.257

- ↳ A country specific carbon content of lignite used for electricity production was used in emission calculations for the period 1990-2005 (33.95 tC/TJ), which is based on studies of the Public Power Corporation (PPC 1993). For the period 2006-2014 plant specific values for CC were used, based on verified EU-ETS reports, ranging from 33.95 to 35.37 tC/TJ. These values lie out of the range suggested by the 2006 IPCC Guidelines. However, given that the net calorific value of the Greek lignite is one of the lowest (see Papanicolaou et al., 2004 for an overview of the properties of the Greek lignites) a high value for the carbon content is expected. Moreover, according to international literature (Fott, 1999) the suggested value by IPCC corresponds to a net calorific value of 13 TJ / kt, which is not representative of national circumstances (see Table 3.14 and Figure 3.5) .
- ↳ The NCV and EF used for Electricity generation are mean values of lignite that is mined from various mining fields, located in 5 different locations in Greece (scattered both to north and south Greece). The lignite used in Industry originates from a single mining field. The quality of lignite from this mining field is superior than the others used for Electricity generation. For that reason the NCV is greater and the EF is lower of lignite used in Industry compared to the mean values of the ones used for Electricity production.
- ↳ Based on chemical composition data of natural gas provided by DESFA (Hellenic Gas Transmission System Operator S.A.) a country specific CO₂ EF of NG per year was calculated. Especially for the public electricity and heat sector and for the years 2005-2014, a CO₂ EF of NG, based on plant specific data (ETS reports), was also calculated (plant specific EF).



Source: Fott. P.. (1999). Environmental Science & Policy. 2

Figure 3.5 *The relationship between the net calorific value and the carbon content of lignite*

For the estimation of CH₄ and N₂O emissions (as well as of other gases) from stationary combustion a Tier 1 methodology with 2006 IPCC defaults emission factors was applied.

Further analysis of fuel consumption by technology is presented hereafter.

3.2.4.3 Energy industries (CRF Source Category 1A1)

3.2.4.3.1 Source category description and methodological issues

Public electricity and heat production (CRF Source Category 1.A.1.a)

Electricity production in Greece increases continuously at an average annual rate of 3.4% for the period 1990 - 2008. For the years 2009-2010, it decreases at an average annual rate of 5.1% and increases at an average annual rate of 3.1% in 2011 and 2012. For years 2013 - 2014, it decreased by an average annual rate of 9.1%. Gross electricity production in 2014 (50.5 TWh) was approximately 44.2% higher compared to 1990 levels (**Figure 3.6**).

Electricity generation from the use of fossil fuels is approximately 74% of electricity production in 2014. Specifically, 51% of electricity is produced by solid fuels (lignite), while the share of liquid fuels (diesel, heavy fuel oil and refinery gas) and natural gas is 9.5% and 13.4% respectively. The rest of electricity production, i.e. around 24%, derives from renewable energy sources as hydropower, wind energy, PVs and biogas.

The calculation of GHG emissions from this sector was performed as described in section 3.2.4.2. The allocation of energy consumption by technology was made on the basis of Public Power

Corporation (PPC) verified ETS reports on the installed capacity and the characteristics of electricity production plants. Therefore:

- ↳ Electricity production from lignite is produced exclusively by steam turbines.
- ↳ Natural gas is used mainly in combined cycle units and secondarily in gas turbines.
- ↳ Heavy fuel oil is used in gas turbines and in internal combustion engines (only in the islands' electricity systems).
- ↳ Diesel is used in gas turbines and in internal combustion engines in the islands' electricity systems.

It is noted that emissions from industrial CHP plants are not included in electricity and heat production, but are allocated to the relative industrial sectors (as suggested by the IPCC Guidelines).

GHG emissions from electricity and heat production for the period 1990 – 2014 are presented in **Table 3.15**.

GHG emissions from electricity generation in 2014 decreased by 0.4% compared to 1990 levels. During the period 1990-2007, an increasing trend of emissions was observed. This increase is attributed to the high increase of electricity demand in Greece as well as to the structural characteristics of the Greek electricity generation system. It should be mentioned that the availability of hydroelectric plants has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 (by 3.3% compared to 1998) was not followed by a similar increase of emissions (1.3%) because of the penetration of natural gas and the high availability of hydroelectric plants. On the contrary, electricity generation from hydroelectric plants in 2000 decreased by 14% compared to 1999, while energy demand increased by 6.2% and as a result fossil fuels consumption and GHG emissions increased accordingly.

During the period 2008-2014, a decreasing trend of emissions was observed. This decrease is attributed to the increasing share of NG and RES in the Greek energy system, along with a decrease in electricity consumption during the last years, as a result of energy efficiency measures and the economic recession that the country is facing.

CO₂ emissions in 2014 accounted for 99.6% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 84% of total emissions in 2014. However, due to the penetration of natural gas and RES technologies, total emissions per electricity produced by fossil fuels has a decreasing trend.

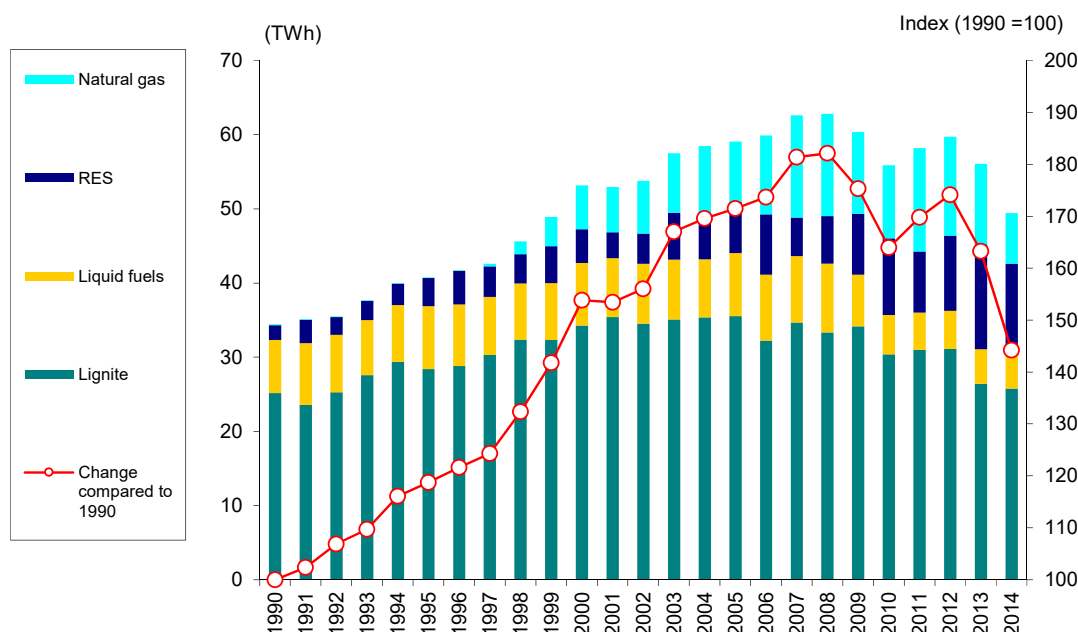


Figure 3.6 Electricity production (in TWh) by energy type for the period 1990 – 2014

Petroleum refining (CRF sector 1.A.1.b)

The inventory for the sector of petroleum refining includes emissions from the production of heat, steam and/or electricity in furnaces, gas turbines and internal combustion engines within the refineries as well as emissions from thermal cracking of heavy hydrocarbons. Additionally, emissions from fluid catalytic cracking/CO boiler, flaring and production of chemicals, such as hydrogen, are also included. Hydrogen production, where natural gas is used as feedstock, is accounted in the Industrial Processes sector.

GHG emissions from refineries (*Table 3.16*) are calculated on the basis of fuel consumption (liquid and gaseous fuels only) which is obtained from the national energy balance and plant specific data derived from verified ETS reports and the estimated emission factors described previously. It is noted that only CO₂ and N₂O emissions from catalytic cracking are included in this sub-source category, while CH₄ emissions are supposed to be included in Fugitive emissions from fuels.

The total increase of GHG emissions from refineries in 2014, compared to 1990 levels, is estimated at 123%. This increasing trend is a result of the requirements for the production of sulphur-free fuels (sulphur content less than 10 ppm) set by the EU Directive 2003/17/EC.

Table 3.15 *GHG emissions from public electricity and heat production per gas and fuel type and total emissions for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO₂ emissions (in Mt)																									
Liquid fuels	5.42	5.86	5.77	5.91	5.79	6.26	6.16	5.97	5.80	6.01	6.43	5.98	5.87	6.44	5.76	6.34	6.48	6.64	6.95	5.33	3.99	3.78	3.81	3.40	3.51
Solid fuels	35.20	33.59	36.04	35.83	37.74	36.02	35.05	38.51	40.47	39.73	42.21	43.17	42.40	42.89	44.43	44.40	40.73	42.57	41.21	41.18	39.68	40.71	41.99	36.11	33.95
Gaseous fuels								0.11	0.79	1.97	2.88	2.86	3.05	3.39	3.68	3.57	4.26	5.69	5.72	4.17	4.64	5.97	5.10	4.59	2.98
CH₄ emissions (in kt)																									
Liquid fuels	0.21	0.23	0.23	0.23	0.23	0.24	0.24	0.23	0.23	0.23	0.25	0.23	0.23	0.25	0.23	0.25	0.25	0.26	0.27	0.21	0.16	0.15	0.15	0.14	0.14
Solid fuels	0.29	0.28	0.30	0.29	0.31	0.30	0.29	0.32	0.33	0.33	0.35	0.35	0.35	0.35	0.36	0.36	0.33	0.35	0.34	0.34	0.32	0.32	0.33	0.29	0.28
Gaseous fuels								0.00	0.01	0.04	0.05	0.05	0.06	0.06	0.07	0.06	0.08	0.10	0.10	0.08	0.08	0.11	0.09	0.08	0.05
N₂O emissions (in kt)																									
Liquid fuels	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.03
Solid fuels	0.43	0.41	0.44	0.44	0.46	0.44	0.43	0.47	0.50	0.49	0.52	0.53	0.52	0.53	0.55	0.55	0.50	0.52	0.51	0.50	0.48	0.48	0.50	0.44	0.41
Gaseous fuels								0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL (Mt CO₂ eq)	40.77	39.60	41.97	41.90	43.69	42.43	41.37	44.76	47.24	47.88	51.72	52.20	51.51	52.92	54.07	54.51	51.65	55.09	54.07	50.86	48.49	50.63	51.08	44.25	40.59

NO: Not Occurring. The use of natural gas for electricity generation started in 1997.

Table 3.16 *GHG emissions from petroleum refineries for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂ (kt)	2375	2374	2306	2285	2458	2484	2722	2772	2850	2584	3103	3148	3255	3106	3258	3656	4331	4380	4047	3714	3669	3333	3560	5063	5305
CH ₄ (kt)	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.11	0.11	0.10	0.09	0.09	0.08	0.09	0.12	0.11
N ₂ O (kt)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02
TOTAL (kt CO₂ eq)	2380	2379	2311	2289	2463	2488	2727	2777	2855	2589	3109	3154	3261	3112	3264	3663	4338	4388	4054	3721	3675	3339	3566	5072	5313

Other energy industries (CRF Source Category 1.A.1.c)

The inventory for the other energy industries includes GHG emissions from the combustion of natural gas during oil and gas extraction.

Data collected during the formulation of the NAP for the period 2005 – 2007 and verified ETS reports (for years 2005 - 2014) were used in this inventory. GHG emissions (**Table 3.17**) are calculated on the basis of the consumption of natural gas and the emission factors as described previously. To be stated that the CO₂ EF of natural gas was estimated to comprise emissions from the processing of sour gas, based on data derived from verified ETS reports.

GHG emissions from the other energy industries in 2014 decreased by approximately 67.4% compared to 1990. The annual variation of emissions is related to the changes of the primary production of crude oil and natural gas.

Table 3.17 *GHG emissions (in kt CO₂ eq) from other energy industries for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Emissions (in kt CO ₂ eq)																									
CO ₂	102.0	108.5	94.2	89.5	103.1	98.6	103.9	110.4	83.6	6.2	104.0	98.9	104.3	90.3	109.0	91.2	97.0	93.6	88.9	86.0	48.9	46.0	45.4	41.6	33.3
CH ₄	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.00	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.01
N ₂ O	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.00	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.04	0.03	0.02	0.02	0.02	0.02
TOTAL	102.1	108.6	94.2	89.6	103.2	98.7	104.0	110.5	83.7	6.2	104.1	98.9	104.4	90.4	109.1	91.2	97.1	93.6	89.0	86.1	49.0	46.0	45.4	41.6	33.3

3.2.4.3.2 Recalculations

No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Division 24/CP.19, IPCC 2006). Implementation of the 2006 IPCC Guidelines for the CRF 1A1 sector includes the application of the assumption that carbon in fuels is 100% oxidized during combustion, the new GWPs for CH₄ and N₂O and the use of the 2006 IPCC defaults CH₄ and N₂O EFs.

3.2.4.4 Manufacturing industries and construction (CRF Source Category 1.A.2)

3.2.4.4.1 Source category description and methodological issues

Emissions from energy consumption for the production of steam and process heat are mainly reported under Manufacturing industry and construction.

Data collected (through questionnaires) during the formulation of the NAP for the period 2005 – 2007 and verified installation ETS reports of 2005 - 2014 provided significant information

regarding the structure of energy demand in industry per activity / technology. Energy consumption in activities not included in the EU emissions trading scheme (e.g. grey iron foundries) is estimated on the basis of the official data (national energy balance).

The calculation of GHG emissions from this sector was performed as described in section 3.2.4.2. The assumptions made for the estimation of GHG emissions for the period 1990 – 2014 (**Table 3.18**) are the following:

- ↳ The energy consumption in the energy balance sector *Iron & Steel* is allocated to steel production (exclusively in electric arc furnaces) and grey iron foundries.

Plant specific data on energy consumption for steel production cover the period 1990 – 2003 and 2005 - 2014. According to those data natural gas represents the main fuel consumed while the consumption of other fuels includes small quantities of heavy fuel oil, LPG and diesel oil. The specific consumption for steel production has decreased from 3.6 GJ / t steel in 1990 to 1.6 GJ / t steel in 2003. For 2004, it was assumed that unit consumption decreased further to 1.5 GJ / t steel while heavy fuel oil, LPG and diesel oil consumption remained constant at 2003 levels. For 2005 - 2014 activity data were available through the verified ETS reports. Emission factors as described previously were applied.

- ↳ Primary aluminium production and ferroalloys production are included, among others, in the energy balance sector of *Non ferrous metals*.

The available plant specific energy consumption data (heavy fuel oil) refer only to primary aluminium production and cover the years 1990 and 1998 – 2003 and 2005 - 2014. On the basis of those data an average specific consumption is estimated (heavy fuel oil consumption per aluminium produced) which is used for the estimation of energy consumption for the period 1991 – 1997. The specific consumption for 2004 is kept constant at 2003 levels. For 2005 - 2014 plant specific energy consumption data were available through the verified ETS reports.

The rest of the energy consumption in the sector (according to the energy balance data) refers exclusively to steam production in boilers.

The emissions from the non-energy use of solid fuels for ferroalloys production were reallocated to the industrial processes sector (2.C.2) as from 2010 submission

- ↳ Energy consumption reported in the energy balance under *Chemicals, Paper, pulp and print* and *Food and Tobacco* refers exclusively to steam production in boilers.

- ↳ The rest of the industrial sectors are included in Other industries (1.A.2f instead of 1.A.2g in the CRF tables). With the exception of *Mining* and *Non metallic minerals*, energy consumption refers exclusively to steam production in boilers.

Energy consumption in *Mining* refers to internal combustion engines and therefore CH₄ and N₂O emissions are estimated using the respective 2006 IPCC default emission factors.

Energy consumption in Non metallic minerals is disaggregated into energy consumption for cement production (SNAP 030311), lime production (SNAP 030312), ceramics production

(SNAP 030319) and glass production (SNAP 030105) according to verified ETS reports of years 2005 - 2013.

GHG emissions from manufacturing industries and construction are closely related to industrial activity trends. However, it should be noted that in cases of major industrial units, variations in emissions should be attributed to the realization of investments for the modernization of the installations and for capacity expansion.

Overall, GHG emissions from industry in 2014 decreased by 41.8% compared to 1990.

3.2.4.4.2 Recalculations

No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Division 24/CP.19, IPCC 2006). Implementation of the 2006 IPCC Guidelines for the CRF 1A2 sector includes the application of the assumption that carbon in fuels is 100% oxidized during combustion, the new GWPs for CH₄ and N₂O and the use of the 2006 IPCC defaults CH₄ and N₂O EFs. Moreover, other petroleum products (e.g. paraffin) were reallocated to the IPPU sector.

Table 3.18 *GHG emissions (in kt) from manufacturing industries and construction for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Iron and Steel																									
CO ₂	447.32 0.02	432.65 0.02	430.13 0.02	380.56 0.02	370.14 0.01	356.02 0.01	262.40 0.01	286.40 0.01	272.49 0.01	318.84 0.01	286.42 0.01	311.30 0.01	324.94 0.01	305.69 0.01	230.37 0.01	185.86 0.00	174.29 0.00	200.12 0.00	190.46 0.00	160.48 0.00	160.29 0.00	149.26 0.00	198.42 0.00	172.76 0.00	148.06 0.00
CH ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N ₂ O																									
Non ferrous metals																									
CO ₂	582.21	711.77	707.28	690.42	663.00	673.97	702.83	692.99	785.48	902.71	935.90	928.15	975.37	1012.18	977.70	816.18	831.62	825.06	747.33	538.50	507.91	466.12	532.10	772.21	622.90
CH ₄	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01
N ₂ O	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Chemicals																									
CO ₂	807.80	622.40	505.65	547.52	487.73	602.61	874.31	839.83	917.10	548.34	649.13	591.64	529.78	648.65	914.53	781.25	758.14	617.16	750.30	806.09	977.93	807.61	669.75	342.96	356.93
CH ₄	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01
N ₂ O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Paper, pulp and print																									
CO ₂	306.05	291.47	284.28	268.62	253.38	213.18	292.34	343.72	308.68	317.61	377.28	347.13	357.17	367.54	254.10	231.01	270.78	257.47	241.55	198.58	179.81	151.75	118.99	138.34	133.24
CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food processing – Beverages – Tobacco																									
CO ₂	916.84	942.51	951.79	970.21	929.84	946.20	1016.37	983.52	1069.94	972.35	1096.77	1002.00	1047.87	1100.61	882.98	797.05	854.19	711.12	657.43	592.88	502.90	404.06	510.77	568.35	645.79
CH ₄	0.03	0.03	0.03	0.03	0.03	0.03	0.23	0.23	0.24	0.23	0.28	0.27	0.29	0.25	0.26	0.29	0.26	0.26	0.31	0.29	0.28	0.29	0.22	0.13	0.16
N ₂ O	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.02
Other industries																									
CO ₂	6278.26	6387.00	6165.54	5903.01	5906.08	6689.92	6939.35	7048.49	6798.49	6079.92	6502.25	6791.51	6190.91	5668.10	5358.68	7323.02	7480.06	7348.19	6738.69	5140.25	4484.41	2938.25	3427.75	3234.54	3490.41
CH ₄	0.38	0.37	0.37	0.36	0.35	0.38	0.20	0.20	0.18	0.17	0.18	0.18	0.17	0.15	0.14	0.22	0.21	0.20	0.19	0.15	0.14	0.12	0.12	0.10	0.12
N ₂ O	0.16	0.16	0.16	0.15	0.16	0.18	0.18	0.19	0.18	0.16	0.19	0.19	0.18	0.17	0.18	0.24	0.26	0.25	0.27	0.24	0.20	0.14	0.16	0.15	0.20
TOTAL	9404.19	9455.11	9111.73	8826.27	8676.54	9554.98	10171.40	10281.24	10236.02	9216.81	9936.57	10060.92	9513.55	9183.78	8699.88	10239.45	10477.61	10063.51	9437.82	7538.95	6900.74	4985.60	5525.83	5287.88	5475.46

3.2.4.5 Other sectors (CRF Source Category 1.A.4)

3.2.4.5.1 Source category description and methodological issues

Residential – Tertiary sector (CRF Source Category 1.A.4 a and b)

GHG emissions from the residential – tertiary sector result from energy consumption for heat in order to cover the needs for the space heating, water heating etc. Thermal needs in these sectors are covered mainly by liquid fossil fuels, while the contribution of biomass (fuel wood), especially in the residential sector, is also significant (mainly in rural areas). The penetration of natural gas to the fuel mixture has an increasing trend.

Activity data of biomass consumption were obtained from fuelwood statistics of the Ministry of Rural Development and Food.

Two basic technologies are considered: central heating boilers, and other stationary equipment (e.g. oil stoves, fireplaces etc.). For the allocation of fuel consumption by technology, it is assumed that the consumption of diesel, heavy fuel oil, gas works gas (until 1997) and natural gas concern central heating boilers and the consumption of the rest of the fuels concern the other stationary equipment.

GHG emissions (*Table 3.19* for the residential sector and *Table 3.20* for the commercial/institutional sector) are calculated on the basis of fuel consumption as it is presented in Annex II, the emission factors of CO₂ presented in Table 3.13 and default 2006 IPCC EF for CH₄ and N₂O as in the previous categories of stationary combustion (s. section 3.2.4.2).

GHG emissions from the residential and the commercial/institutional sector in 2006 increased substantially compared to 1990 levels, as a result of the great increase of liquid fuel consumption since 1996, according to the national energy balance. However, a decreasing trend of the last years is attributed to the penetration of natural gas to the fuel mixture, the increasing use of biomass and the economic recession (years after 2007). The GHG emissions of residential sector in 2014 compared to 1990 decreased by 18.8%, while the emissions of tertiary sector increased by 8.1%.

Agriculture (CRF Source Category 1.A.4c)

GHG emissions from agriculture result from combustion activities are related to heating needs (e.g. space heating in greenhouses) and to agricultural machinery. Fuel consumption is not allocated to forestry or fisheries since the available information does not allow for such a disaggregation.

Energy needs are covered by diesel and heavy fuel oil in boilers and by lignite and biomass in other stationary equipment. Agricultural machinery uses diesel oil and gasoline. The distribution of diesel consumption between thermal needs and machinery is kept constant during the whole period 1990 – 2014.

GHG emissions (**Table 3.21**) are estimated on the basis of fuel consumption as it is presented in Annex II, CO₂ emission factors presented in Table 3.13 and default 2006 IPCC EF for CH₄ and N₂O as in the previous categories of stationary combustion (s. section 3.2.4.2).

The majority of GHG emissions from agriculture are attributed to agricultural machinery.

3.2.4.5.2 Recalculations

No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Division 24/CP.19, IPCC 2006). Implementation of the 2006 IPCC Guidelines for the CRF 1A4 sector includes the application of the assumption that carbon in fuels is 100% oxidized during combustion, the new GWPs for CH₄ and N₂O and the use of the 2006 IPCC defaults CH₄ and N₂O EFs. Moreover, the stationary and off-road emissions from agriculture were reported, separately.

Table 3.19 *GHG emissions (in kt) from the residential sector for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂	4654	4730	4634	4600	4628	4853	6579	6883	7218	7060	7653	8236	8531	10137	9698	9960	9631	8676	8466	7476	6742	7979	7014	3588	3781
CH ₄	3.70	4.30	5.11	4.69	4.27	4.20	4.24	4.01	3.90	4.45	4.97	4.54	3.59	3.53	3.98	3.41	3.84	3.79	3.75	3.73	3.58	3.84	3.91	3.89	3.89
N ₂ O	0.13	0.15	0.17	0.16	0.14	0.14	0.15	0.15	0.15	0.16	0.18	0.17	0.14	0.15	0.16	0.15	0.16	0.15	0.15	0.14	0.13	0.15	0.14	0.13	0.13

Table 3.20 *GHG emissions (in kt) from the commercial / institutional sector for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂	519	687	637	606	621	666	807	780	795	768	785	1021	1039	1141	1232	1549	1611	1512	1508	1240	1150	1085	1353	829	561
CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00

Table 3.21 *GHG emissions (in kt) from agriculture for the period 1990 - 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO ₂	2893	3032	2814	2737	2750	2559	2609	2600	2600	2610	2612	2647	2874	3078	2630	2705	2863	2541	2480	1959	1682	1739	890	486	469
CH ₄	0.39	0.40	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.38	0.40	0.37	0.39	0.41	0.41	0.45	0.43	0.44	0.41	0.44	0.41	0.51	0.98	0.49	0.39
N ₂ O	1.03	1.07	0.99	0.98	0.98	0.91	0.92	0.92	0.92	0.92	0.92	0.93	1.03	1.12	0.95	0.97	1.01	0.90	0.88	0.69	0.62	0.66	0.09	0.12	0.14

3.2.4.6 Uncertainties and time-series consistency

In general, the uncertainty of emissions of the stationary combustion sector is relatively small. The uncertainty associated with activity data -i.e. fuel consumption- is less than 5%, since the AD are obtained from the national energy balance and are cross-checked with data from other sources (e.g. plant specific data from major industrial installations). On the other hand, the uncertainty associated with emission factors is also very low for the case of CO₂, less than 5%, since plant and country specific EFs are mainly applied. For the case of CH₄ and N₂O EFs, the uncertainty is higher, about 100 and 300% respectively, since IPCC defaults emission factors per technology / activity are applied. The results of uncertainty analysis are presented in **Table 1.9**. The detailed calculations of uncertainty are presented in Annex IV (**Tables IV.1 – IV.3**).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on plant-specific data, e.g. from the European Union emissions trading scheme (EU ETS) reports, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

3.2.4.7 Source-specific QA/QC and verification

The following source-specific QC procedures are applied to the stationary combustion sector. These procedures are based on the plant specific data that become available through the ETS reports. To be mentioned that ETS reports have been both verified by external verification bodies and reviewed by the competent authorities of Ministry of Environment and Energy (MEEN).

1. **Activity data comparison:** Cross-checking between energy consumption data derived from national energy balance and plant specific energy consumption data of major industrial plants derived from verified ETS reports is performed. The findings of the above quality check are communicated to the competent department of MEEN that is the compiler of national energy balance. By this way both the national energy balance and the energy consumption used in emission calculations is verified and improved.
2. **Emissions comparison:** Verified ETS reports were used for the computation of plant specific CO₂ EFs and NCVs. For quality control purposes emissions calculated by applying PS EFs and NCVs are compared with the emissions calculated by using IPCC defaults EFs and NCVs derived from energy balance.

3.2.4.8 Recalculations

Please refer to specific categories. No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new

requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006).

3.2.4.9 Planned improvements

Based on the findings of internal inventory reviews described in section 1.6, EU internal audits and UNFCCC ERT reviews, actions are being planned and executed that lead to recalculations / improvements of the stationary combustion GHG emission inventory.

3.2.5 Transport (CRF Source Category 1.A.3)

3.2.5.1 Source category description

Internal aviation, road transportation, railways and internal navigation are included in the transport sector. Emissions from international marine and aviation bunkers are not included in national totals, but are calculated and reported separately as Memo items.

In total, GHG emissions from transport (*Table 3.22(a,b,c)*) in 2014 increased by approximately 20% compared to 1990 emissions (from 14.44 Mt CO₂ eq in 1990 to 17.34 Mt CO₂ eq in 2014) whereas the most important increase of 71% occurred in 2009.

In 2014, the majority of GHG emissions derived from road transport, the contribution of which increased from 83% in 1990 to approximately 88% of total emissions of the sector, as a result of two contradictory parameters: a) the significant increase of the number of vehicles in the country and b) the considerable progress in antipollution technology of the vehicles engines.

The share of internal navigation in the emissions of the transport sector fluctuated from 9-15% during the whole time period with 8% in 2014. Additionally, internal aviation has a contribution of 3.2% in 2014, while the contribution of railways decreased from 1.4% in 1990 to less than 0.3% in 2014. The contribution of other transport (pipeline transportation) is negligible

Table 3.22(a) *GHG emissions in the transportation sector per category for the period 1990 – 1999*

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Emissions (kt)										
Aviation	CO ₂	319	279	307	338	338	359	385	437	445	532
	CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	N ₂ O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Road transport	CO ₂	11826	12675	12976	13277	13463	13896	14565	14905	15657	15937
	CH ₄	2.77	2.74	2.68	2.70	2.62	2.64	2.67	2.70	2.74	2.79
	N ₂ O	0.20	0.24	0.30	0.37	0.45	0.55	0.58	0.64	0.72	0.81
Railways	CO ₂	199	155	148	152	164	136	142	133	148	129
	CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	N ₂ O	0.08	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.05
Navigation	CO ₂	1809	1856	1903	1,740	1,834	1,745	1,495	1,817	2,807	2,774
	CH ₄	0.12	0.12	0.13	0.11	0.13	0.12	0.11	0.13	0.21	0.21
	N ₂ O	0.43	0.46	0.45	0.45	0.42	0.37	0.30	0.32	0.48	0.40
Other	CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
kt CO₂	Total	14153	14965	15334	15507	15799	16136	16587	17292	19057	19372
kt CH₄	Total	2.91	2.88	2.83	2.83	2.77	2.78	2.8	2.85	2.97	3.02
kt N₂O	Total	0.72	0.77	0.82	0.89	0.94	0.98	0.95	1.03	1.28	1.28
kt CO₂eq	Total	14437	15264	15648	15842	16149	16498	16940	17671	19516	19832

Table 3.22(b) GHG emissions in the transportation sector per category for the period 2000 – 2009

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Emissions (kt)										
Aviation	CO ₂	591	530	455	520	600	551	590	612	588	659
	CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	N ₂ O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Road transport	CO ₂	16132	16484	17067	18102	18217	18419	19002	19894	19179	21053
	CH ₄	2.87	2.90	2.78	2.74	2.77	2.63	2.64	2.53	2.25	2.03
	N ₂ O	0.48	0.49	0.50	0.51	0.53	0.51	0.54	0.55	0.52	0.45
Railways	CO ₂	129	129	129	129	129	128	131	119	116	97
	CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	N ₂ O	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
Navigation	CO ₂	1575	2,146	1,934	1,915	2,154	2,063	2,262	2,114	1,896	2,865
	CH ₄	0.11	0.12	0.12	0.13	0.11	0.13	0.12	0.11	0.13	0.21
	N ₂ O	0.34	0.43	0.46	0.45	0.45	0.42	0.37	0.30	0.32	0.48
Other	CO ₂	NO	2.06	5.43	3.62	2.21	3.81	4.91	7.44	14.32	0
	CH ₄	NO	0	0	0	0	0	0	0	0	0
	N ₂ O	NO	0	0	0	0	0	0	0	0	0
kt CO₂	Total	18427	19289	19585	20666	21100	21161	21985	22739	21779	24674
kt CH₄	Total	3	3.04	2.92	2.89	2.9	2.78	2.78	2.66	2.4	2.26
kt N₂O	Total	0.89	0.99	1.03	1.03	1.05	1	0.98	0.92	0.91	0.99
kt CO_{2eq}	Total	18766	19660	19966	21046	21486	21529	22347	23080	22112	25028

Table 3.22(c) GHG emissions in the transportation sector per category for the period 2010-2014

	Year	2010	2011	2012	2013	2014
	Emissions (kt)					
Aviation	CO ₂	565	495	490	338	550
	CH ₄	0.01	0.01	0.01	0.01	0.01
	N ₂ O	0.02	0.02	0.02	0.02	0.03
Road transport	CO ₂	18986	17315	13680	15726	15113
	CH ₄	1.81	1.49	1.19	1.14	1.13
	N ₂ O	0.35	0.23	0.19	0.17	0.18
Railways	CO ₂	63	47	78	56	56
	CH ₄	0.00	0.00	0.00	0.00	0.00
	N ₂ O	0.02	0.02	0.03	0.02	0.02
Navigation	CO ₂	2,331	1,667	1,676	1,394	1,394
	CH ₄	0.11	0.15	0.13	0.14	0.14
	N ₂ O	0.34	0.45	0.43	0.40	0.40
Other	CO ₂	0	0	0	0	0
	CH ₄	0	0	0	0	0
	N ₂ O	0	0	0	0	0
kt CO₂	Total	21945	19524	15924	17514	17113
kt CH₄	Total	1.93	1.65	1.33	1.29	1.28
=kt N₂O	Total	0.73	0.72	0.67	0.61	0.63
kt CO₂eq	Total	22212	19782	16160	17730	17335

Table 3.23(a) *Energy consumption (in TJ) in the transportation sector per category. for the period 1990 – 1999*

Energy consumption (in TJ)										
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aviation	4535	3967	4365	4801	4811	5101	5473	6218	6324	7562
Road transport	161632	173271	177404	181534	184040	189962	199073	203664	213921	217708
Railways	2717	2113	2027	2070	2242	1854	1940	1811	2027	1765
Navigation	23330	23952	24545	22460	23640	22477	19251	23352	36070	35606
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	192213	203303	208341	210865	214733	219394	225737	235045	258341	262642
Energy consumption (in TJ)										
International aviation	34646	29875	31168	33175	39373	36921	35360	34201	35895	40309
International marine	103780	95234	109383	127626	135575	145732	128205	128561	143481	127454

Table 3.23(b) *Energy consumption (in TJ) in the transportation sector per category. for the period 2000 – 2009*

Energy consumption (in TJ)										
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aviation	8404	7531	6470	7390	8536	7836	8398	8702	8371	9377
Road transport	220339	225137	233504	247661	249222	252021	261964	275857	265340	291459
Railways	1765	1765	1765	1765	1765	1750	1793	1622	1579	1322
Navigation	20288	27633	24929	24660	27717	26573	29131	27207	24427	36765
Other	NO	37	97	65	40	68	88	133	257	0
Total	250795	262103	266765	281541	287280	288248	301374	313521	299974	338923
Energy consumption (in TJ)										
International aviation	35360	32862	32863	42776	43972	33762	40497	41389	43039	37018
International marine	147166	142896	127902	131103	132162	117826	127192	129689	126934	107766

Table 3.23(c) *Energy consumption (in TJ) in the transportation sector per category. for the period 2010-2014*

Energy consumption (in TJ)					
Year	2010	2011	2012	2013	2014
Aviation	8024	7028	6956	4805	7823
Road transport	265482	242539	193035	221586	213834
Railways	855	641	1069	770	1838
Navigation	29961	21479	21533	17929	18736
Other	0	0	0	0	0
Total	304321	271687	222593	245089	242231
Energy consumption (in TJ)					
International aviation	29614	32220	35711	35114	40203
International marine	112372	114475	93842	88440	77357

3.2.5.2 Methodological issues

Road transportation

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or they result from a combination of specific emission factors and road traffic data.

Carbon dioxide emissions calculations from road transport are based on the consumption of gasoline, diesel, LPG and natural gas and the carbon content of the fuels consumed. For the estimation of emissions from road transportation, except CO₂, the newer version of COPERT, (COPERT 4 Computer programme to calculate emissions from road transport - Users Manual, D. Gkatzoflias, L. Ntziachristos and Z. Samaras (LAT/AUTH)., 2007, ETC-ACC European Topic Centre on Air and Climate Change), was applied.

COPERT 4 is an MS Windows software program aiming at the calculation of air pollutant emissions from road transport. The technical development of COPERT is financed by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre on Air and Climate Change. Since 2007, the European Commission's Joint Research Centre has been coordinating and financing the further scientific development of the model. In principle, COPERT has been developed for use from the National Experts to estimate emissions from road transport to be included in official annual national inventories. In this version of COPERT hybrid vehicle fuel consumption and emission factors were introduced as well as N₂O/NH₃ emission factors for PCs and LDVs and heavy duty vehicle emissions calculation methodology.

The major revisions made since previous version of the methodology are the following:

- New emission factors for diesel Euro IV PCs
- Revised emission factors for LDVs
- New emission factors for Euro V and VI PCs, LDVs and HDVs
- Emission factors for urban CNG buses
- Hybrid fuel consumption and emission factors
- New corrections for emission degradation due to mileage
- Revised CO₂, N₂O, NH₃ and CH₄ calculations
- Effect of biodiesel blends on emissions from diesel cars and HDVs
- Split of NO_x emissions to NO and NO₂
- Developments on the cold start emission front
- Developments on evaporation losses

The methodology applied is also part of the EMEP/CORINAIR Emission Inventory Guidebook. The Guidebook, developed by the UNECE Task Force on Emissions Inventories and Projections, is intended to support reporting under the UNECE Convention on Long-Range Transboundary Air Pollution and the EU directive on national emission ceilings. The COPERT 4 methodology is fully consistent with the Road Transport chapter of the Guidebook. The use of a software tool to calculate road transport emissions allows for a transparent and standardized, hence consistent and comparable data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and EU legislation.

Basic data requirements for the application of the model include: (a) energy consumption by fuel type, (b) fuel characteristics, (c) the number of vehicles per vehicle category, engine size or weight and emission control technology, (d) other parameters such as: the mileage per vehicle class and per road class, the average speed per vehicle type and per road (urban, rural and highway) and (e) climatic conditions. The energy consumption as well as the associated emissions are calculated based on those data and a number of equations described in Ntziachristos and Samaras (2000).

It should be noted here that COPERT IV, is a simulation model for road transport sector and not an optimization one. The solution algorithm is based on the minimisation of differences between energy consumption as reported in the national energy balance account and the estimated (by the model) energy consumption. This is achieved by adjusting appropriately the mileage driven by each vehicle category.

In this year's calculations the annual mileage driven was reconsidered for all vehicle categories as a result of economic crisis. The annual mileage was reassessed taking into account fuel consumption data. The different vehicle categories population along with the total annual kilometres driven by each category as well as fuel consumption data are presented in **Figures 3.7-3.10**.

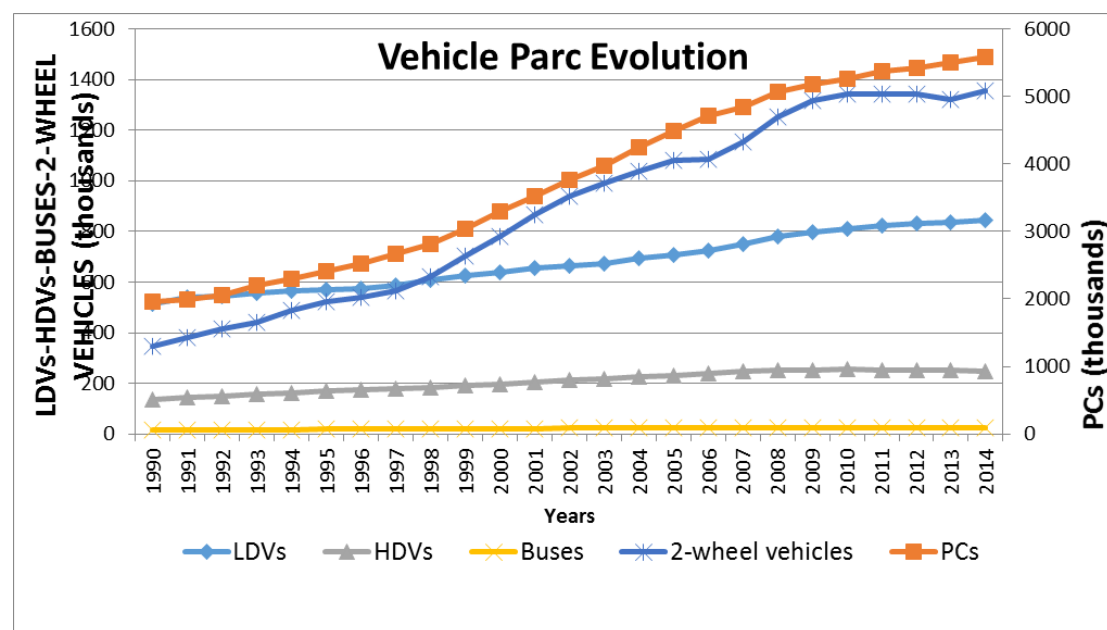


Figure 3.7 *Vehicles population evolution for all vehicles categories during the whole time period 1990 – 2014*

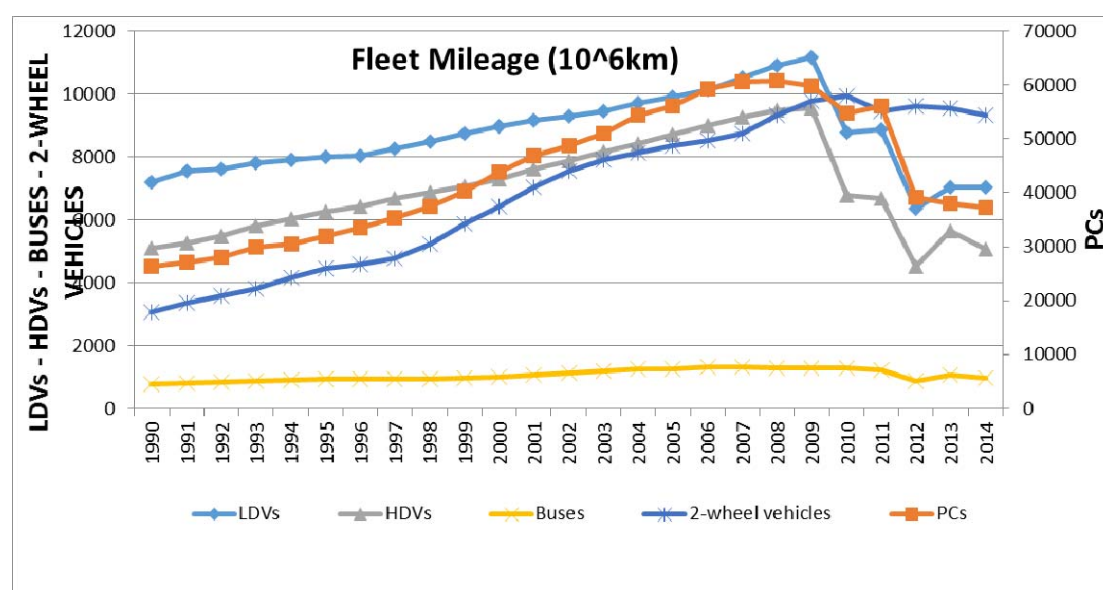


Figure 3.8 *Annual mileage driven by all vehicles categories during the whole time period 1990 – 2014*

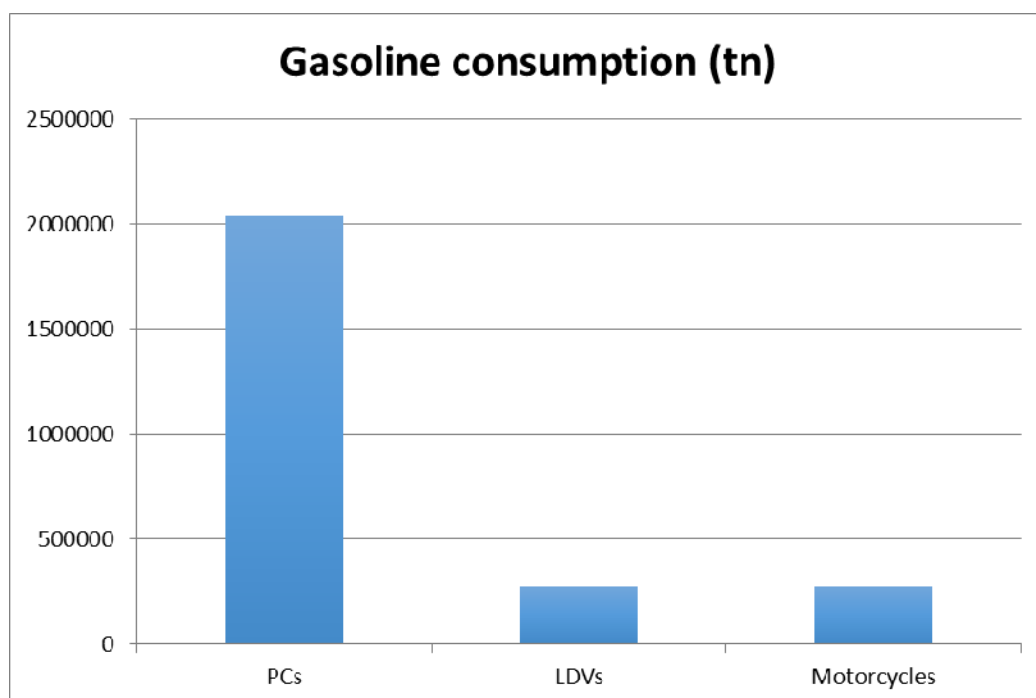


Figure 3.9 Gasoline consumption (kt) by all vehicles categories for 2014

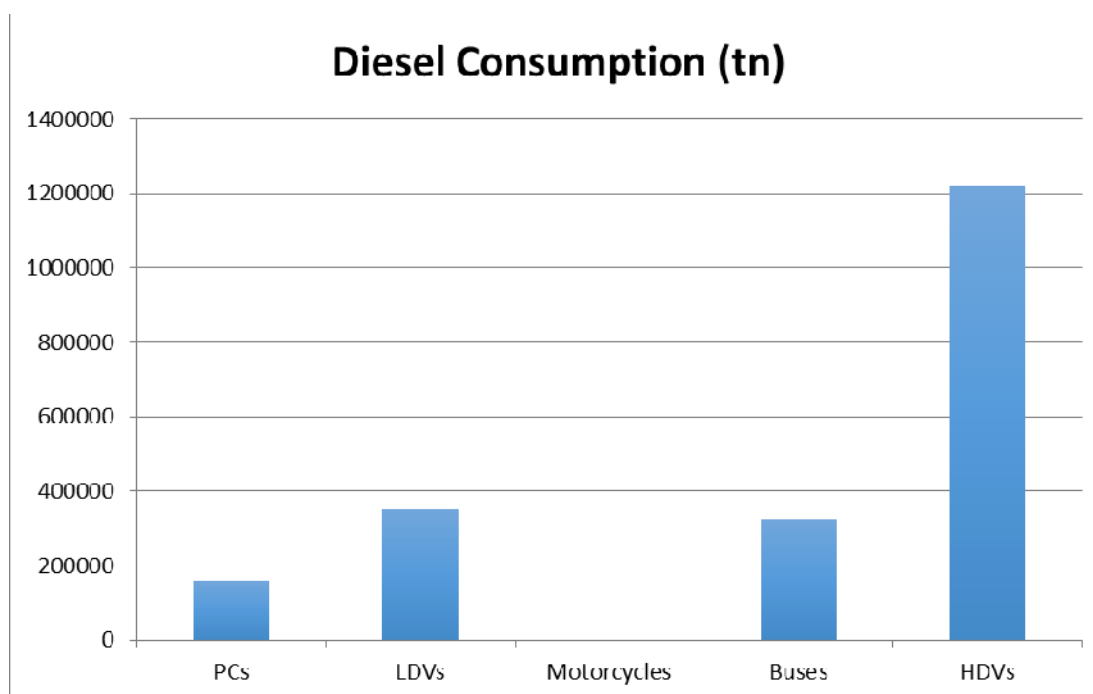


Figure 3.10 Diesel consumption (kt) by all vehicles categories for 2014

In the last years, the passenger cars fleet has almost tripled compared to 1990 levels, while an increase of the share of medium and larger size passenger vehicles is observed (from 27% in 1990, to 36% in 2008). However this situation tends to change as a result of the high taxation imposed on vehicles with engines over 2000cm³ (in 2014, about 24% of passenger cars have an engine capacity greater than 2000cm³).

Road transport is a key category of CO₂ emissions. CO₂ emissions in 2014 increased by approximately 28% compared to 1990 emissions, CH₄ emissions decreased (about 35%), while N₂O emissions decreased by 10% (**Table 3.24(a,b,c)**). During this period, energy consumption augmented by 32%.

Up to 2009, a significant increase of GHG emissions was observed attributed to economic development, an increase in the vehicles fleet as well as in fuel consumption. On the contrary, from 2010, as a consequence of economic crisis, this trend decelerated or inversed, although the percentage of car ownership in Greece is lower than the EU average. It should be noted that, despite the increase of the population of circulating vehicles, as there is a remarkable increase of less polluting vehicles, CO, NO_x and NMVOC emissions considerably decrease. Finally, another considerable reduction of SO₂ emissions attributed to the improvement of the fuels characteristics (i.e. the reduction of their sulphur content) is observed in 2010.

Up to 2013 submission, emissions from lubricants combustion in road transportation were estimated using an adjustment coefficient applied to the total lubricants consumption as it was proposed by a previous in country review. CO₂ emissions from energy combustion of lubricants from road transportation in 1990 are several times higher than the possible calculations based on fleet data and distance travelled. During the in-country review of initial report (Report FCCC/IRR/2007/GRC / 28Dec2007), the ERT identified this issue as a potential overestimation in the base year and decided to calculate and apply an adjustment for the whole time-series. The ERT concluded that the most appropriate methodology for the adjustment in accordance with the Technical Guidance for Adjustments (attached to decision 20/CMP.1) would be the use of an appropriate driver (lubricant consumption/fuel consumption) from a cluster of countries which estimate CO₂ emissions from the combustion of lubricants. The lubricant consumption per fuel consumption ratio in 1990, based on Greece's activity data allocation, was 0.0236 (3.938,62 TJ/166.745,16 TJ), which was nine times higher than the average of other countries that report CO₂ emissions from combustion of lubricants. To resolve this issue, the ERT and the Greek inventory team compiled a proxy bottom-up calculation for the amount of lubricants combusted in road transportation. This resulted in CO₂ emission estimates an order of magnitude lower than reported by Greece, comparable with estimates from other Parties. The adjusted estimate for CO₂ emissions from energy combustion of lubricants from road transportation in the base year amounts to 31.71 Gg CO₂ compared to the 142.97 Gg CO₂ originally reported by Greece in the 2006 inventory submission. The respective emissions for 2010 amounts to 51.86 Gg CO₂. For this year's calculations however, the lubricants consumption taken from the energy balance was considered as reliable, as the corresponding lubricant consumption per fuel consumption ratio is 0.0035, hence in the range of accepted values (as reported before). Therefore, the calculations were performed using the statistical lubricants consumption. Similarly, for years 2011 and 2012, the lubricants consumption was taken from the energy balance. It is to be noted that, in 2012, the lubricants

consumption considerably decreased as a result of crisis and, possibly, reduced maintenance of vehicles fleet. From 2013, lubricants were calculated according to the new guidelines. Following the revised guidelines, such emissions should be reported separately for (i) 2-stroke engines and (ii) all other engines. As the former work with a gasoline-lubricant mix with the lube oil considered to be a part of the fuel itself, emissions should be reported as part of the CRFs the 2-stroke mobile sources are allocated in (i.e. CRF 1.A.2.g vii, 1.A.3.b, 1.A.4.a ii, b ii, c ii, and c iii). On the other hand, any other emissions from (unintended) lubricant co- combustion should be reported under CRF 2.D.1 – Lubricant use.

CO₂ emissions were based on fuel consumption and, hence, they are reported separately. On the contrary, all the other pollutants emissions are calculated with COPERT and are based on the distance travelled and not on the statistical fuel consumption, as emission factors are determined experimentally with measurements of the gas mass exhausted per kilometre at the end-of-pipe.

Finally, concerning N₂O emissions, it should be noted that N₂O depends on the car fleet composition and characteristics and increases considerably for 1st and 2nd generation catalytic cars, compared to conventional ones, whereas it decreases for newer catalyst equipped cars compared to the older catalytic cars. A second important parameter is the S fuel content that influences considerably the N₂O emissions (2000, 2005 and 2009). All the above parameters contribute to the final formation of the implied emission factors. CH₄ emissions depend also on the car fleet composition and characteristics. As for the fluctuations of the IEF of N₂O and CH₄, they are due to the fact that N₂O and CH₄ are calculated with COPERT based on the fleet composition etc. In general, although statistical fuel consumption is used to calibrate the corresponding calculated consumption, during the previous years the statistical consumption was smaller than the calculated through COPERT, and, hence the IEF was larger. This difference was discussed in previous NIR submissions and was connected to fuel smuggling and other illegal uses. In 2010, the statistical consumption, as a result of the measures taken along with the economic crisis, has substantially decreased as well as the corresponding calculated fuel consumption and converged with the statistical values and hence, N₂O and CH₄ IEF decreased. Especially for N₂O, an important decrease of the IEF was already observed for year 2009 as a result of the fuel S content decrease. Last but not least, we would like to underline the old vehicles withdrawal programme that is being running in Greece since 2011.

Table 3.24(a) GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from road transportation for the period 1990 – 1999

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Emissions (in kt CO₂ eq)										
CO ₂ (kt)	11826	12675	12976	13277	13463	13896	14565	14905	15657	15937
CH ₄ (kt)	2.77	2.74	2.68	2.70	2.62	2.64	2.67	2.70	2.74	2.79
N ₂ O (kt)	0.20	0.24	0.30	0.37	0.45	0.55	0.58	0.64	0.72	0.81
TOTAL	11946	12807	13125	13448	13658	14122	14801	15160	15938	16247
Energy consumption (in TJ)										

Gasoline	101541	104793	108344	110997	113180	116560	123663	127728	132906	135430
Diesel	58672	66728	67073	68408	68968	71510	73707	74611	79738	81331
LPG	1419	1750	1987	2129	1892	1892	1703	1325	1277	946
Natural Gas										
Biomass										
TOTAL	161632	173271	177404	181534	184040	189962	199073	203664	213921	217707

Table 3.24(b) GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from road transportation for the period 2000 – 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Emissions (in kt CO₂ eq)										
CO ₂ (kt)	16132	16484	17067	18102	18217	18419	19002	19894	19179	21053
CH ₄ (kt)	2.87	2.90	2.78	2.74	2.77	2.63	2.64	2.53	2.25	2.03
N ₂ O (kt)	0.48	0.49	0.50	0.51	0.53	0.51	0.54	0.55	0.52	0.45
TOTAL	16341	16697	17280	18318	18439	18632	19225	20118	19387	21235
Energy consumption (in TJ)										
Gasoline	138212	142747	149465	156184	159603	163251	165060	172491	169258	169720
Diesel	81418	81633	82925	90464	88655	87759	93910	98610	92084	117008
LPG	710	757	710	568	520	520	520	568	568	804
Natural Gas			404	446	444	490	516	600	535	660
Biomass							1958	3588	2897	3266
TOTAL	220340	225137	233504	247662	249222	252020	261964	275857	265342	291458

Table 3.24(c) GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from road transportation for the period 2010-2014

Year	2010	2011	2012	2013	2014
Emissions (in kt CO₂ eq)					
CO ₂ (kt)	18986	17315	13680	15726	15113
CH ₄ (kt)	1.81	1.49	1.19	1.14	1.13
N ₂ O (kt)	0.35	0.23	0.19	0.17	0.18
TOTAL	19133	17418	13764	15803	15193
Energy consumption (in TJ)					
Gasoline	154520	139739	119291	114959	110749
Diesel	102962	89262	65408	92063	87398
LPG	1987	8468	2366	8800	9387
Natural Gas	658	626	617	562	640
Biomass	5355	4444	5355	5203	5659
TOTAL	265482	242539	193037	221587	213833

Navigation

Carbon dioxide emissions from internal navigation are calculated according to the IPCC Tier 1 default methodology, which is based on the relative consumption of energy per fuel and default emission factors. In Greece, the AD (fuel consumption by fuel type) for navigation, separated between National and International navigation, are obtained from the national energy balance, which is submitted to the EUROSTAT and other international statistics agencies. Hence, these data are verified and accepted as reliable. The consumption fluctuations are affected by the existing national economic conditions and international circumstances the complication of which overpasses the scope of the present NIR.

The other GHG emissions are calculated according to the default methodology of CORINAIR, which is based on the relative consumption of energy per fuel and default emission factors (SNAP 0804 – EEA 2001). Calculation estimates for emissions from liquid fuels in navigation are based on EFs from the 2006 IPCC Guidelines.

The application of a higher Tier methodology requires detailed data for the composition of the fleet and the routes performed, which are not available at present. Hence, although in the GPG it is mentioned that “Fuel use data may be obtained using several approaches” and “it may be necessary to combine these data sources to get full coverage of shipping activities”, such an approach would promote significant errors due to unreliable data input. On the contrary, the AD (fuel consumption by fuel type) for navigation, separated between National and International navigation, are obtained from the national energy balance, which is submitted to the EUROSTAT and other international statistics agencies and is considered reliable. The different activity data sources mentioned in page 2.54 of the GPG are either unavailable or, even if they are scarcely available, they cannot be combined with the total fuel consumption and lead to consistent calculations.

After a research made with the Laboratory of Fuels of the National Technical University of Athens, new country specific carbon content was applied. As a consequence, recalculations of the whole time series were carried out as country specific EF for CO₂ and NCV were used.

Internal navigation (CO₂ emissions) is a key category. GHG emissions from navigation in 2014 were lower (23%) than the emissions in 1990, on the basis of fuel consumption data from this sector (*Table 3.22a,b,c*). This is another impact of recession.

Table 3.25 *Energy consumption (in TJ) from internal navigation for the period 1990 – 2014*

	Energy consumption (in TJ)			
	Diesel	Fuel Oil	Lubricants	Total
1990	13816	9513	764	24094
1991	14680	9272	161	24113
1992	14310	10236	241	24786
1993	14392	8068	201	22661
1994	13364	10276	281	23921

	Energy consumption (in TJ)			
	Diesel	Fuel Oil	Lubricants	Total
1995	11719	10758	362	22839
1996	9416	9834	322	19573
1997	9704	13648	442	23794
1998	14474	21595	522	36592
1999	11884	23723	643	36249
2000	10815	9473	482	20770
2001	14186	13447	482	28115
2002	13570	11360	482	25411
2003	12377	12283	683	25343
2004	12665	15053	563	28280
2005	13487	13086	482	27055
2006	14721	14410	804	29935
2007	13158	14049	592	27799
2008	12706	11721	362	24789
2009	11267	25498	161	36926
2010	11144	18817	281	30242
2011	10568	10911	281	21760
2012	7731	13802	120	21653
2013	7360	10568	80	18008
2014	7731	11006	120	18857

Domestic aviation

Since 2013, GHG emissions from domestic aviation are taken from EUROCONTROL, based on the combination of energy consumption data and air traffic data (Landing and Take off cycles, LTOs). The emission factors used and the distribution of consumption in LTOs and cruise are the suggested CORINAIR values (SNAP 080501 & 080503 – EEA 2001) for average fleet.

The data on energy consumption derive from the national energy balance and EUROCONTROL, while data on LTOs are provided by the Civil Aviation Organisation and EUROCONTROL. ETS data used in 2011 emissions calculations do not exist anymore, as this system for aviation was postponed, and, thus, the only reliable source of data is considered to be EUROCONTROL.

As reported in the previous years NIRs (2012 and older), some inconsistencies were identified, as according to the Civil Aviation Organisation the number of LTOs increased by 71% from 1990 to 2004 while energy consumption (as recorded in the national energy balance) for the same time period decreased by 15.6%. For this reason adjustments were made to the energy consumption data of the whole time period, as suggested in a previous in-country review.

In the following, a description of how the fuel consumption of 0.08 TJ/flight was estimated is provided. More specifically, during the in-country review of the initial report of Greece (Report FCCC/IRR/2007/GRC / 28Dec2007), the ERT informed Greece of the potential problem of an overestimation in the base year for CO₂, CH₄ and N₂O emissions from civil aviation. To determine whether fuel consumption and consequently emissions of CO₂, CH₄ and N₂O were overestimated in 1990 or underestimated in 2004, the ERT estimated fuel consumption for 2004 based on number of LTOs, and the average share (10.20 per cent) of LTO emissions in relation to total emissions from domestic flights (as provided in the Revised 1996 IPCC Guidelines). This approach depends mainly on the length of the domestic flight, which depends on the size of the country. As almost all domestic flights from Athens are in the range of 100-500 km, and flights from Greece to the Greek islands are relatively short, the share of LTOs in total flight fuel consumption would be expected to be closer to the upper part of the range or even higher than the range indicated in the Revised 1996 IPCC Guidelines. For example, the share of LTOs in total fuel consumption for domestic flights reported by Italy (with larger distances between major domestic hubs) was 25.4 per cent in 1990 and 25.0 per cent in 2004. Applying the upper part of the IPCC range (20 per cent) to reported fuel consumption in 2004 for Greece resulted in 383 kg of fuel per LTO. The ERT considered that this would be the expected amount of fuel consumption for Greece for fleets operating domestic routes. Furthermore the ERT compared Greece's ratio, fuel consumption/domestic flight (0.085 TJ/flight), in 2004 with data from a cluster of comparable countries and concluded that Greece's data were closely aligned with the cluster of countries selected (United Kingdom 0.08 TJ/flight, Italy 0.12 TJ/flight, Norway 0.05 TJ/flight). The ERT agreed that fuel consumption in 2004 as reported in the NIR is a solid starting point for extrapolation back to 1990. The adjusted estimate for CO₂, CH₄ and N₂O emissions from civil aviation in the base year amounts to 593.691 Gg CO₂ eq., compared to the 1,469.238 Gg CO₂ eq. reported by Greece in the 2006 GHG inventory submission.

Although GHG emissions from internal aviation since 1990 have doubled in 2009, in 2014 they present an increase of 74% compared to the 1990's emissions (*Table 3.26(a,b,c)*).

Railways

GHG emissions from railways are calculated according to the default methodology proposed in CORINAIR, which is based on the relative consumption of energy per fuel and the typical emission factors (SNAP 0802 – EEA 2001). Emissions of CH₄ were recalculated for the whole time series with the correct emission factor.

GHG emissions from railways (*Table 3.22(a,b,c)*) decreased by about 72% from 1990 to 2014.

Table 3.26(a) *GHG emissions (in kt CO₂ eq). energy consumption (in TJ) and air movement (in LTOs) for the period 1990 – 1999*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	Emissions (in kt CO₂)									
CO ₂	319	279	307	338	338	359	385	437	445	532
CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N ₂ O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
TOTAL (in kt CO ₂ eq)	322	282	310	341	341	362	388	443	451	538
<i>Energy Consumption</i> (TJ)										
Kerosene	4359	3791	4172	4590	4592	4869	5224	5936	6037	7219
Aviation gasoline	176	176	192	211	219	232	249	282	287	343
Air movement (LTOs)	60535	52653	57949	63750	63783	67626	72558	82440	83851	100264

Table 3.26(b) *GHG emissions (in kt CO₂ eq). energy consumption (in TJ) and air movement (in LTOs) for the period 2000 – 2009*

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Emissions (in kt CO₂)									
CO ₂	591	530	455	520	600	551	590	612	588	659
CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N ₂ O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
TOTAL (in kt CO ₂ eq)	597	536	461	526	606	557	596	618	594	665
<i>Energy Consumption</i> (TJ)										
Kerosene	8027	7183	6172	7054	7640	7224	7627	8023	7717	8645
Aviation gasoline	377	347	298	336	896	612	771	680	654	733
Air movement (LTOs)	111481	99765	85721	97974	106108	100336	105927	111424	107182	120063

Table 3.26(c) *GHG emissions (in kt CO₂ eq). energy consumption (in TJ) and air movement (in thousands LTOs) for the period 2010-2014*

Year	2010	2011	2012	2013	2014
Emissions (in kt CO₂)					
CO ₂	565	495	490	338	550
CH ₄	0.01	0.01	0.01	0.01	0.01
N ₂ O	0.02	0.02	0.02	0.02	0.03
TOTAL (in kt CO ₂ eq)	571	501	496	344	560
Energy Consumption (TJ)					
Kerosene	7783	6817	6867	4716	7733
Aviation gasoline	240	211	90	90	90
Air movement (LTOs)	108102	94687	95044	87392	91453

3.2.5.3 Uncertainties and time-series consistency

Road Transport

Several input data in applying the methodology can obviously be only estimates. Such data include total annual mileage, share of mileage to different driving modes (urban, rural, highway), mean travelling speeds, etc. There is a certain degree of uncertainty in estimating these data. A firm checkpoint in estimating the accuracy of calculations is that the total calculated fuel consumption per fuel type should equal the consumption statistics for the level of activity considered. If however the calculated value does not match the true one, the "soft" input variables should be modified. "Soft" in this case denotes those variables associated with large uncertainty as for example the distribution of mileage in driving conditions (urban, rural, highway) 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 (e.g. driving cycles applied)
- Errors concerning assessment of vehicle park and usage (e.g. errors in total kilometres travelled and in the average trip length as well as erroneous estimates of the vehicle park sub-categories).

Aviation

In this sector 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.

Navigation

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 (fuel consumption for vessel categories) and ship movement information.

3.2.5.4 Source-specific QA/QC and verification

Road traffic

1. Cross-checking vehicles fleet comparing to the previous year data

2. Cross-checking fuel consumption data from the energy balance with the respective data calculated from COPERT IV.
3. Association of emissions trends with the input parameters trends.

Aviation

1. Cross-checking consumption data and number of flights
2. Cross-checking data trends and emissions trends

Railways/Navigation

1. Cross-checking data trends and emissions trends

3.2.5.5 Recalculations

Domestic Aviation

Recalculations for year 2013 were performed as a consequence of a change of fuel consumption in EUROCONTROL data..

3.2.5.6 Planned improvements

Future actions for the improvement of the estimation of GHG emissions from transport include the following:

Road Transport

- The reconstruction of the whole timeseries fleet population and composition database is already being accomplished based on the most up to date and accurate data existed. However, the effort still continues for further improvement in the future.
- As was already mentioned in previous years NIRs, the problem with emissions calculation cross-check using statistical data for energy consumption due to fuel smuggling and other illegal uses, was tackled by Greek government with specific legal measures. However, still new measures are planned to be taken to further limit fuel smuggling and illegal uses.

Navigation

- In the navigation sector, there is a very limited possibility to use detailed fleet data in order to calculate emissions. The application of the analytic methodology requires detailed data for the composition of the fleet and the routes performed, which are not available at present.

3.3 Fugitive emissions from fuels (CRF Source Category 1.B)

3.3.1 Coal mining and handling (CRF Source Category 1.B.1a)

3.3.1.1 Source category description

The geological process of coal formation also produces methane (CH₄), some of which remains trapped in the coal seam until it is mined. Generally, deeper underground coal seams contain more in-situ methane than shallower, surface seams.

Coal mining in Greece concerns exclusively the extraction of lignite. All lignite mines in Greece are surface mines and methane is emitted directly into the atmosphere, as the rock strata overlying the coal are removed during the process.

Fugitive emissions from coal mining and handling (CH₄ emissions) are a key category. CH₄ emissions (**Table 3.27**) from the mining of lignite in 2014 account for 1.5% of total GHG emissions from *Energy*. Moreover, lignite mining is the third more important source of CH₄ emissions (following enteric fermentation and solid waste disposal on land). A 2.0% decrease for the period 1990 – 2014 is observed.

Table 3.27 *CH₄ emissions from lignite mining (in Mt) and primary production of lignite (in kt) for the period 1990 – 2016*

Year	Production (Mt)	CH ₄ emissions (kt)
1990	51.90	45.20
1991	52.70	45.90
1992	55.05	47.95
1993	54.82	47.75
1994	56.67	49.36
1995	57.66	50.22
1996	59.78	52.07
1997	58.84	51.25
1998	60.88	53.03
1999	62.05	54.05
2000	63.89	55.65
2001	66.34	57.79
2002	70.47	61.38
2003	68.30	59.49
2004	70.04	61.01
2005	69.40	60.45
2006	64.52	56.20
2007	66.46	57.89
2008	65.72	57.24
2009	64.89	56.52
2010	56.52	49.23
2011	58.67	51.10
2012	62.96	54.83
2013	53.92	46.97
2014	50.85	44.29

3.3.1.2 Methodological issues

CH₄ emissions from lignite mining are calculated on the basis of lignite production and the use of typical emission factor (Tier 1 methodology), as information with regard to the availability of measurements that would allow the calculation of national factors do not exist. More specifically:

- ↳ The national energy balance is the basic source for the activity data (production of lignite, see Table 3.27) used for the calculation of emissions.
- ↳ The typical emission factor (1.2 m³ / t of lignite) suggested by 2006 IPCC GLs, which also covers emissions from post-mining activities, is used. The density of methane has been considered equal to 0.67 kg / m³.

3.3.1.3 Recalculations

No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006). Implementation of the 2006 IPCC Guidelines for the CRF 1B1 sector includes the application of the new GWPs for CH₄ and the use of the 2006 IPCC updated EFs.

3.3.1.4 Source-specific QA/QC and verification and planned improvements

According to GPG, when surface mining is a key category, it is good practice to estimate emissions using national emission factors. The inventory team has contacted the Public Power Company (PPC), which is the operator of all lignite mines in Greece, in order to gather information (site measurements) for the estimation of a national EF. However, the inventory team was informed that the needed measurements are not available, since they are very difficult and expensive to carry out and that the PPC lacks the necessary know-how to contact such measurements.

Moreover, for verification purposes, the inventory team examined the NIR and CRF tables of other parties to the Kyoto Protocol, which report CH₄ emissions from surface mining of lignite by using a Tier 2 approach (national EFs). Three parties were identified, namely Germany, Poland and Spain. The implied EFs they use in 2010 submission were 0.011, 0.01 and 0.31 kg CH₄ /t lignite produced (mining and post mining activities included), respectively. The respective EF of Greece is 0.87 kgCH₄/t lignite produced (=1.2m³ CH₄/t lignite * 0.67 kgCH₄ / m³CH₄), which is by one or two orders of magnitude higher. Therefore, comparing the CH₄ emissions from surface mining reported by Greece with the ones reported by other KP parties, it is concluded that the reported CH₄ emissions by Greece are rather conservative and for sure they are not underestimated.

The inventory team has contacted the inventory teams of some countries that apply a CS EF for CH₄ emissions associated to surface lignite mining. However, the countries that were approached have developed a CS EF for surface mining based on measurements from underground mines, which are located in the vicinity of the surface mines. Since in Greece, there are no underground mines in the vicinity of surface mines, this method cannot be applied. Nevertheless, the inventory team plans to contact more inventory teams and gather information of how these countries have estimated national EFs for surface mining, in order to develop respective national EF for Greece.

3.3.2 SO₂ scrubbing (CRF Source Category 1.B.1c)

3.3.2.1 Source category description

When SO₂ scrubbing technology is used in conjunction with combustion of coal, the process, which removes sulphur dioxide from the flue gas, also releases CO₂ from the chemical reactions during the process. Typically, calcium carbonate reacts with sulphur oxides in flue gas to produce

calcium sulphate and carbon dioxide. The emissions of this category have been reallocated to the Industrial Processes sector (2.A.3), as from 2010 submission.

3.3.3 Oil and natural gas (CRF Source Category 1.B.2)

3.3.3.1 Source category description

Activities related to primary production (extraction), processing, storage and transmission/distribution of crude oil, petroleum products and natural gas are included in this sector. GHG released in the atmosphere during these operations is the direct result of leaks, disruptions and maintenance procedures. Moreover, the sector includes also emissions resulting from venting and flaring of gases that cannot be controlled by other means.

- ↳ The Greek market of oil and petroleum products comprises four refineries, approximately 50 companies active in the marketing of petroleum products and a large number of retailers and gas stations. The refining capacity of the four refineries exceed 20 Mt of crude oil.
- ↳ The basic infrastructure of the system for transport, storage and distribution of natural gas in Greece includes (a) the main pipeline with a length of 512 km, and branch pipelines to several cities with a length of about 947 km, (b) the terminal of the liquefied natural gas which includes two storage tanks with a total capacity of 130,000 m³ and (c) the medium and low pressure distribution network of natural gas. The expected length of the low pressure network, to cover the needs of four major Greek cities (Athens, Thessalonica, Larissa and Volos) is 6,500 km.

GHG emissions (**Table 3.28**) from oil and natural gas in 2014 accounted for 0.1% of total GHG emissions from *Energy*. Overall, emissions in 2014 increased by 16.2% compared to 1990 levels.

The parameters affecting GHG emissions trends from oil and natural gas are the gradual penetration of natural gas in the Greek energy system and the domestic production of crude oil and natural gas.

- ↳ The introduction of natural gas in the Greek energy system started in 1996 and at the moment its development is in progress. Therefore an increasing trend in the future is expected.
- ↳ The domestic production of crude oil and natural gas (**Table 3.29a** and **Table 3.29b** respectively) present a continuous decreasing trend and as a result emissions from venting and flaring are decreasing.

3.3.3.2 Methodological issues

GHG emissions from oil and natural gas are estimated according to the Tier 1 methodology described in the 2006 IPCC GLs.

In relation to the estimation of emissions from oil systems, the following should be noted:

- ↳ The national balance of energy is the main source of information regarding the activity data, (see Table 3.29a) used for the calculation of emissions.
- ↳ Emissions are estimated for the following activities:
 - Primary production of crude oil (CO₂ and CH₄),
 - Crude oil transport by tankers (CO₂ and CH₄),
 - Refining and storage of oil products (CH₄, NO_x, CO, NMVOC and SO₂),
 - Distribution of oil products (NMVOC) and
 - LPG transport (CO₂ and N₂O).
- ↳ Emissions from crude oil transport are reported under Venting, while emissions from LPG transport are reported under Other (1.B.2d - Other).

In all cases the emission factors are estimated as the average values of the proposed range from 2006 IPCC GLs.

Table 3.28 *GHG emissions (in kt CO₂ eq) from oil and natural gas for the period 1990 – 2014*

Year	Oil	Natural gas	Venting and flaring	LPG transport
1990	9.74	9.25	60.28	0.00
1991	8.74	8.64	61.06	0.01
1992	9.02	8.18	51.17	0.01
1993	7.52	5.89	41.66	0.01
1994	9.29	2.25	36.96	0.01
1995	9.79	2.10	32.30	0.01
1996	11.80	2.32	35.78	0.01
1997	11.93	5.51	33.13	0.01
1998	12.02	19.25	25.95	0.01
1999	10.27	23.16	7.97	0.01
2000	12.58	29.59	28.91	0.01
2001	12.31	29.24	22.76	0.01
2002	11.90	31.91	23.10	0.01
2003	12.31	36.39	20.73	0.01
2004	11.99	40.86	21.61	0.01
2005	11.95	45.69	20.67	0.01
2006	12.12	52.97	22.70	0.01
2007	12.30	59.19	24.47	0.01
2008	11.51	64.87	23.92	0.01
2009	11.00	62.27	22.17	0.01
2010	12.45	66.28	25.91	0.03
2011	10.60	83.52	28.39	0.15
2012	13.14	75.81	26.29	0.06
2013	12.75	69.38	22.67	0.34
2014	13.26	60.48	18.03	0.39

Table 3.29a *Key activity data for the estimation of GHG emissions from oil systems for the period 1990 - 2014*

Year	Primary production		Imports	LPG
	Crude oil (kt)	Natural gas liquids (kt)	Crude oil (kt)	supply (TJ)
1990	773	57	14539	277
1991	789	47	12362	304
1992	653	34	13967	330
1993	537	25	11777	357
1994	500	31	12914	369
1995	435	22	15329	412
1996	483	31	17529	443
1997	436	29	17957	462
1998	293	22	18569	498
1999	15	1	15944	462
2000	256	23	19371	454
2001	171	20	18906	472
2002	165	24	19116	431
2003	120	17	19782	410
2004	118	15	20297	407
2005	100	11	18699	520
2006	94	11	19836	520
2007	74	7	20330	568
2008	59	3	19286	568
2009	80	7	17780	804
2010	115	9	20129	1987
2011	98	8	16514	8468
2012	94	8	20978	3643
2013	70	6	19434	19872
2014	64	5	20826	20700

In relation to the estimation of emissions from natural gas systems, the following should be noted:

- ↳ Activity data for the estimation of emissions (Table 3.29b) derive from the national energy balance and the Public Gas Corporation (length of transmission pipeline).
- ↳ Emissions are estimated for the following activities
 - Production and processing of natural gas (CO₂ and CH₄) and
 - Transmission and distribution of natural gas (CH₄).
- ↳ The use of natural gas in the period 1990 – 1995 (domestic natural gas only) is negligible (self-consumption in the energy sector and feedstock for ammonia production) and restricted at the area of production.
- ↳ The emission factors used for the estimation CO₂ and CH₄ emissions derive from the 2006 IPCC GLs.

Table 3.29b *Key activity data for the estimation of GHG emissions from natural gas systems for the period 1990 - 2014*

Year	Primary production	
	Natural gas (10 ⁶ m ³)	Sour gas (%)
1990	123	29%
1991	116	37%
1992	109	33%
1993	81	33%
1994	38	79%
1995	36	69%
1996	38	68%
1997	37	51%
1998	33	61%
1999	2	50%
2000	36	47%
2001	35	46%
2002	37	73%
2003	27	7%
2004	25	20%
2005	16	25%
2006	23	17%
2007	21	14%
2008	14	21%
2009	11	36%
2010	7	86%
2011	6	67%
2012	6	67%
2013	6	67%
2014	5	60%

In relation to emissions from venting and flaring (CO₂, CH₄ and N₂O), it should be mentioned that in most cases more than one variable is used as activity data (see **Table 3.30** for a detailed presentation of emissions from venting and flaring) and as a result significant inter-annual changes are observed in both emissions and implied emission factors.

3.3.3.3 Recalculations

No recalculation were performed in 2016 submission. However, in 2015 submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006). Implementation of the

2006 IPCC Guidelines for the CRF 1B2 sector includes the application of the new GWPs for CH₄ and N₂O and the use of the 2006 IPCC updated EFs.

Table 3.30 *GHG emissions (in kt) from venting and flaring for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Venting																									
Oil																									
CO ₂	0.09	0.09	0.07	0.06	0.06	0.05	0.05	0.05	0.03	0.00	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH ₄	0.65	0.67	0.55	0.45	0.42	0.37	0.41	0.37	0.25	0.01	0.22	0.14	0.14	0.10	0.10	0.08	0.08	0.06	0.05	0.07	0.10	0.08	0.08	0.06	0.05
NG																									
CO ₂	4.92	4.64	4.36	3.24	1.52	1.44	1.52	1.48	1.32	0.08	1.45	1.41	1.49	1.09	1.01	0.65	0.93	0.85	0.57	0.45	0.29	0.25	0.25	0.25	0.21
CH ₄	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.04	0.16	0.27	0.37	0.37	0.39	0.44	0.49	0.52	0.60	0.73	0.77	0.64	0.70	0.85	0.78	0.70	0.53
Flaring																									
Oil																									
CO ₂	37.14	37.91	31.37	25.80	24.02	20.90	23.21	20.95	14.08	0.72	12.30	8.22	7.93	5.77	5.67	4.80	4.52	3.56	2.83	3.84	5.53	4.71	4.52	3.36	3.07
CH ₄	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N.G.																									
CO ₂	0.52	0.49	0.46	0.34	0.16	0.15	0.16	0.16	0.14	0.01	0.15	0.15	0.16	0.11	0.11	0.07	0.10	0.09	0.06	0.05	0.03	0.03	0.03	0.03	0.02
CH ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.3.4 Uncertainties and time-series consistency

In general, the uncertainty of emissions of the fugitive emissions from fuels sector is relatively high. The uncertainty associated with activity data is small, less than 5%, since the AD are obtained from the national energy balance and plant specific data. On the other hand, the uncertainty associated with emission factors is rather high (300%), since both the methodologies applied are of low tier (Tier 1) and the EFs are the default ones. The results of uncertainty analysis are presented in **Table 1.9**. The detailed calculations of uncertainty are presented in Annex IV (**Tables IV.1 – IV.3**).

The time-series consistency of emissions is controlled by applying consistent methodologies inline with IPCC guidelines.

4. Industrial processes and Product use (CRF sector 2)

4.1 Overview of sector

This chapter includes information on GHG emissions from *Industrial processes* and description of the methodologies applied per source for the calculation of emissions.

According to the IPCC Guidelines, the following source categories are found in this sector:

- Mineral industry
- Chemical industry
- Metal industry
- Non-energy products from fuels and solvent use
- Electronics industry
- Emissions of fluorinated substitutes for ozone depleting substances
- Other Product Manufacture and Use

The remainder of this chapter is organized as follows. Paragraph 4.1 continues with the presentation of emissions trends from *Industrial processes*, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for the industrial processes sector. Then the following paragraphs present detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source of emissions.

4.1.1 Emissions trends

In 2014, GHG emissions from *Industrial processes* account for 12.20% of total emissions (excluding LULUCF) and have decreased by 12.12% compared to base year emissions and increased by 10.17% compared to the emissions of 1990 (**Figure 4.1**), while the average annual rate of increase is estimated at 0.69% for the period 1990 – 2014.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2014 reaching a minimum value of 10.23 Mt CO₂ eq in 2011 and a maximum value of 16.39 Mt CO₂ eq in 1999. The low value for 2011 is directly related to the effects of the economical recession whereas the maximum value is attributed to changes in industrial production and especially in HCFC-22 production. It should be noted that had it not been for the consumption of f-gases subcategory, the decrease of the recent years would have been much deeper. In **Figure 4.1** a second higher value of emissions can be observed for 2005, also being related to HCFC-22 production, since in the next year the respective plant ceased its operation.

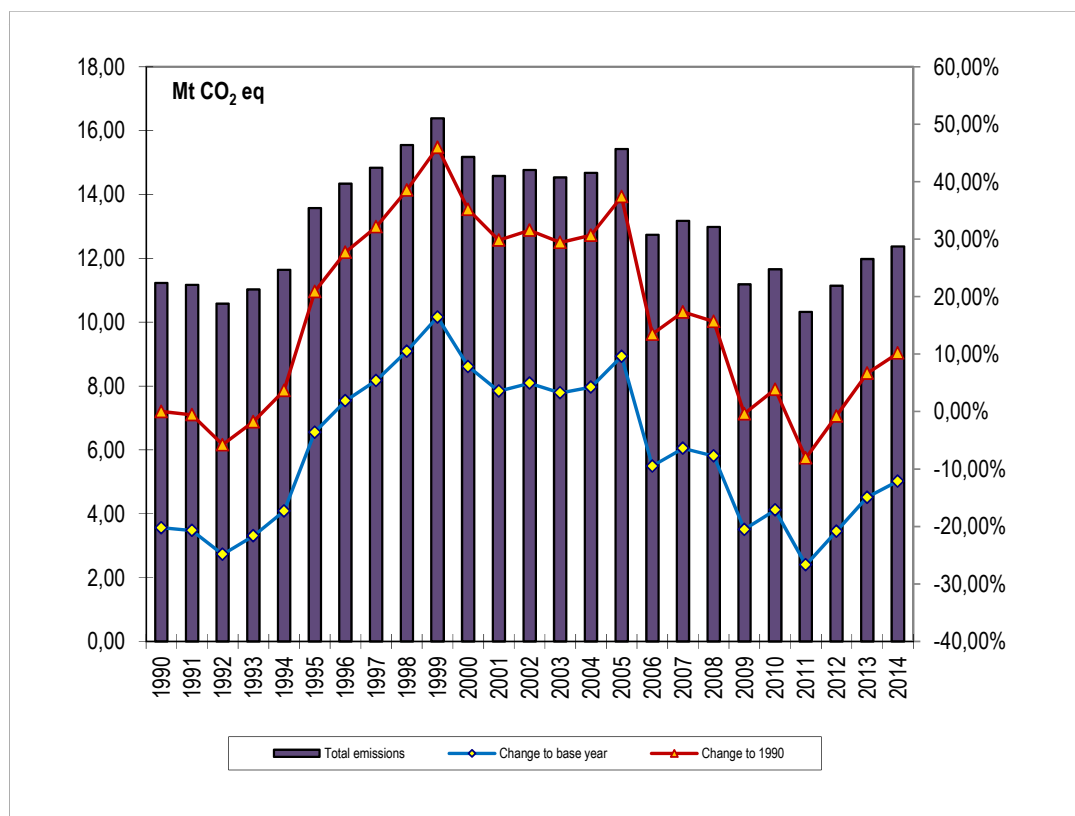


Figure 4.1 *Total GHG emissions (in Mt CO₂ eq) from Industrial Processes for the period 1990 - 2014*

The Industrial Processes sector is responsible for emissions of carbon dioxide, nitrous oxide, methane and f-gases. Emissions per gas from industrial processes are presented in **Table 4.1**.

Carbon dioxide represents the major GHG from industrial processes, with a contribution ranging from 47.88% to 77.34%. Overall, CO₂ emissions in 2014 decreased by 27.14% from 1990, with an average annual rate of decrease estimated at -0.01%. CO₂ emissions derive mainly from mineral products.

The contribution of f-gases to total emissions from industrial processes is also very significant, increasing from 12.26% in 1990 to 33.55% in 2005. The contribution continues to be important until 2006 where an abrupt decrease is observed (from 33.55% in 2005 to 22.12% in 2006). This abrupt decrease is totally due to the cease of HCFC-22 production in 2006. In the recent years (2006-2014) the trend is again increasing, following the substitution of CFCs according to the protocol of Montreal, reaching a contribution of 47.68% in 2014.

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2014, with an average annual rate of change of -6.15%. In 2013 compared to 2012 this trend accounted for 62.61% decrease, in accordance with the installation of an abatement technique for

the recovery of N₂O emissions in the sole plant operating in Greece, followed by an increase of 2.69% for the year 2014 compared to 2013.

The contribution of CH₄ emissions (from chemical and metal industry) to total emissions from the sector is generally negligible, and since 2001 no emissions are reported due to the cease of ethylene and 1,2 dichloro-ethane production in 1998 and 2000, respectively, and emissions are only due to metal production. The average rate of decrease is -4.18% for the period 1990-2014.

Table 4.1 *GHG emissions (in kt CO₂ eq) per gas from industrial processes for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO ₂	8,650.20	8,554.31	8,180.83	7,868.10	7,862.15	8,360.40	8,354.33	8,549.88	8,785.34	8,691.74	8,903.19	8,939.01	8,841.78
CH ₄	1.38	1.45	1.37	1.46	1.47	1.56	1.58	1.62	1.57	0.63	0.56	0.32	0.46
N ₂ O	1,199.37	1,013.35	1,055.24	1,010.19	987.26	984.04	1,104.79	988.42	839.27	866.83	884.73	766.81	743.97
HFC	1,182.82	1,400.08	1,149.07	2,032.44	2,712.11	4,157.38	4,820.17	5,166.49	5,767.51	6,721.15	5,261.83	4,781.39	5,090.07
PFC	190.26	191.19	187.74	112.94	70.31	62.85	53.73	125.64	155.48	105.31	122.26	84.10	88.29
SF ₆	2.93	3.02	3.11	3.20	3.29	3.42	3.51	3.56	3.60	3.69	3.81	3.88	4.06
TOTAL	11,226.96	11,163.40	10,577.36	11,028.32	11,636.59	13,569.65	14,338.11	14,835.60	15,552.78	16,389.35	15,176.38	14,575.50	14,768.63
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
CO ₂	9,008.62	8,983.06	9,581.38	9,351.32	9,248.16	8,599.05	6,625.46	6,580.30	4,940.78	5,485.76	5,981.72	6,302.11	
CH ₄	0.43	0.49	0.57	0.60	0.64	0.62	0.50	0.46	0.48	0.31	0.26	0.26	
N ₂ O	696.51	669.75	668.55	569.94	567.31	551.25	498.60	557.12	601.59	439.64	164.36	168.78	
HFC	4,733.36	4,927.91	5,077.45	2,722.45	3,245.14	3,710.35	3,964.12	4,388.67	4,661.66	5,061.78	5,650.22	5,758.13	
PFC	89.28	87.86	91.51	87.21	103.04	118.95	91.35	129.44	110.53	147.77	172.56	134.63	
SF ₆	4.06	4.26	6.16	7.98	9.46	7.18	5.02	5.86	5.13	5.05	5.15	4.92	
TOTAL	14,532.25	14,673.33	15,425.62	12,739.51	13,173.76	12,987.40	11,185.04	11,661.84	10,320.16	11,140.31	11,974.28	12,368.83	

Throughout the inventory years, the main sources of emissions from *Industrial processes* are mineral products as well as production and consumption of halocarbons and SF₆ (*Figure 4.2*). Emissions show an upward trend until 1999. After 1999 this trend declines, mainly because of the gradual decrease of HCFC-22 production. A second higher value is observed in 2005, mainly as a result of the f-gases consumption contribution in combination with the cease of HCFC-22 production in the next year (2006). In the most recent years of the time series an ongoing decrease appears, resulting in an abrupt decline in 2009 mainly due to the important reduced production levels of mineral products. This is partly counterbalanced by a rather small increase in 2010, which is attributed to the system's recovery from the economical shock experienced in 2009, while in 2011 there is again a decrease in the emissions, mainly due to the decrease of the production of minerals (60.78% decrease in 2011 compared to 2005). However, since 2012 there is an increase in emissions mainly due to the increased production of cement (44.59% increase in mineral production for 2014 compared to 2011) and the increase in emissions from Product Uses as Substitutes for ODS (22.99% increase for 2014 compared to 2011).

The contribution of Product Uses as Substitutes for ODS to total emissions of the sector has increased considerably in the recent years (47.0% in 2014 against 0.31% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons. However, in 2014 emission increased by 1.27% compared to 2013.

Metal Industry in general has a stable contribution to the Emissions of Industrial Processes (10.71% in 1990 versus 9.74% in 2014).

Finally, the contribution of emissions from the chemical production decreases from 26.10% in 1990 to 4.82% in 2014, mainly due to the abrupt decrease in nitric acid emissions. It should be mentioned that the decrease is lower than the one experienced in the previous years, due to the reallocation of emissions from H₂ production from the energy sector.

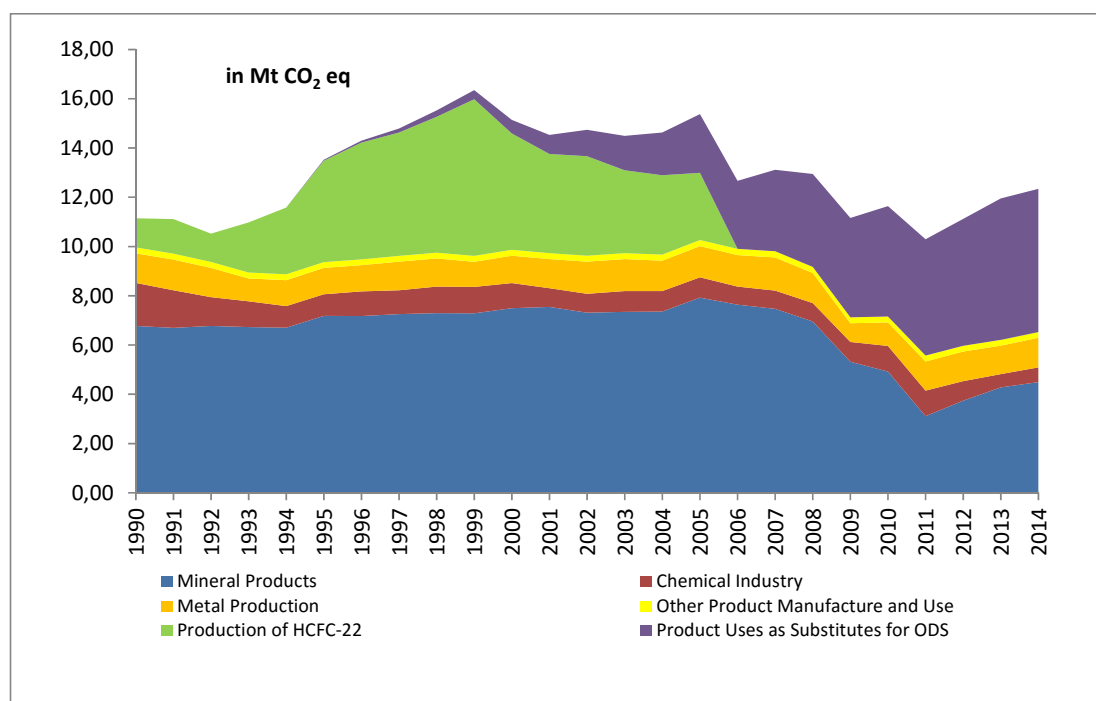


Figure 4.2 *GHG emissions (in Mt CO₂ eq) from Industrial processes per main source category for the period 1990 – 2014*

4.1.2 Methodology

The calculation of GHG emissions from Industrial processes is based on based on the new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. In particular, 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006) were used in this submission. In addition, methodologies described in the 2000 IPCC Good Practice Guidance and the EMEP/CORINAIR Emission Inventory Guidebook 2013 were used whenever appropriate. In

addition, depending on data availability, country specific methodologies are implemented, mostly in cases of time series recalculation due to access of updated data, but also in cases where the lack of data does not allow the use of the above mentioned methodologies.

CO₂ emissions from the majority of mineral and metal industries, as well as PFC emissions from primary aluminium production are estimated on the basis of country-specific emission factors. These emission factors derive of plant specific activity and emission data, in the context of the EU ETS, as well as from other information received by the plants and by the Hellenic Statistical Authority. All the information received is archived in the Input File, according to the Greek QA/QC system. For the *Product Uses as Substitutes for ODS* subcategory, the emission factors used are selected by the default range provided in the 2006 IPCC Guidelines, taking into account the expert judgment provided by the National Association of Refrigerating and Cooling Technicians. Default emission factors from the 2006 IPCC Guidelines are used for the estimation of GHG emissions from the rest source categories of the sector.

Activity data for the calculation of emissions from industrial processes are provided by a variety of sources. First, national production data are provided by the National Statistical Authority (El.Stat.). More specifically, in the recent years the data used in the inventory are substantially improved by the raise of confidentiality issues and the timely provision of data, after close cooperation with the ElStat, which has been achieved through various meetings and personal communication between the inventory team and the Production Statistics Section of the service. Additionally, plant specific information has been collected through questionnaires for the formulation of the NAP and verified reports under the EU ETS (years 2005-2014). It should be noted that in some cases (cement production, hydraulic lime production, glass production, magnesia production, nitric acid production, primary aluminium production, ferroalloys production and HCFC-22 production) further information and data have been requested and provided by the plants. Such data are considered confidential in some cases and, therefore, might not be presented neither in the current report nor in the CRF tables, although they are used for the calculations of emissions. Instead publicly available data are reported, wherever available, in order to help understand the timeseries trend.

For the *Product Uses as Substitutes for ODS*, data have been provided by ICAP market surveys, the National Statistics Authority (Division of Trade and Services Sector Statistics and Division of Secondary Sector Division), the National Organization of Medicines, the Public Power Corporation, the Hellenic Aerosol Association, Appliances Recycling SA, the National Association of Refrigeration Importing and Trading Companies and other industries and private companies that are related to the production and sales of equipment containing f-gases. For the recycling amount of f-gases in refrigeration and air-conditioning, the data provided by the Appliances Recycling SA. As regards to the foam blowing and aerosols subcategories data have been continue to collected by the respective producing industries.

Finally, in some cases data have been recalculated to ensure consistency of the time series and to improve accuracy and completeness of the sectors. This has been mostly performed in order to estimate emissions from the first time and also due to the availability of more detailed updated data.

The methodology applied for the calculation of emissions per source category is briefly presented in **Table 4.2**, while a detailed description is given in the corresponding sections (Sections 4.2 – 4.22).

Table 4.2 *Methodology for the estimation of emissions from industrial processes*

	CO ₂		CH ₄		N ₂ O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
Mineral industry	CS, T1	CS, PS, D						
Chemical industry	T1, T1a	D, CS	T1	D	D,CS	D,CS		
Metal industry	CS, T1	CS, PS, D	CR	CR			T3	PS
Non-energy products from fuels and solvent use	T1	D						
Electronics industry								
Product Uses as Substitutes for ODS							CS, IE, T2	D, IE
Other Product Manufacture and Use					OTH	OTH	CS	CS
Other								

T1, T2, T2a, T3, T3b: IPCC methodology Tier 1, 2, 2a, 3 and 3b respectively

D: IPCC default methodology and emission factor

CS: Country specific emission factor and methodology

PS: Plant specific emission factor and methodology

CR: Corrinair default methodology

Key categories

The key categories for 2014 (either with or without LULUCF) included in *Industrial processes* are presented in **Table 4.3** (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations). It should be noted that the number of key categories in the IP sector has been substantially increased as a result of the breaking-up of larger categories in the key categories analysis, following the recommendations of the 2010 Expert Review Team.

Table 4.3 *Key categories from industrial processes in the year 2014*

Source category	Gas	Level assessment	Trend assessment
Cement production	CO ₂	☒	☒
Other Process Uses of Carbonates	CO ₂		☒
Nitric acid production	N ₂ O		☒
Other Chemicals	CO ₂		☒
Ferroalloys production	CO ₂	☒	
Ammonia production	CO ₂		☒
Foam Blowing Agents	Fgases		☒
Refrigeration and Air conditioning	Fgases	☒	☒

Uncertainty

The results of the uncertainty analysis are presented in Paragraph 1.7, while the detailed calculations are presented in Annex VII. Moreover in each of the sources described below the uncertainty will be discussed in the respective paragraph.

4.1.3 Completeness

Table 4.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the industrial processes sector.

The completeness has generally been improved in the current inventory. The main improvements include the following subcategories:

- Reallocation of CO₂ emitted from limestone use in the Iron and steel Industry from "2.A.4 Other Process Uses of Carbonates" subsector to the "2.C.1 Iron and Steel Production" subsector, as suggested by the IPCC 2006 guidelines.
- CO₂ emissions derived from the oxidation of NMVOC were included in the whole sub-category 2.G.4, as suggested by the IPCC 2006 guidelines.
- Regarding foam blowing subcategory data have been collected for this submission too, in order to evaluate the total amount of imports in Greece.

The main reasons for the non estimation of GHG emissions refer to the lack of emission factors in the IPCC Guidelines (e.g. CO₂ emissions from *asphalt roofing* and *road paving with asphalt*).

Table 4.4 *Industrial processes – Completeness*

	CO ₂	CH ₄	N ₂ O	HFC	PFC	SF ₆
A. Mineral Industry						
1. Cement production	☒					
2. Lime production	☒					
3. Glass Production	☒					
4. Other Process Uses of Carbonates						
Ceramics	☒					
Other uses of Soda Ash	☒					
Non-metallurgical Magnesium Production	☒					
Other	☒					
B. Chemical industry						
1. Ammonia production	☒	NA	NA			
2. Nitric acid production			☒			
3. Adipic acid production	NO		NO			
4. Caprolactam, Glyoxal and Glyoxylic Acid Production	NO		NO			
5. Carbide Production	NO	NO				
6. Titanium Dioxide Production	NO					

7. Soda Ash Production	NO				
8. Petrochemical and Carbon Black Production	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			
9. Fluorochemical Production			NA		
10. Other					
Sulfuric acid production	NA	NA	NA		
Hydrogen Production	<input checked="" type="checkbox"/>	NA	NA		
C. Metal production					
1. Iron and steel production	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			
2. Ferroalloys production	<input checked="" type="checkbox"/>	NA			
3. Aluminium production	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	
4. Magnesium Production	NO			NO	NO
5. Lead Production	<input checked="" type="checkbox"/>				
6. Zinc Production	<input checked="" type="checkbox"/>				
D. Non-energy Products from Fuels and Solvent Use					
1. Lubricant Use	<input checked="" type="checkbox"/>	NA	NA		
2. Paraffin Wax Use	<input checked="" type="checkbox"/>	NA	NA		
3. Other					
Solvent use	<input checked="" type="checkbox"/>	NA	NA		
Road paving with asphalt	NE	NA	NA		
Asphalt roofing	NE	NA	NA		
E. Electronics Industry					
F. Product Uses as Substitutes for ODS					
1. Refrigerating and air conditioning equipment				<input checked="" type="checkbox"/>	NO
2. Foam blowing				<input checked="" type="checkbox"/>	NO
3. Fire Protection				<input checked="" type="checkbox"/>	NO
4. Aerosols				<input checked="" type="checkbox"/>	NO
5. Solvents				NA	NO
6. Other Applications				NA	NA
G. Other Product Manufacture and Use					
1. Electrical Equipment				NA	<input checked="" type="checkbox"/>
2. SF6 and PFCs from Other Product Use					
3. N2O from Product Uses			<input checked="" type="checkbox"/>		
4. Other	<input checked="" type="checkbox"/>	NA	NA		
H. Other					
	NA	NA	NA		

NE: Not Estimated

IE: Included Elsewhere

NO: Not Occurring

NA: Not Applicable

4.2 Cement Production (CRF Source Category 2.A.1)

4.2.1 Description

Emissions of CO₂ occur during the production of clinker, which is an intermediate component in the cement manufacturing process. CO₂ emissions are attributed to the calcination of limestone (mainly CaCO₃), to produce lime (CaO) and carbon dioxide as a by-product.

Cement production (CO₂ emissions) is a key category by level and trend assessment. CO₂ emissions from cement production in 2014 (*Table 4.5*) accounted for 30.90% of total GHG emissions from industrial processes and for 3.89 % of total national emissions including *LULUCF* (3.77 % of total national emissions excluding *LULUCF*). The average annual rate of decrease of CO₂ emissions from cement production during the period 1990 – 2014 was -0.79% (emissions decreased by 33.67% from 1990 to 2014).

Table 4.5 *CO₂ emissions from cement production (in kt) and clinker production (in kt) for the period 1990 - 2014*

Year	Clinker production (kt)	CO ₂ emissions (kt)
1990	10645.13	5761.69
1991	10561.79	5715.77
1992	10831.27	5861.14
1993	10851.82	5875.03
1994	10930.92	5916.41
1995	11743.73	6356.39
1996	11773.83	6374.25
1997	11831.56	6407.69
1998	11789.07	6383.24
1999	11761.21	6366.36
2000	12071.73	6536.76
2001	12130.78	6565.92
2002	11666.18	6313.27
2003	11754.73	6368.13
2004	11754.73	6363.90
2005	12442.36	6791.12
2006	12244.24	6599.22
2007	12035.08	6406.63
2008	11361.40	6053.53
2009	8649.32	4581.72
2010	7926.64	4208.60
2011	4569.17	2430.43
2012	5856.10	3099.30
2013	6915.19	3638.96
2014	7233.53	3821.93

4.2.2 Methodological Issues

During the inventory preparation the calculation of CO₂ emissions from cement production is very important, as this is a key category by both trend and level assessment.

For the years 2005-2014 detailed data have been accessed via the verified EU ETS reports of the plants. These data refer to the quantities of carbonate raw material (CaCO₃, MgCO₃) used for the production of clinker. The general equation used for each of the eight operating cement plants is described by the following equation:

$$\text{CO}_2\text{Emissions} = \sum_i (\text{EF}_i \cdot \text{M}_i \cdot \text{F}_i) - \text{M}_d \cdot \text{C}_d \cdot (1 - \text{F}_d) \cdot \text{EF}_d$$

where, EF_i is the emission factor for the particular carbonate i, M_i is the weight or mass of carbonate i consumed in the kiln, F_i is the fraction calcination achieved for carbonate i, M_d is the weight or mass of CKD not recycled in the kiln, F_d is the fraction calcination achieved for the CKD not recycled to the kiln, EF_d is the emission factor for the non-calcined carbonate in CKD not recycled to the kiln.

According to the collected data, in 2014 the average content of the raw materials in CaCO₃ and MgCO₃ has been estimated at 77.45% and 2.54%, whereas the emission factor used is 0.44 and 0.522, respectively, deriving from the stoichiometry of the reaction.

As regards to the emissions from the non-calcined CKD not recycled to the kiln, these have already been included in the emissions from carbonates reported by the plants, therefore an assumption of F_d=1 has been used to avoid double counting.

Emissions prior to 2005 in the past were calculated using the Tier 2 methodology, based on clinker production. Following the change of the methodology to Tier 3, and according to the IPCC GPG (plant specific data became available in the context of EU ETS reports), the overlap methodology has been used in order to ensure the consistency of the time-series. This was achieved as for the years 2005-2007 emissions have been estimated by both methods (Tier 2 and the Carbonates Method). More details are provided in the NIR 2009, p. 125.

It should be noted that for the emissions estimated using the Tier 2 methodology (that is previous to the 2008 submission), the parameters of CaO and MgO content were determined using plant specific information collected during the formulation of NAP (See also NIR 2007, 2008 etc.). Especially for year 2014 the percentage of CaO and MgO content in the clinker was reported 51.84% and 1.97%, respectively.

In the recent years (2008 – 2013) the plants also reported emissions from non-carbonate carbon (organic carbon). The percentage of organic carbon to the raw material has been low (average content of 0.17%) and the respective emissions constituted the 1.74% of total emissions from cement production in 2013. In 2014 submission, there was a recalculation of emissions for the

years prior to 2008, using the overlap methodology in order emissions from non-carbonate carbon sources (TOC) to be taken into account for the whole time series.

For reasons of consistency between both the previous years and the other countries, the activity data of the more recent years (2005-2014) are still expressed in kt of clinker produced. The value of clinker is provided by the plants.

4.2.3 Uncertainties and time-series consistency

The uncertainty of the current category's estimations is quite low (2% for EF and AD), 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).

As regards to the time series, data are generally well in line in terms of methodology. This has been achieved by making use of the overlap methodology in 2009, in order to ensure the consistency of the time series (up to that year, emissions have been calculated using the Tier 2 and the country specific carbonates methodology). The recalculation methodology applied is in line with the IPCC GPG and has been approved by the ERT reviewers since 2009.

It is quite clear from the Chart in **Figure 4.3** that the cement production is experiencing intense reduction for the years 2009 to 2011, which is attributed to the economical recession that has been very important in the Construction Sector of Greece. It should be mentioned, actually, that the decrease of 2011 is much more intense than the one of 2008 to 2009 (-24.31% versus -42.25%, respectively), depicting the reduction of the number of construction (-23.95% versus -54.69%, respectively). In 2012 to 2014 an increase in emissions is observed, which however no safe projection can be made for the years to come in the current unstable economical circumstances.

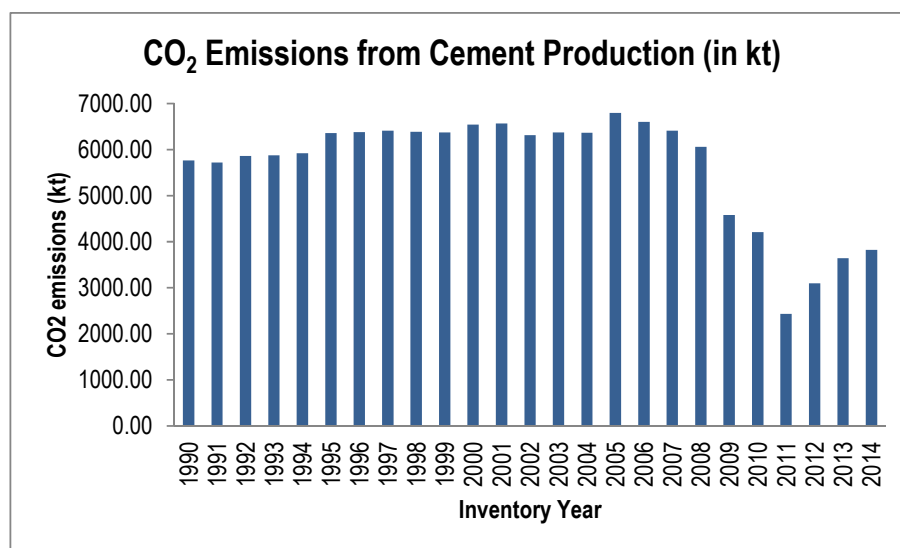


Figure 4.3 *CO₂ emissions (in kt) from Cement Production for the period 1990 – 2014*

During the years 1990-2005, emissions show some low level fluctuations (**Figure 4.2**). In general, annual variations of clinker production and, as a result, of CO₂ emissions are rather low, since a decrease in the domestic demand is counterbalanced by increased exports. However, there has been an abrupt shift in the production level between 1994 and 1995, amounting to 1 million tonnes of clinker produced. The shift was due to an increase of production in one particular plant, as result of a change in ownership, which led to increased use of already existing production capacity. Also in the years 2005-2008 a general decrease of emissions is observed, a decrease that becomes very abrupt in 2009 probably due to the economical recession of the country. The decreasing trend remains in 2010 and become even deeper in 2011. This is also verified by the decreased number of new constructions, although in years 2012 to 2014 there is an increase in emissions derived from cement production.

The IEF of 2014 is close to the mean IEF of the previous years, probably because of the fact that the carbonates percentage of the raw materials is close to the mean values of previous years. The average CaO and MgO content of clinker, as well as the percentage of CaO/MgO, for the years 2005-2014, as provided by the plants, is presented in **Table 4.6**. Any fluctuations, therefore, of the emission factors can be explained according to the fluctuations of the percentages of calcium and magnesium oxides in the clinker.

Table 4.6 *CaO and MgO content of clinker (2005-2014)*

Year	CaO content of clinker (%)	MgO content of clinker (%)	CaO/MgO (%)
2005	64.68	2.93	22.08
2006	64.65	3.03	21.34
2007	64.47	3.26	19.76
2008	64.73	3.25	19.94
2009	65.00	2.99	21.74
2010	65.21	2.74	23.77
2011	65.31	2.81	23.21
2012	58.14	2.04	28.57
2013	51.77	2.08	24.95
2014	51.84	1.97	26.38

4.2.4 Source-specific QA/QC and verification

In order to perform quality assurance activities, the total clinker produced reported by the plants is also checked with the value provided by the ElStat. In general the two sources agree, especially in the recent years where the produced clinker is additionally requested by the plants as a part of Greece QA procedures. Additional QA/QC procedures include the collection of additional information for the Construction sector, as provided by ElStat. In this framework the number of new constructions and the Production Index in Constructions are used as additional indications of the overall trend.

4.2.5 Recalculations

No recalculations have been performed during this submission.

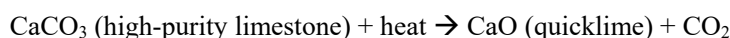
4.2.6 Planned improvements

The current submission can be considered satisfactory.

4.3 Lime production (CRF Source Category 2.A.2)

4.3.1 Description

Lime production leads to carbon dioxide emissions because of the calcination of limestone (CaCO_3) or dolomite ($\text{CaCO}_3 \cdot \text{MgCO}_3$) to produce lime or dolomitic lime. Lime production in Greece is based on limestone.



CO_2 emissions from lime production in 2014 (**Table 4.7**) did not constitute a key category and they accounted for 2.37% of total GHG emissions from *Industrial processes* and for 0.30% of total national emissions (including *LULUCF*). Emission factors are characterized by fluctuations, mainly because of the difference between plant-specific data and EISTat data. The average annual rate of decrease of CO_2 emissions from lime production, for the period 1990 – 2014, is estimated at - 0.48%.

Table 4.7 *CO₂ emissions (in kt) from lime production and production of lime(in kt) for the period 1990 - 2014*

Year	CO ₂ emissions (kt)	IEF	Lime production(kt)
1990	404.00	0.82	491.03
1991	391.78	0.82	476.17
1992	379.55	0.82	461.31
1993	362.95	0.82	442.00
1994	351.25	0.82	427.58
1995	362.35	0.82	442.12
1996	370.07	0.82	452.06
1997	377.57	0.81	464.71
1998	414.33	0.81	508.92
1999	445.77	0.82	540.98
2000	411.17	0.83	497.93
2001	394.81	0.83	477.76
2002	408.84	0.83	495.27
2003	359.59	0.83	435.56
2004	359.45	0.82	435.79

2005	403.16	0.80	505.76
2006	408.85	0.84	489.30
2007	468.98	0.84	555.97
2008	341.76	0.76	451.11
2009	288.78	0.76	380.77
2010	229.96	0.70	328.64
2011	193.00	0.73	263.64
2012	208.54	0.76	272.66
2013	293.97	0.86	342.82
2014	292.61	0.87	336.19

4.3.2 Methodology

For years 2005 – 2014, 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. The emissions are estimated according to the following equation, making use of plant-specific data provided by the verified reports of the plants under the EU ETS:

$$CO_2 Emissions = \sum_i (EF_i \cdot M_i \cdot F_i) - M_d \cdot C_d \cdot (1 - F_d) \cdot EF_d$$

where, EF_i is the emission factor for the carbonate i , M_i is the weight or mass of carbonate i consumed, F_i is the fraction calcination achieved for carbonate i , M_d is weight or mass of LKD, C_d is the weight fraction of original carbonate in the LKD fraction, F_d is the fraction calcinations achieved for LKD and EF_d is the emission factor for the non-calcined carbonate.

The principal carbonates detected in the Greek lime industry were $CaCO_3$ and $MgCO_3$. The activity data resulted in 671.96 kt of $CaCO_3$ eq for the production of lime in 2014. The emission factor for $CaCO_3$ is 0.44 and for $MgCO_3$ 0.522.

As regards to the emissions from the non-calcined carbonate remaining in LKD, they have already been included in the emissions from carbonates reported by the plants, therefore an assumption of $F_d=1$ has been used to avoid double counting.

The lime production of Greece refers to high-calcium (hydrated and non-hydrated) and hydraulic lime. Both values (activity data) are provided by the ElStat for the years 1993-2014, whereas for the years 1990-1993 the missing data have been calculated using the trend extrapolation method as described in the IPCC GPG. For years 1990-1992 as the emissions were missing in order to calculate them an average emission factor of the years 1993-2009 was used. The EFs for the years 1993-2004 were calculated from the ElStat activity data and the calculated emissions based at first on a tier 2 methodology. For these years, according to the Tier 2 methodology suggested in the

2006 IPCC guidelines the EF of 0.59 kg CO₂/kg lime was used for hydraulic lime and 0.75 kg CO₂/kg lime for high calcium lime. Since then, these data were recalculated in 2009 to tier 3 methodology (based on the years 2005-2009 which were under the ETS system).

Hydraulic lime data for 2008-2014 are provided directly by the sole plant producing it in Greece. The IEF shows important fluctuations, as it has been already stated in previous NIRs. This can be attributed to the fact that activity data reported are calculated using ElStat data for hydrated, non-hydrated and hydraulic lime, as described in the IPCC GPG, although the emissions are calculated according to the verified ETS reports, as provided by the plants. These fluctuations can also be attributed to the carbonates content of the raw material. Especially, for 2011 and 2012 the CaCO₃ content of the raw material was 94.09% and 93.73% respectively, while for 2013 and 2014 the CaCO₃ content was 97.17% and 97.92% respectively (*Figure 4.4*).

Lime production in the national statistics is reported as non-hydrated lime, hydrated lime and hydraulic lime, as mentioned above. The hydrated lime production data are converted to non-hydrated lime using the correction for the proportion of hydrated lime as described in the IPCC GPG, using a water content of 28%.

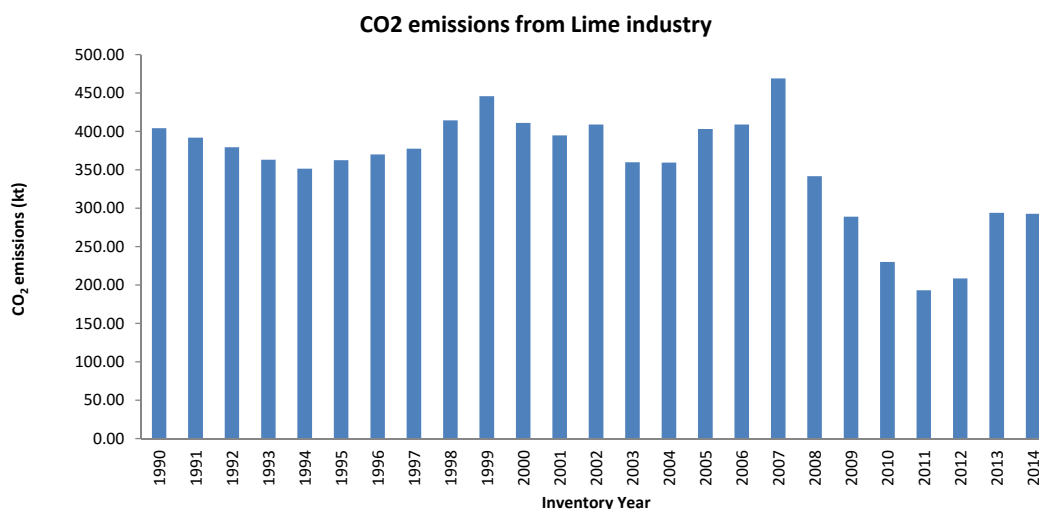


Figure 4.4 *CO₂ emissions for lime production for the period 1990 – 2014*

4.3.3 Uncertainties and time-series consistency

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. The non-marketed lime has been taken into account: All the lime plants that report to the El Stat report

also under the EU ETS, according to information received by the first. It should be noted that these reports are also verified by external auditors, according to the basis of the Hellenic ETS system. Finally, as regards to the sugar industry of Greece data indicate that indeed 3 out of 5 plants produce lime, but the CO₂ produced by the cracking of the carbonates is fully bound during the production process. In particular, hydrated lime is added to the sugar juice in order to raise the pH and to react with the impurities. Afterwards CO₂ is transmitted in the sugar pulp, where sugar lime is decomposed and insoluble calcium carbonate sediments are formed.

As regards to the time series consistency, the emissions have been recalculated in 2009 to improve the consistency between the different methods used. This has been performed by making use of the overlap methodology, as suggested in the IPCC Guidelines. The information over this recalculation can be found in the 2009 NIR. It should be noted that in the 2009 centralised reviews the ERT concluded that “the recalculation methodologies used are in line with the IPCC good practice guidance”. In 2013 submission a recalculation has also been performed as an error in the calculation of the conversion of hydrated lime to non-hydrated lime was detected. Correction for the moisture proportion of hydrated lime, as described in the IPCC guidelines, was used and a recalculation was then applied for the whole time series, according to the overlap methodology.

In general emissions show some fluctuations throughout the years. This is due to the production levels, as well as to the EF, that is calculated based on the reporting of the plants (the inclusion of minor carbonates changes the IEF from year to year). Especially after 2008, important decreases depict the economical recession of the infrastructure sector, which is counter balanced during the last three years.

4.3.4 Source specific QA/QC and verification

The source specific quality control is being performed by implementing the Tier 2 methodology, using the ElStat production data. Comparing to the default factors the IEFs are in an accepted range and are more close to the stoichiometric factor of high calcium lime (0.785). However, for the previous years the emission factor is more close to the emission factor used for dolomite lime than for the high calcium one.

4.3.5 Recalculations

Updated activity data for the year 2013 were used. This change did not have an impact on the CO₂ emissions of that year.

4.3.6 Planned improvements

The current submission can be considered satisfactory.

4.4 Glass Production (CRF Source Category 2.A.3)

4.4.1 Description

Glass production leads to carbon dioxide emissions due to the thermal decomposition of carbonate compounds included in raw materials.

CO₂ emissions from glass production are not a key source. CO₂ emissions from glass production in 2014 have decreased by 16.74% compared to 1990 levels.

4.4.2 Methodology

In the recent years, the estimation of carbon dioxide emissions from glass production is based on accounting for the carbonate input to the glass melting furnace, by using the following equation:

$$CO_2 Emissions = \sum_i (M_i \cdot EF_i \cdot F_i)$$

where, M_i is mass of carbonate i consumed, EF_i is the emission factor for carbonate i , and F_i is the fraction of calcination achieved for the particular carbonate. The reported carbonates are Na₂CO₃, CaCO₃ and MgCO₃ with emission factors 0.415, 0.44 and 0.522, respectively. The implied emission factor for 2014 is 0.15 t/t.

Since February 2006 there is only one plant operating in Greece, whereas since 2005 this plant used to have two factories. Production data have been given for both factories for years 2005-2006 and for the only plant operating for the years 2007-2014. Also for the years 2005-2014 the reports in the EU ETS context have been extensively used.

Activity data (glass production) for the period 1990 – 1992 are provided by the ElStat, while activity data for the period 2001 – 2004 were collected (through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC) in the framework of the formulation of the NAP for the period 2005 – 2007, according to the EU Directive 2003/87/EC. Activity data for the period 1993 – 1999 were estimated by means of a linear interpolation due to the lack of sufficient official data for that period.

Table 4.8 *Glass production (in kt) and CO₂ emissions (in kt) for the period 1990 - 2014*

Year	Glass Production (kt)	CO ₂ emissions (kt)
1990	134.94	20.20
1991	124.57	18.65
1992	97.26	14.56
1993	99.71	14.92
1994	108.55	16.25
1995	117.32	17.56

1996	126.10	18.88
1997	134.87	20.19
1998	143.65	21.50
1999	152.42	22.82
2000	161.20	24.13
2001	169.91	25.43
2002	170.75	25.56
2003	147.27	22.04
2004	138.16	20.68
2005	129.54	18.16
2006	103.09	14.50
2007	115.91	17.38
2008	116.26	17.15
2009	93.66	13.33
2010	113.64	15.16
2011	87.62	11.40
2012	116.01	15.59
2013	114.47	16.65
2014	109.26	16.82

4.4.3 Uncertainty and time-series consistency

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%.

As regards to the time-series consistency, data have been recalculated in 2009 using the overlap methodology. Information on the performed recalculations is given in the 2009 NIR submission. It should be noted that the methodology used is in line with the IPCC GPG.

As it can be observed in **Figure 4.5**, the decrease in CO₂ emissions in 1992 can be attributed to the fact that flat glass production (for glass panes) ceased in 1992, according to an available sector study¹, as there was a continuous decrease in production of flat glass, due to the decreasing domestic demand and the increasing competition with the international markets and therefore the producing company ceased its operation.

Emissions for the period 2002-2006 show a continuous decrease. This slope is justified by the fact that one of the two glass industries that were operating in Greece at that period was about to close and has reduced significantly the annual glass production. Moreover, the other glass industry had invested in plants of neighbour countries, making easier the import of glass to Greece.

¹Development of nine (9) market surveys for SMEs, Sector: “Glass Manufacture and Glass Products”. EOMMEX

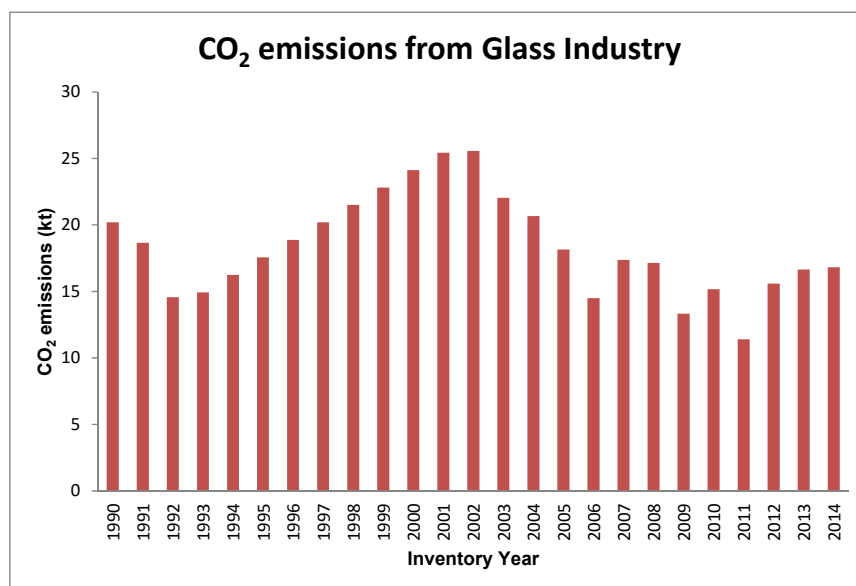


Figure 4.5 *CO₂ emissions (in kt) from Glass Production for the period 1990 – 2014*

Emissions in 2008 decreased by 1.27% with regards to 2007. This increase is not well in line with the slight increase observed in the production level (by 0.30%). According to the activity data this difference is due to the fact that the carbonate contents of soda and of dolomite are lower than the ones reported in 2007.

Emissions in 2009 have decreased by 22.28% with reference to 2008, with a similar decrease in the production levels, as a result of the economical crisis in the *Industrial Processes* Sector of Greece.

In 2010 this decrease is partially counterbalanced with an increase of 13.73%, as it happens with other Categories of the IP Sector. However, the increase in production of glass was equal to 21.3%, which is in line with the cullet ratio provided by the plant, which was higher by 14.28% for this year. After a direct communication with the sole plant operating in Greece the inventory team was informed that the cullet ratio used each year for the production of new glass shows variations, which could lead to a smaller increase in CO₂ emissions, when compared to the production increase.

In 2012 an increase in CO₂ emissions of 36.80% was observed, in accordance with the increase in production level equal to 32.39%. The cullet ration used in 2012, according to the data provided by the plant, was 9.97% less than in 2011.

In 2013 CO₂ emissions increased by 6.79% since 2012 accompanied by a decrease of cullet ration and a small decrease of production equal to 1.32%, followed by an increase in emissions in 2014 by 1.01% compared to 2013, while the production level decreased by 4.56%.

4.4.4 Source specific QA/QC and verification

The category-specific QA/QC procedures regard the estimation of emissions with different tiers, since all the data refer to only one plant operating in Greece. The default emission factor as

described in the CORINAIR Guidelines (SNAP 03314-03317) is 0.15 kg CO₂/kg glass produced for the case of container glass, leading to emissions that are very close to the ones described by the plant. New data were requested and acquired concerning the actual percentage of the cullet ratio for the last years, 2008-2014. The percentages result from four types of glass produced in the specific plant, namely blue, white, amber and green. This information, along with the variations in production level, could explain the fluctuations in CO₂ emissions that are observed during the last years.

4.4.5 Recalculations

No recalculations have been performed in this submission.

4.4.6 Planned improvements

The current submission can be considered satisfactory for the time being.

4.5 Other Process Uses of Carbonates (CRF Source Category 2.A.4)

4.5.1 Description

Limestone (CaCO₃) and dolomite (CaCO₃.MgCO₃) are basic raw materials having commercial applications in a number of industries including agriculture, construction and environmental pollution control. In industrial applications involving the heating of limestone or dolomite at high temperatures, CO₂ is generated.

CO₂ emissions from Other Process Uses of Carbonates is a key category by trend assessment, according to the results of the key analysis carried out in the present inventory. Emissions in 2014 (**Table 4.9**) accounted for 2.94% of total GHG emissions from *Industrial processes* and for 0.36% of total national emissions (excluding *LULUCF*).

Table 4.9 *Limestone use and magnesite consumption (in kt) and CO₂ emissions (in kt) for the period 1990 – 2014*

Year	Limestone & magnesite consumption (kt)	CO ₂ emissions (kt)	IEF
1990	1,273.08	589.53	0.46
1991	1,240.05	570.38	0.46
1992	1,139.29	520.71	0.46
1993	1,038.94	477.33	0.46
1994	907.60	418.81	0.46
1995	967.96	449.80	0.46
1996	895.08	413.60	0.46
1997	972.44	450.17	0.46
1998	1,029.96	475.74	0.46

1999	976.92	450.31	0.46
2000	1,132.80	520.66	0.46
2001	1,230.56	563.43	0.46
2002	1,228.78	564.80	0.46
2003	1,314.54	599.20	0.46
2004	1,346.67	612.99	0.46
2005	1,599.14	714.33	0.45
2006	1,323.07	613.24	0.46
2007	1,238.64	578.58	0.47
2008	1,180.19	545.46	0.46
2009	964.41	437.49	0.45
2010	1,040.15	466.92	0.45
2011	1,069.14	473.74	0.44
2012	937.11	414.75	0.44
2013	792.04	333.43	0.42
2014	847.13	363.24	0.43

4.5.2 Methodology

The present inventory includes emission estimates from the following four broad source categories:

- 2.A.4.a Ceramics,
- 2.A.4.b Other uses of soda ash,
- 2.A.4.c Non-metallurgical magnesia production, and
- 2.A.4.d Other uses of carbonates.

The 2.A.4.d sub-category includes limestone use in metal production (primary aluminium), SO₂ scrubbing and mineral wool.

CO₂ emissions are estimated according to the following general equation:

$$CO_2 Emissions = \sum_i (M_i \cdot EF_i \cdot F_i)$$

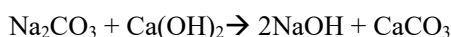
where, CO₂ emissions refer to the emissions from ceramics, other uses of soda ash, Non-metallurgical magnesia production, primary aluminium, SO₂ scrubbing and mineral wool, M_i is mass of carbonate i consumed, EF_i is the emission factor for carbonate i , and F_i is the fraction of calcination achieved for the particular carbonate.

In relation to the estimation of CO₂ emissions from limestone and dolomite use, the following are noted:

↳ **Ceramics production:** Carbonates consumption data (in the context of the ETS reports) have been used to estimate emissions in the years 2005-2014. Activity data refer to CaCO_3 and MgCO_3 consumption (emission factors 0.44 and 0.522 respectively). Limestone consumption data are available also for the period 2000-2004 (questionnaires of the plants under the NAP formulation). Missing data for the period 1990 – 1999 were filled in on the basis of the ceramics production trend reported by the ElStat for the same period. The total CaCO_3 equivalent in 2014 amounts to 41.43 kt, showing a decrease with reference to 2012 (51.30 kt). It is also interesting that more than half of the ceramics plants operating in Greece have declared zero emissions in 2014, as a result of their decreased market activity. This suggests that the effects of the economical recession refer to a more limited number of stronger plants, rather than an one-way decrease in emissions. The fluctuation in IEF since 2005 can be attributed to the EFs of carbonates, oxides and organic carbon (CaCO_3 , CaO , MgCO_3 , MgO , organic carbon, K_2CO_3 , Na_2CO_3 , BaCO_3) used in the ceramics production procedure.

↳ **Soda ash use:** Carbon dioxide is considered to be emitted during the soda ash use in:

a. pulp and paper industry, for the production of NaOH based on the reaction:

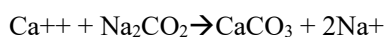


(In Greece is more possible that NaOH is directly purchased by the plants)

b. desulphurization of fuels

(All the Greek plants use limestone in the SO_2 scrubbing process, as it is already reported in the respective ETS reports -see also below).

c. as pH and water hardness regulator, on the basis of the following reaction:



In this case the Na^{++} ions remain dissolved in the water while the CaCO_3 is in the form of sediment that precipitates. In these cases there are no CO_2 emissions.

d. indetergents

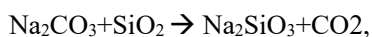
In this case soda ash is used for three reasons:

- as an additive for the pH regulation at 9.0-9.5. This assures the optimum application of the detergent and produces small amounts of CO_2 based on the reaction:



- as an additive for water hardness' regulation, aiming to the formulation of Ca and Mg carbonates based on the reaction provided above.

- as a raw material for silicates production in composite detergents. Sodium silicate is the produced in electric furnaces based on the reaction:



resulting in CO_2 emissions.

e. chemicals production

In this case soda ash is used in the production of sodium phosphates, sodium silicates, chrome chemicals and photographic chemicals.

f. glass production (included in CRF Source Category 2.A.3 and described in Paragraph 4.4)

The required activity data on imports and exports of soda ash at a national level are provided by the Hellenic Statistical Authority (ElStat). Provided there is no soda ash production in Greece the annual national consumption refers to the 'Imports-Exports' value. Data referring to years previous to 1998 are not easily accessible since they are available only on hard copies and therefore are estimated using the Trend Extrapolation methodology, as described in the IPCC GPG. The trend extrapolation has been based on the years 1998-2009. The wide range of years was considered satisfactory as a basis for applying the trend extrapolation methodology.

The soda ash used by the glass industry is then removed, as it is already accounted in emissions from Glass Production. In order to estimate the emissions the following should be mentioned:

- For years 2005-2014 the consumption is estimated based on the data provided by the one plant operating in Greece.

- For years 2001-2004, Na_2CO_3 actual consumption is provided by the 1st NAP. In view of the trend changes and to avoid the extended use of trend extrapolation method, the surrogate method has been used to estimate the logistical soda ash quantity used based on the actual quantity reported by the plants. This is in line with the IPCC GPG/Ch.7.

- For years previous to 2001 no detailed data are available on glass industries and the same methodology cannot be applied. Trend interpolation is used in line with the IPCC GPG/Ch.7.

- Data on glass production are available from previous inventories for years 1990-1993, as provided by the ElStat (for the following years these data are not available due to the change of PRODCOM units and/or codes from quantities to pieces of various unknown sizes and types). The plant specific data acquired through personal communication for the years 2005-2009 are used for the estimation of the relevant quantities using the surrogate method, so as to avoid, to the point possible, the extended use of linear interpolation, as suggested in the IPCC GPG/Ch.7.

The EF used is the default one suggested in 1996 IPCC Guidelines (0.415 t/t soda ash used). It should be noted that in the 1st National Allocation Plan (NAP) three glass factories report under glass industry (two operating for the same firm), while since 2006 there is only one left operating in Greece.

↳ **Magnesia production:** Emissions are estimated using information for the single plant operating in Greece for the years 1999-2014 and the produced quantities of magnesia that have been provided by the Hellenic Statistical Authority for the years 1990-1998. The calculation of emissions for the whole time-series was performed according to the available data per year, as described in the following:

Years 2005-2014: for that period the following data were provided by the single plant operating in Greece:

- the quantities and the chemical analysis of the magnesite used in the kilns
- the production of magnesia (both types as a total)

-detailed calculations of CO₂ emissions

The emissions reported for that period were the ones provided by the plant, which have been verified by external verification bodies and reviewed by the competent authorities of Ministry of Environment, Energy and Climate Change (MEECC), in the context of EU Directive 2009/29/EC.

Based on the CaCO₃ and MgCO₃ contents of the magnesite provided for the years 2005-2008, the implied emission factor (tn of CO₂/tn of magnesite) has been estimated in September 2010, which ranges between 0.4933-0.4975, depending on the CaCO₃ content of magnesite (average calcium carbonate content at 2.59% versus to 92.34% average magnesium carbonate content). The IEF is very close to the one estimated in the recent years, therefore the reporting is considered complete.

In the same time, using the quantity of magnesia produced, the emission factor of tn of CO₂/tn of magnesia produced has been estimated. This EF oscillates between 0.97-1.17, while the average is 1.05 t CO₂/t magnesia, and is considered a country specific one, as it has been estimated using information of the chemical analysis of the ore. This EF was used for the calculation of years prior to 1999, as it is described further below.

Years 1999-2004: for that period the quantities of magnesite used in the kilns and the production of magnesia (both types as a total) has been provided by the single plant operating in Greece. Emissions have been estimated using the quantity of magnesite produced and the average carbonate contents of the years 2005-2008 in order to ensure the consistency between the time-series.

Years 1990-1998: As regards to the years previous to 1999, the produced quantities of magnesia have been provided by the Hellenic Statistical Authority, since there were more than one plant operating in Greece in the period 1990-1999. Emissions have been calculated using the average EF of 1.10 t CO₂/t magnesia that has been estimated from the years 2005-2008, in order to ensure time-series consistency. In order to report activity data in the form of magnesite consumption (instead of magnesia), as it is required by the CRF reporting and since emissions from magnesia production are only a part of the emissions from Limestone and Dolomite Use, for the years 1990-1998, the IEF of 0.4951 t CO₂/t magnesite (mean value of the detailed estimations of 2005-2008), has been used backwards.

It should be noted that, provided that data on the fraction calcination achieved are not available, it has been assumed that the fraction calcination is equal to 1.

✎ **Primary aluminium production:** Data on primary aluminium production are plant specific and confidential (there is only one plant in Greece). The emission factor used is 0.44, whereas the single carbonate estimated is CaCO₃. Plant specific data on limestone consumption cover the years 1990 and 1998 – 2014. The specific limestone consumption has been used for filling in missing data. In 2012 the limestone consumption amounts to 53.66 kt of CaCO₃ eq, while in 2011 it was 117.04 kt of CaCO₃ eq. Since 2013 the limestone consumption was zeroed as the limestone kiln ceased its operation and after personal communication with the plant we were informed that any need in raw materials was covered through imports.

- ↳ **SO₂ scrubbing:** The operation of flue gas desulphurization systems in Greece started in 2000. The estimation of emissions is based on data collected during the formulation of the NAP for the period 2000 – 2003 and concern limestone consumption in two power plants. Limestone consumption for 2004 was estimated assuming that the specific limestone consumption per electricity produced in those two power plants is kept constant at 2003 levels. For years 2005-2014 data from verified installation ETS reports were used. The emission factor used (0.44 t CO₂ / t limestone) derives from the stoichiometry of the reaction and in 2014 emissions increased by 7.13%.
- ↳ **Mineral wool:** Mineral wool is an insulating material industrially produced through melting and fiberizing of ores. Emissions occur during the production where decomposition of carbonate (amphibolites, bauxite and CaO) and consumption of graphite electrodes occur. The production of mineral wool by the only plant operating in Greece started in 2002 (Line 1). In 2008 a second line (Line 2) started its operation at the same plant. Activity data and CO₂ emission for the years 2002-2012 were provided by the sole plant operating in Greece after personal communication. The limestone consumption for the years prior to 2013 were calculated based on a default EF equal to 0.44 t CO₂ / t limestone. Since 2013 AD and CO₂ emission are provided by the EU-ETS reports.

Figure 4.6 summarizes the contribution of the above mentioned sub-categories in the Other Process Uses of Carbonates category, depicting the annual variations in CO₂ emissions.

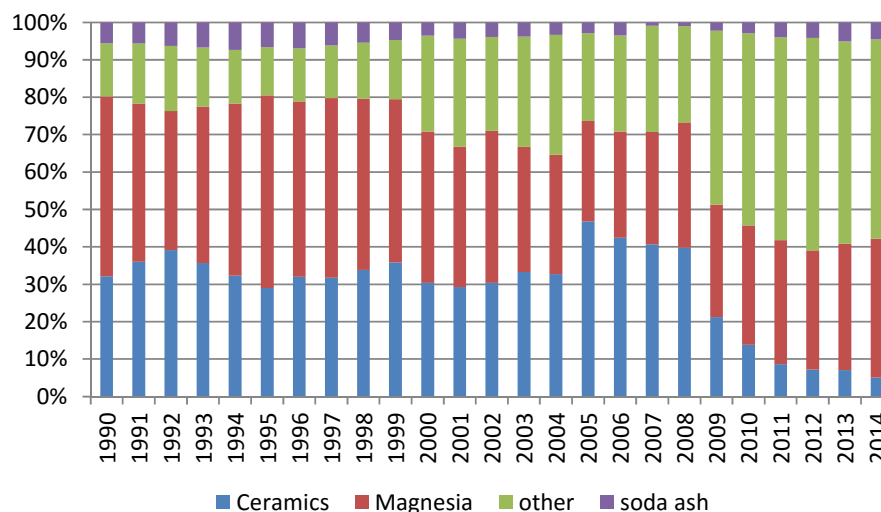


Figure 4.6 Contribution of each subcategory of the Other Process Uses of Carbonates category for the period 1990 – 2014

4.5.3 Uncertainties and time-series consistency

In general the uncertainty associated with the emission factor for this source category is relatively low, as the emission factor is the stoichiometric ratio reflecting the amount of CO₂ released upon calcination of the carbonate. In practice, there are uncertainties, in part due to variations in the

chemical composition of the limestone and other carbonates and therefore the value of 5% is being used to account for the EF uncertainty.

Assuming that carbonate consumption is allocated to the appropriate consuming sectors/industries, the uncertainty concerning the activity data is associated with the weighing or proportioning of the carbonates and with the overall chemical analysis pertaining to carbonate content and identity. Therefore the uncertainty value associated with the activity data is estimated at 10%. This uncertainty value also accounts for the assumption of 100% calcination.

The time-series consistency is ensured by the fact that the applied methodology is consistent with the IPCC Guidelines and remains the same throughout the time-series. In addition the abrupt increase of emissions in 2005 was investigated (**Figure 4.7**). Although slight corrections have been made for years 2005, 2006 and 2007 to accurately depict reported data, the peak remains and is attributed to the lower consumption of carbonates in 2006 with reference to 2005, mainly in the ceramics plants. From 2008 a severe decrease in emissions occurred due to the economic recession and the closure of over half of the ceramic industries in Greece. In particular in 2014 the respective decrease in emissions in the Ceramics Sector is -94.55% compared to 2005, affecting the overall decrease of the category's emissions by -49.15%.

However, since 2009 an increase in emissions from SO₂ scrubbing occurred, determining the trend in emissions for the whole subcategory. In addition, emissions from magnesia production, which is the second dominant industry of this subcategory, are following the same trend as SO₂ scrubbing emissions for the recent years.

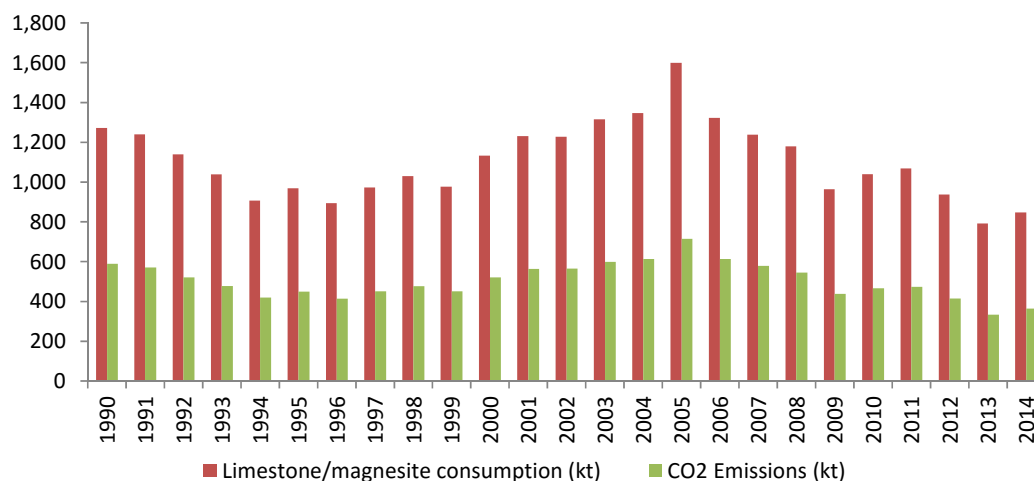


Figure 4.7 *CO₂ emissions (in kt) and Limestone/ magnesite consumption (in kt) from Other Process Uses of Carbonates for the period 1990 – 2014*

In **Table 4.10** emission factors for each subcategory are presented. The variation of the EFs, in addition to the percentage of contribution of each subcategory every year, is the main reason for the fluctuations of the IEF throughout the timeseries. Therefore, with reference to the emission factor used in the most recent years (2005-2014), the deviation from the stoichiometric one is attributed to the fact that in the years that magnesite production is higher, as the IEF equal to 0.495 t CO₂/t magnesite is taken into account, the overall resulting IEF is higher than 0.44.

Table 4.10 *Emission factors range for the Limestone and dolomite use subcategories over the years 1999-2014*

Subcategory	EF Range (Years 1999-2013)
Ceramics	0.413-0.470
Soda ash use	0.415
Primary aluminium Production	0.434-0.44
SO ₂ scrubbing	0.44
Magnesia Production	≈0.483
Mineral wool Production	≈0.44

4.5.4 Source specific QA/QC and verification

The verification of the activity data by alternative sources is generally hard to be performed, given the complexity and the divergence of the manufacturing plants. In addition, although the activity data used are plant specific, the uncertainty of the estimation of emissions from limestone and dolomite use is increased by the fact that in some cases there is no production data available by the ElStat (i.e. ceramics production) in a way that it is really difficult to estimate emissions in different Tiers. It should be noted however that all the reports made available in the ETS context have been additionally checked by external accredited verifiers, as defined by the Greek ETS system, and also that whenever available data are being cross-checked with information from different sources (i.e. in the case of magnesite production).

4.5.5 Recalculations

Emissions from the use of limestone in the iron and steel industry have been reallocated from 2.A.4 Other Process Uses of Carbonates category to the 2.C.1 Iron and Steel category, according to the 2006 IPCC guidelines.

4.5.6 Planned improvements

Emissions from the use of limestone in the aluminium industry will be reallocated in the 2.C.3 Aluminium Production category in the next submission.

4.6 Ammonia production (CRF Source Category 2.B.1)

4.6.1 Description

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 CO₂ emissions.

Up to 1999 there were two ammonia plants in Greece. The first one (Plant A) has been operating since 1990, with an interruption between the years 1994-1997. It should be mentioned that imported Natural Gas was introduced to the Greek energy system by the Public Gas Company (DEPA) in 1996 and that till 1996 the NG consumption in Greece corresponds to small amounts of domestic NG explored by the company Kavala Oil. As a result, the plant has been using natural gas, provided by the Public Gas Company SA (DEPA) since 1998 while in the years 1990-1993 natural gas has been provided to the plant by the Kavala Oil Corporation.

The other plant (Plant B) has been operating since 1990 and up to 1999 with intervals. According to information already provided in NIR 2010, it used lignite as feedstock until 1991, and liquid fuels until its closure in 1999. In absence of gas consumption data, only CO₂ emissions from Plant A have been estimated. CO₂ emissions in IP refer to emissions from natural gas (years 1990-1993 and 1998-2012), whereas emissions from the other fuels used, namely liquid fuels, (years 1990-1993 and 1995-1998) are included in the energy sector. CO₂ emissions from lignite used during years 1990-1991 had been reallocated during 2014 submission from the Energy Sector (1A2c) into the Industrial Processes Sector. It should also be mentioned that both plants were closed during year 1994.

Ammonia production is a key category by trend assessment. CO₂ emissions have decreased by 62.99% since 1990 and have increased by 13.78% since 2013, representing 1.95% of GHG emissions from *Industrial processes* and 0.25% of emissions from total GHG emissions (including *LULUCF*).

4.6.2 Methodology

The methodology used for the estimation of CO₂ emissions is based on the following equation (Tier 1a, IPCC 1996):

$$E = TRF \cdot CCF \cdot COF \cdot 44/12$$

where E stands for CO₂ emissions, TRF is the total fuel requirement (GJ of natural gas), CCF is the carbon content factor, COF is the carbon oxidation factor and 44/12 is the stoichiometric ratio of carbon dioxide to carbon.

The country specific carbon content of fuel (natural gas) is estimated as described:

- The CC of domestic NG is 16.20 tC/TJ (it is the mean value of CC of NG from the different reservoirs that NG was extracted). This value has been used for years 1990-1993.
- The CC of imported NG is calculated based on the chemical composition data of natural gas provided by DESFA (Hellenic Gas Transmission System Operator S.A.), as described in 3.2.4.4.2 of the present NIR. It should be noted that there is no urea production in Greece. The above mentioned plant only markets urea as a result of import.
- The carbon oxidation factor is assumed to be 100%.

The CC of imported NG per year is presented in **Table 4.11**.

Table 4.11 *Carbon Content of imported NG for years 1998-2014*

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
CC (tC/TJ)	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10	15.10
Year	2007	2008	2009	2010	2011	2012	2013	2014	
CC (tC/TJ)	15.10	15.12	15.14	15.16	15.07	15.16	15.10	15.10	

Activity data concerning fuel consumption for the years 1998-2009 have been provided by the plant using natural gas and by DEPA. Data for 2010 – 2012 are plant specific and provided by the sole plant operating in Greece, while since 2013 data are provided to the inventory team under the EU ETS system. National ammonia production for the whole time-series has been provided by the ElStat and for the years 1998-2014 by the one plant still operating in Greece. All the activity data and the estimated emissions are presented in **Table 4.12**.

Table 4.12 *Ammonia production, natural gas consumption and CO₂ emissions for the period 1990 - 2014*

Year	Ammonia Production (kt)	NG consumption (TJ)	CO ₂ emissions (kt)
1990	313.03	4046.40	652.04
1991	255.61	3866.40	620.50
1992	167.94	3676.50	218.32
1993	69.78	2369.70	140.72
1994	0.00	0.00	0.00
1995	96.98	IE	IE
1996	133.91	IE	IE
1997	122.16	IE	IE
1998	244.76	3221.06	177.48
1999	233.33	5152.26	283.96
2000	147.48	5005.86	275.90
2001	68.70	2451.96	135.77
2002	94.14	2815.91	155.94
2003	150.18	4918.21	272.40
2004	159.92	5224.00	289.46

2005	143.88	4755.67	263.30
2006	160.90	5284.66	292.59
2007	165.77	5401.55	299.16
2008	125.91	4155.71	230.37
2009	102.86	3379.32	187.61
2010	159.00	4870.54	270.76
2011	157.59	4728.78	262.51
2012	106.69	3214.67	178.73
2013	128.14	3831.36	212.13
2014	144.56	4359.26	241.31

4.6.3 Uncertainty and time-series consistency

Although the data are plant-specific, a level of uncertainty originates from the fact that the gaseous inputs are generally more uncertain than the liquid or solids inputs. Therefore the EF 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.

The emissions over the time-series are characterised by intense fluctuations. This is due to the fact that the operation of both plants was quite unstable, while part of the emissions is still accounted in the energy sector, due to lack of information on the liquid fuels used, since the relevant plant has ceased operation since 1999. More specifically, the emissions estimation that refer to liquid fuels for years 1993-1999 are included in the category 1.A.2.c for Chemicals of Manufacturing Industries and Constructions of the Energy sector, under “Liquid Fuels”.

Emissions show a minimum in 2001 (135.77 kt CO₂) and a maximum in 2007 (299.16 kt CO₂). As described above, from 1990 to 1993 the ammonia production refers to the national production from both plants, whereas the emissions are resulted from the operation of plant A alone. The fluctuation noticed in these years is therefore attributed to the different percentage of each industry's contribution to total ammonia production. The high EF during years 1990-1991 can be attributed to the reallocation of emissions from lignite, while the low IEF for years 1992, 1998 and 1999 can be attributed to the fact that the emissions refer to one industry, while the production to both. This changes in 2000 (final closure of plant B) and as a result the IEF is close to the average value of the next years (1.781 kt CO₂/kt NH₃). Between 2000 and 2001 the NG consumption and the ammonia production are both reduced to half (51% and 53% accordingly). The interannual change of the IEF is attributed to the carbon content of the imported natural gas that changes from 15.03% to 15.10% from 2000 to 2001, respectively. However, for the recent years the IEF is quite stable and any minor fluctuations can be attributed to the variation of the carbon content of the NG used (*Table 4.11*). Any other change of the IEF is attributed to the CC and consumption of natural gas.

4.6.4 Source-specific QA/QC and verification

The source-specific QA/QC procedures include the comparison of emissions calculated with different tiers. The default EF reported in the 2006 IPCC Guidelines is about 1.7 t CO₂/t ammonia produced.

However based on the European average values for specific energy consumption (Mix of modern and older plants), reported also in the 2006 IPCC guidelines, the default EF is 2.1 t CO₂/t ammonia produced. The estimated IEF is in the range of reported emission factors, as it can be clearly seen in *Figure 4.8*.

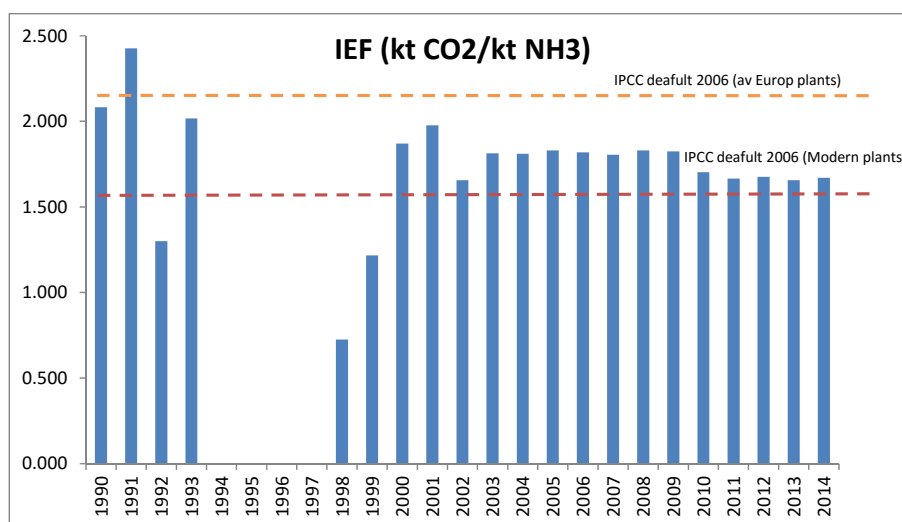


Figure 4.8 Fluctuation of the IEF in the inventory years

Additional QC checks include the gathering of data from different sources. This is being performed in two ways:

1. Ammonia production: the plant-specific production data are cross-checked with alternative sources. These sources include ElStat (Prodcom department, confidential data) and the Ministry of Economy, Infrastructure, Shipping and Tourism have been used, whenever available.
2. NG Consumption: The natural gas quantity used by the one plant operating in Greece is gathered by both the NG provider (DEPA) and by the sole plant producing ammonia in the recent years. In addition, for years 1990-1993 data have been received by Kavala Oil. In order to ensure time-series consistency and also consistency with the energy sector, DEPA and national statistics are being used, while the ammonia's producer information is gathered for additional QC use. In general there is a difference of 5% between the two values, which can be considered quite stable and is attributed to the general uncertainty of the gaseous fuels input.

4.6.5 Recalculations

No recalculations have been performed in this submission.

4.6.6 Planned improvements

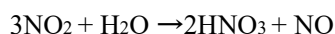
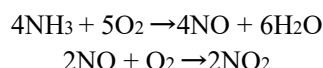
Up to now the methodology used is Tier 1a and the EF is country or plant specific. In addition, and following the internal QC procedures, there is an implemented improvement plan in ammonia production sector that has as follows:

- An effort is being made to define the liquid fuel used as feedstock for ammonia production in the years 1992-1999, procedure that has been proved quite difficult up to now. However, in order to ensure the time-series consistency the Industrial Sector inventory team is working closely with the Energy sector team and the relevant industry, in order to define the pre-mentioned fuel.
- Once the liquid fuel is defined, the default methodology can be used for the estimation of emissions, using the ammonia production data.
- The fuel quantities estimated will be reallocated from the Energy to the IP sector.

4.7 Nitric acid production (CRF Source Category 2.B.2)

4.7.1 Description

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



Nitric acid production (N_2O emissions) is a key category by trend assessment. Nitrous oxide emissions from nitric acid production in 2014 (*Table 4.13*), account for 0.22% of total GHG emissions from *Industrial Processes* and for 0.03% of total national emissions (without *LULUCF*). Emissions in 2014 have decreased by 98.49% from 1990 and increased by 29.94% since 2013.

4.7.2 Methodology

N_2O emissions from nitric acid production are estimated according to the following equation (default methodology, IPCC 2000):

$$E = EF \cdot NAP \cdot (1 - DF \cdot ASUF)$$

where, E is N_2O emissions, NAP is nitric acid production, EF is the emission factor, DF is the N_2O destruction factor for abatement technology and $ASUF$ is the abatement system utilisation factor on an annual basis.

The following are noted in relation to the application of the above equation:

- For the years prior to 2014 the emission factor used is the average of the default values suggested by the IPCC Guidelines (IPCC GPG, 2000) for units operating under medium pressure (7 kg N₂O / t HNO₃). The inventory team has communicated with the relevant plant and the EF used is according to the operation conditions reported by the plant. (The methodology used for the production of nitric acid is Dual Pressure. Ammonia is catalytically burned in presence of air at 4 bars.).
- Nitric acid production data derive from ElStat and the individual industrial units for 1990-2012. Actually, since 2006 there is only one unit producing nitric acid in Greece therefore, data are received directly by the unit.
- The activity data and emission factor concerning nitric acid production for the years since 2013 are provided by the ETS reports.
- The abatement system used by the Greek installations for reduction of NO_x emissions is the absorption tower. This technology does not affect the N₂O emissions (IPCC 2000), and for this reason *DF* and *ASUF* parameters in the above mentioned equation are not considered for the years prior to 2013.
- Since 1/1/2013 a catalytic conversion system of N₂O to nitrogen operates in the nitric acid plant, as reported by the sole plant operating in Greece, therefore a CS methodology, equivalent to the IPCC Tier 2 methodology, is being used.

Table 4.13 **Nitric acid production (in kt) and N₂O emissions (in kt) for the period 1990 – 2014**

Year	HNO ₃ production (kt)	N ₂ O emissions (kt)
1990	511.08	3.58
1991	421.38	2.95
1992	440.65	3.08
1993	418.45	2.93
1994	406.84	2.85
1995	404.84	2.83
1996	462.31	3.24
1997	406.04	2.84
1998	334.13	2.34
1999	346.99	2.43
2000	355.33	2.49
2001	298.65	2.09
2002	287.53	2.01
2003	265.39	1.86
2004	252.32	1.77
2005	251.52	1.76

2006	204.01	1.43
2007	202.55	1.42
2008	194.61	1.36
2009	169.32	1.19
2010	197.42	1.38
2011	219.11	1.53
2012	141.48	0.99
2013	173.93	0.07
2014	182.13	0.09

4.7.3 Uncertainty and time-series consistency

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 AD accuracy, the uncertainty value accounts mainly from the uncertainty of the produced nitric acid quantity.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data inline with IPCC guidelines. In the case of nitric acid production, the default methodology has been used for the years prior to 2013, while a country specific methodology is used since 2013.

The trend of the time-series can be seen in **Figure 4.9**. As it can be seen from this Figure, the trend is generally decreasing, apart from 2010-2011 that emissions appear to be increased in relation to 2009. This however was counterbalanced by the 2012 decrease in emission, which appeared to be even lower than 2009 (-16.44% since 2009 and -35.43% since 2011). Since the same emission factor has been used for all the years of the time series, according to the information provided by the plant, the changes of the emissions indicate the general change of the production level.

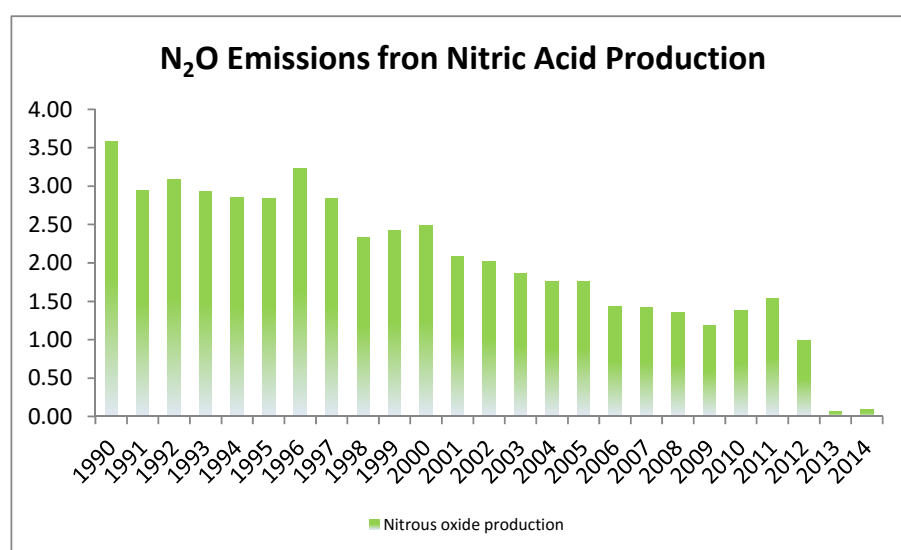


Figure 4.9 *N₂O emissions (in kt) from Nitric Acid Production for the period 1990 – 2014*

In 2013 and 2014 a severe decrease in emission is noticed due to the installation of a catalytic conversion system of N_2O to nitrogen in the nitric acid plant.

4.7.4 Source-specific QA/QC and verification

According to the QA/QC procedures, all the information received by the plants is archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

In specific, the main source for the estimation of emissions is the data received directly by the one plant operating in Greece. Additional Quality Control Checks make use of confidential information provided by the ElStat, regarding HNO_3 production. Although PRODCOM data are provided each year, they may not be finalized by the annual submission of the inventory. However, even in that case the Service unofficially provides the Inventory Team with the provisional data, following the QC procedures of the Service. In that case the final QC checks may take place in the following year, and the respective results are presented in the next submission. Since 2013 the data are acquired by the ETS reports that are also verified by the accredited verifiers of the Greek Emissions Trading System. Until 2012, the estimate was the best available according to the data provided by the sole plant operating in Greece. In addition, for the years prior to 2013 the emission factor used is stable $7 \text{ kgN}_2\text{O} / \text{t HNO}_3$, equal to the average of the default values suggested by the IPCC Guidelines (IPCC GPG, 2000) for units operating under medium pressure, according to the information provided by the plant.

4.7.5 Recalculations

No recalculations have been performed during this submission.

4.7.6 Planned improvements

After the installation of an abatement technique for the recovery of N_2O emissions no improvements are planned as the current submission can be considered satisfactory.

4.8 Petrochemical and Carbon Black Production (CRF Source Category 2.B.8)

4.8.1 Description

CO_2 , CH_4 and NMVOC emissions from the production of ethylene and 1,2 dichloro-ethane, as well as NMVOC emissions from the production of polyvinylchloride and polystyrene are included in this category.

CO_2 and CH_4 emissions deriving from the Petrochemical and Carbon Black Production (namely ethylene and 1,2 dichloro-ethane production) ceased in 2000, due to the cease of ethylene and 1,2 dichloro-ethane production in Greece in 1998 and 2000, respectively. With regards to CH_4 emissions, their contribution to total GHG emissions from *Industrial Processes* is less than 0.01%

for the period 1990 – 2000. **Table 4.13** presents the emissions from Petrochemical and Carbon Black Production.

Table 4.14 *Emissions from Petrochemical and Carbon Black Production(in kt) for the period 1990 – 2001*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO ₂ emissions	28.61	29.15	29.68	29.30	30.43	32.03	33.38	33.02	31.23	8.52	6.06	NO
CH ₄ emissions	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.02	0.01	NO

4.8.2 Methodology

CO₂ Emissions

CO₂ emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

$$E_{CO_2} = PP \cdot EF \cdot GAF/100$$

where E_{CO_2} = are the CO₂ emissions from production of petrochemical (t), PP is the annual production of petrochemical (t), EF is the CO₂ emission factor for petrochemical (t CO₂/t product produced) and GAF is the Geographic Adjustment Factor (equal to 110% for Eastern Europe for Tier 1 CO₂ emission factors).

Default emission factors (IPCC Guidelines) are used. Wherever available the updated 2006 IPCC guideline EFs are being used. With regards to CO₂ emissions the default EFs were used in both the cases of ethylene and Ethylene dichloride according to the 2006 IPCC Guidelines. Activity data (production of ethylene and 1,2 dichloro-ethane) are confidential and provided by ElStat, until the production has ceased in 1998 and 2000, respectively.

CH₄ Emissions

CH₄ emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

$$(\text{Emissions}) = (\text{Production}) * (\text{Emission factor})$$

Default emission factors (IPCC Guidelines) are used. With regards to CH₄ emissions the default EF used in the case of ethylene production is obtained from the 2006 IPCC Guidelines. Concerning the CH₄ emissions' EF for 1,2 dichloro-ethane the default value from 1996 Guidelines is the only one available. Activity data (production of ethylene and 1,2 dichloro-ethane) are confidential and provided by ElStat, until the production has ceased in 1998 and 2000, respectively.

NMVOC Emissions

Emission factors used for ethylene, 1,2 dichloro-ethane, PVC and Polystyrene are the default ones. The EMEP 2013 Guidelines are used as the IPCC Guidelines do not provide default EFs for NMVOC emissions. The available data cover the period 1990 – 2007 for PVC and Polystyrene, whereas the ethylene and 1,2 dichloro-ethane production covers the years from 1990 to 1998 and 2000, respectively.

4.8.3 Uncertainty and time-series consistency

CO₂ emissions from the ethylene and dichloroethane production have been included in 2015 submission for the years 1990-2000. The Tier 1 methodology and the default EFs of the 2006 IPCC guidelines have been used for the calculation of CO₂ emissions, whereas the production data are provided by the ElStat.

To account for both uncertainties type the value of 5% has been considered.

With regards to methane emissions, time-series consistency is ensured by the fact that the same EF and methodology has been used for all the inventory years. In particular, the EF for the CH₄ emissions has been updated in 2015 submissions from 1t/kt ethylene to 3t/kt ethylene according to the 2006 IPCC guidelines.

The time-series show an important decrease from year 1998 to 1999 due to the cease of the ethylene production. After 2000 both emissions have been zeroed, as a result of the production cease.

4.8.4 Recalculations

No recalculation has been performed in this submission.

4.8.5 Planned improvements

The current submission can be considered satisfactory.

4.9 Fluorochemical Production (CRF Source Category 2.B.9)

4.9.1 Description

HFC-23 is generated as a by-product during the manufacture of HCFC-22 and emitted through the plant condenser vent.

HFC-23 emissions from HCFC-22 manufacture used to be a key category by level and trend in the past years. However, the HCFC-22 production has ceased in January 2006 and emissions do not occur ever since.

HFC-23 emissions are shown in Table 4.15.

Table 4.15 *HFC-23 emissions (in kt CO₂ eq) from HCFC-22 production for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
HFC-23	1182.82	1400.08	1149.07	2023.34	2711.95	4114.99	4738.96	5009.50	5515.07	6353.94	4724.75	4024.42	4040.99
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
HFC-23	3366.11	3226.40	2729.12	NO	NO	NO	NO	NO	NO	NO	NO	NO	

4.9.2 Methodology

According to the 2006 IPCC Guidelines, the analytical methodology (Tier 2) should have been applied for the calculation of HFC-23 emissions from HCFC-22 production, as it used to be a key source. This methodology is based on the collection and elaboration of onsite measurement data. However, due to the lack of such data, calculation of emissions has based on production statistics and a reference emission factor. It should be noticed that data on the production of HCFC-22 are confidential and therefore are not presented in the current report. The reference emission factor used is suggested by the 2006 IPCC Guidelines.

4.9.3 Uncertainty and time-series consistency

The estimated uncertainty is estimated at 50% for both activity data and emission factor, as suggested in the 2006 IPCC Guidelines for Tier 1 methodology.

The implemented methodology is in line with the IPCC Guidelines, while no changes or refinements are to be expected in the current category. The estimation methodology used is the same for the whole time-series.

4.9.4 Source-specific QA/QC and verification

In order to ensure the quality control, all the collected data regarding emissions are kept in the Input file of the inventory system. Other QA/QC procedures described in the IPCC GPG are not applicable.

Recalculations

4.9.5 Recalculations

No recalculations have been performed.

4.9.6 Planned improvements

The current submission can be considered satisfactory.

4.10 Other Chemical Production (CRF Source Category 2.B.10)

CO₂ emissions from Hydrogen production are included in this category. In 2011 submission these emissions were included in the Energy Sector, but in 2012 they have been reallocated in the IP sector, in line with the ERT recommendations.

Other Chemical Production (CO₂ emissions) is a key category by trend assessment. The contribution of CO₂ emissions from Hydrogen Production account for 2.65% of the *Industrial Processes* emissions and for 0.32% of *Total Emissions* (excl *LULUCF*) for 2014, showing an increase of 7.64% from 2013. **Table 4.16** presents the emissions from Hydrogen production.

Table 4.16 Emissions from Hydrogen production (in kt) for the period 1990 – 2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO2 emissions	NO	NO	NO	NO	NO	NO	NO	83.17	173.51	60.85	NO	NO	9.75
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
CO2 emissions	14.21	15.06	33.62	21.34	18.78	107.69	265.65	362.13	321.88	323.29	304.78	328.08	

4.10.1 Methodology

CO₂ emissions for H₂ production are estimated on the basis of the natural gas consumed for the process. Hydrogen production emissions refer to years after 1997, as natural gas consumption refers to the imported Natural Gas that was introduced in 1996 to the Greek energy system. Data are provided by the Public Gas Company (DEPA) for the whole time-series and by the verified EU ETS reports of the refineries for years 2005-2014. In **Table 4.17** the estimation parameters can be viewed. It should be mentioned that the activity data reported in the CRF Reporter refer to the quantity of natural gas consumed in TJ, although the CRF reported unit is kt (please also see the relevant comment). This is due to the unavailability of reporting in TJ units in the *Industrial Processes* Sector. The reporting in kt equivalent could have been performed if the NCV was available, however the relative consumption in the energy balance is given directly in energy units and therefore there is no such information to be used accordingly. At this point, it should be mentioned that the associated emissions from hydrogen production from liquid fuels are reported under Energy CRF category 1A1b.

Table 4.17 Parameters for the Estimation of CO₂ Emissions from Hydrogen Production (1997-2014).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
NG Consumption (TJ)	1,509.38	3,149.11	1,104.06	0.00	0.00	176.05	256.52	271.72	607.30
CC (t C/TJ)	15.03	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10
EF (t CO ₂ /TJ) (Oxid Fact=100%)	55.10	55.10	55.11	55.12	55.37	55.38	55.39	55.41	55.37
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
NG Consumption (TJ)	385.44	339.15	1,942.69	4,785.09	6,459.80	5,745.16	5,766.52	5,464.98	5,863.78
CC (t C/TJ)	15.10	15.10	15.12	15.14	15.29	15.28	15.29	15.21	15.26
EF (t CO ₂ /TJ) (Oxid Fact=100%)	55.37	55.38	55.43	55.52	56.06	56.03	56.06	55.77	55.95

It should be noted that the CC values used in table 4.11 (Ammonia production source category) are the values based on the country specific CC, which are calculated as described in Chapter 3 – Energy Sector. On the other hand the CC values used for H₂ production (Table 4.16) are based on the plant specific data provided (through EU ETS reports), and are used as they led to higher accuracy.

4.10.2 Uncertainty and time-series consistency

The uncertainty of the activity data and the EF for the CO₂ emissions estimation is 3% (for both values), on the basis that the relevant information is plant specific and provided by the verified reports.

The time-series of the CO₂ emissions show important fluctuations. Hydrogen production has started in 1997, in a way that the natural gas consumption refers to the imported Natural Gas that was introduced to the Greek energy system by the Public Gas Company (DEPA) in 1996. In the recent years emissions experience a strong increase that was very intense for 2010, due to the important increase of both carbon content and natural gas consumption in the activity data (**Figure 4.10**). However, in 2012 the CO₂ emissions were reported stable compared to 2011, which is connected to the similar NG consumption, as carbon content was reported to be also stable comparing to 2011. In 2014 the CO₂ emissions appeared a decrease by 7.64% since 2013 and 1.48% since 2012.

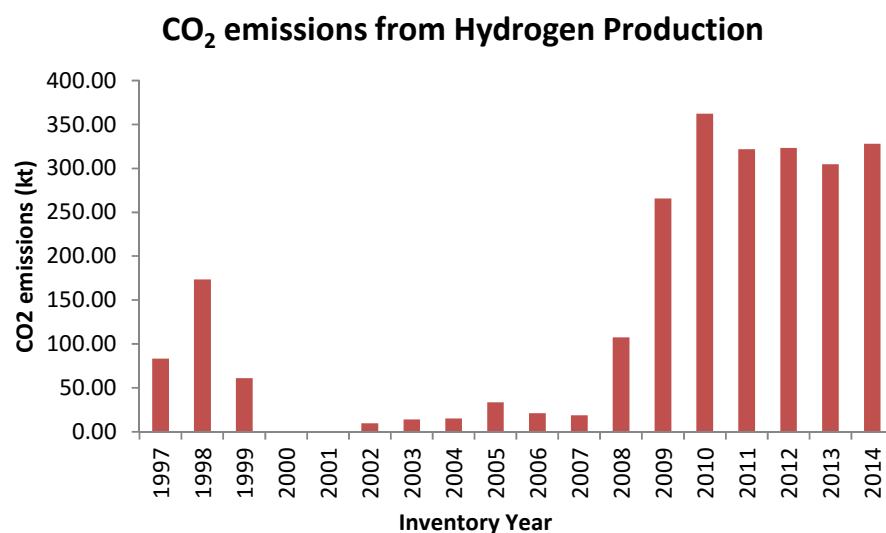


Figure 4.10 CO₂ emissions (in kt) from Hydrogen Production for the period 1990 – 2014

4.10.3 Source-specific QA/QC and verification

For years where data from both DEPA and the EU ETS are available, namely years 2005-2014, the consumed quantities of natural gas are being cross-checked. In addition, the ETS reports used in

the estimation of CO₂ emissions from Hydrogen Production are verified by the accredited verifiers of the Greek Emissions Trading System.

4.10.4 Recalculations

No recalculation was performed during this submission, which is in line with the reviewers comments.

4.10.5 Planned improvements

The current submission can be considered satisfactory.

4.11 Iron and steel production (CRF Source Category 2.C.1)

4.11.1 Description

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. Emissions from Iron and Steel do not constitute a key category.

Carbon dioxide emissions from steel production in 2014 (**Table 4.18**) accounted for 0.57% of total GHG emissions from *Industrial production* and for 0.07% of total national emissions (without *LULUCF*).

Table 4.18 *Steel production, CO₂ emissions and CH₄ emissions (in kt) for the period 1990 – 2014*

Year	Steel production (kt)	CO ₂ Emissions (kt)	CH ₄ Emissions (kt)
1990	999.10	104.89	0.01
1991	980.00	104.15	0.01
1992	924.00	98.85	0.01
1993	980.00	101.87	0.01
1994	848.00	87.39	0.01
1995	939.00	95.51	0.01
1996	809.82	83.64	0.01
1997	1015.67	103.42	0.01
1998	1108.29	113.19	0.01
1999	951.53	98.67	0.01
2000	1104.78	112.68	0.01
2001	1281.51	129.51	0.01
2002	1839.80	181.73	0.02
2003	1700.90	170.64	0.02
2004	1966.24	195.32	0.02

2005	2296.40	229.51	0.02
2006	2415.80	229.61	0.02
2007	2554.52	237.14	0.03
2008	2468.10	215.75	0.02
2009	1999.35	142.82	0.02
2010	1824.14	122.84	0.02
2011	1934.32	133.85	0.02
2012	1247.10	86.82	0.01
2013	1030.00	69.11	0.01
2014	1022.00	70.33	0.01

Emissions have decreased by 32.95% from 1990 to 2014. Especially in years 1990-2000 there was an increasing trend of the production. It should be noted, however, that emissions in 2009-2014 have significantly decreased from 2008 presenting a decrease of 67.40% since 2008, as a result of the decreased economic activity of the sector. Finally, the annual decrease of production level between 2012 and 2013 was 20.40%, followed by a 1.77% increase in CO₂ emissions between 2013 and 2014.

Methane emissions remain at low levels as in 2013 and account for 0.002% of the emissions from *Industrial Processes* in 2014.

4.11.2 Methodology

The methodology used for the estimation of carbon dioxide emissions is based on tracked carbon oxidation throughout the production processes in electric arc furnace operation. For the estimation the following equation has been used:

$$E_{CO_2} = (SC + AN + C + GR + EL - SLB - SLG - D - CL) \cdot \frac{44}{12},$$

where SC=quantity of scrap*carbon content of scrap, AN=quantity of anthracite*carbon content of anthracite, C=quantity of coke*carbon content of coke, GR=quantity of graphite*carbon content of graphite, EL=quantity of electrodes*carbon content of electrodes, SLB=quantity of slab*carbon content of slab, SLG=quantity of furnace and vat slug*carbon content of slug, D=quantity of dust in the dust filter*carbon content of dust and CL=quantity of calamine*carbon content of calamine.

In relation to the estimation of CO₂ emissions from iron and steel production, it should be noted that:

- Activity data for 2005-2014 are plant specific and are based on the verified reports under the EU ETS context.
- According to information received by the ElStat, all the iron and steel plants of the country are included in the EU ETS.

- For the period 1990-2004, information has been collected through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC from all individual plants in Greece, in the framework of the formulation of the NAP, according to the EU Directive 2003/87/EC.
- Data regarding steel production are provided by the ElStat for the years 2004-2014 (in the previous years the relevant Prodcom code did not exist). These data are actually the reported activity data. Especially for 2014 activity data used are received from the data published in the World Steel Association database as data from ElStat are not yet publicly available.
- Emissions from the use of limestone are also included in this sub-category, as suggested by the 2006 IPCC guidelines. Data are generally plant specific, deriving from the EU ETS verified reporting of the plants (for the years 2005-2014) and the reporting performed for the NAP formulation for the previous years. The abrupt reduction in emissions since 2012 can be attributed to the cease of operation of two plants in Greece.
- The emission factor used for the estimation of methane emissions is the default CORINAIR 2013 (SNAP 040207) emission factor (10g/Mg of iron produced), as no emission factor is mentioned in the IPCC guidelines for CH₄ emissions in EAF.

4.11.3 Uncertainty and time-series consistency

The uncertainty associated with the CO₂ EF 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 CH₄ emissions, the uncertainty values are at the same level, in absence of any other data.

The methodology used for the CO₂ emissions is country specific and is the same for the whole time-series. In order to ensure the consistency of the time-series, a recalculation of the previous years has been implemented in 2009.

In specific and following the suggestions of the ERT in-country review of Greece that took place in September 2008, the fraction of total carbon consumption used for the estimation of emissions accounted as residual carbon in slag has been estimated. This was found to be 0.29%. However, the quantities of furnace and vat slag are quite insignificant (0.05% of the overall). According to the same suggestions, once the above mentioned fraction has been found to be insignificant, the CO₂ IEF of years 2005-2007 should be used for the estimation of the entire time-series. In order to do so, the inventory team has collected data on steel production by the ElStat for the years 2004-2006, and used it to estimate the IEF and recalculate emissions. All the information regarding the procedure has been provided in the 2009 NIR. It should be also noted that, in the 2009 centralised review, the ERT have concluded that the recalculation methodologies used are in line with the IPCC good practice guidance.

In general, CO₂ emissions from steel production followed an increasing trend, reaching a maximum value of 237.14 kt in 2007. Then and in the next three years emissions are decreased by 48.20%, as a result of the decreased production. This has been also cross-checked with the general trends in the constructions area, which is safe to be considered as a driver since according to the “2008 Sustainability Report of the world steel industry”, published by the World Steel Association, the Infrastructures sector seems to be the main application of the steel production (50% of steel use in 2007 is designated for use in infrastructure). One out of five plants operating ceased its operation during 2012, reporting zero emissions. In 2013 one more plant ceased its operation. Therefore, a reduction of emissions can be attributed to this in addition to the economic recession that is also present in the Construction Sector. However, in 2014 the emissions have slightly increased (1.77%) while a decrease in production level occurred (-0.78%), which can be attributed to the composition of the raw materials. **Figure 4.10** presents the timeseries of production and CO₂ emissions.

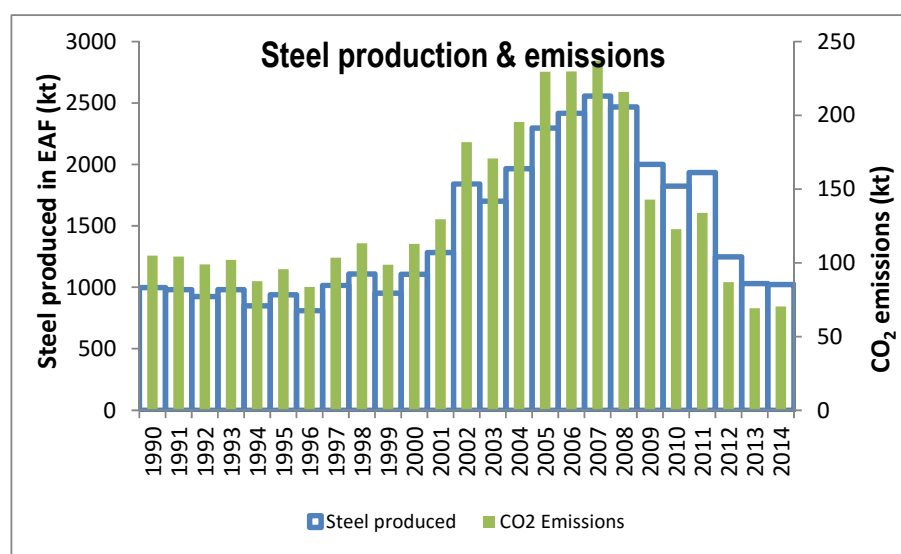


Figure 4.10 Steel production and CO₂ emissions (in kt) for the period 1990 – 2014

On the basis of the completed and detailed data of 2005-2007 a country specific CO₂ emission factor is estimated (0.093 t/t). This emission factor has been calculated a little lower in 2008 (0.080 t/t), and quite more low in the next years. In specific in 2013 and 2014 it was 0.064 and 0.069 t/t, respectively. However, in any case it is close to the default emission factor of 0.080 t/t indicated for electric arc furnaces.

The difference between 2008 and 2009 IEF can be attributed to annual variations of the reduced agents/fuels used and their respective carbon content as well as other material used (e.g. scrap). In addition, it should be noted that (a) emissions from national statistics have been cross checked with the values provided by the World Steel Association and are in line with the slab quantities and (b) the information on the quantities of the carbon content of the materials and the emissions used in

the Inventory are provided by reports of the ETS system which have been verified by accredited verifiers.

4.11.4 Source-specific QA/QC and verification

In order to ensure the quality of the estimation, each plant's reports are checked in two ways: first following the time-series trend of the specific plant and secondly by comparing each plant's report with the general trend for the current year. The data reported in each year are calculated in the specific spread sheet of the year, while all the data are gathered in the Input File of the Inventory at the end of the annual inventory circle.

As an additional quality assurance procedure, plant specific production data are also collected by the inventory team whenever available. Also, less detailed data are collected by international sources, such as the World Steel Association which are cross checked with the data provided by the the Hellenic Statistical Authority.

4.11.5 Recalculations

Emissions deriving from the use of limestone in steel industry have been reallocated from the subcategory "Other process uses of carbonates" to this subcategory, as suggested by the 2006 IPCC guidelines.

4.11.6 Planned improvements

The current submission can be considered satisfactory.

4.12 Ferroalloys production (CRF Source Category 2.C.2)

4.12.1 Description

Ferroalloy production involves a metallurgical reduction process that results in CO₂ emissions. The carbon in the electrodes captures the oxygen from the metal oxide to form CO₂. In addition, the calcination of carbonates fluxes such as limestone or dolomite contributes to these emissions.

As there is only one unit operating in Greece data is plant specific and are characterized by fluctuations.

The CO₂ emissions in 2014 account for the 5.67% of total emissions from *Industrial Processes*, and for the 0.69% of the total national emissions (excl *LULUCF*). As there is only one unit operating in Greece data is plant specific and are characterized by fluctuations. Ferroalloys production is considered a 2014 key category by level assessment.

4.12.2 Methodology

The estimation of CO₂ emissions from ferroalloys production is based on the laterite consumption and the carbon content of it, as well as on the consumption of fuels used as reducing agents and their carbon content.

- Activity data are considered as confidential since there is only one industry operating in Greece.
- Activity data for 2005-2014 derive of the annual verified reports of the industry under the EU ETS.
- Activity data for the period 2000-2004 derive of the reports of the plant during the formulation of the NAP and from additional information concerning the primary fuels and their carbon content for the years 2000-2013. The above mentioned data are combined with supplementary information relevant to the plant production in order to complete the missing data for the period 1990-1999. For the same period of estimation, the carbon content of laterite used is less than 2%, according to plant specific information. Also, detailed information on the emissions from both laterite and reducing agents' use for the years 2000-2014 has been provided by the plant.

4.12.3 Uncertainty and time-series consistency

The uncertainty estimates for both activity data and emission factor are decreased by the fact that plant-specific fuel requirement, laterite consumption and carbon content have been provided by the specific industry. However, this uncertainty should take into account the fact that the provided data cover the years 2000-2014 and for the rest years of the time series the Ni production has been used as a driver. The uncertainty estimate in both cases (AD and EF) has been considered, therefore 7%.

As regards to the time-series consistency, as it has been already mentioned, years 1990-1999 have been estimated using the Ni production as a driver, in absence of any other available data by the industry, whereas years 2000-2014 are reported on the basis of plant specific data. This assures that the same method has been used for the whole time series, enabling the achievement of time-series consistency.

Figure 4.11 presents the emission levels for the whole time-series. As it can be seen the trend follows the trend of other production sectors, indicating an important decrease in 2009 (-45.53% comparing to 2008), as a result of the economical crisis. However, this is partly counterbalanced by an important increase in 2010, which is attributed to the system's recovery from the economical shock experienced in 2009 (51.01% increase). In 2011 a new increase in this sector is presented reaching 27.39% comparing to 2010. Finally, in 2014 an increase in emissions occurred equal to 6.60% compared to 2013.

Regarding raw materials for Ni Production emissions derive from the use of Laterite as described above, as well as Coal, Lignite, Metallurgical coke, Crushed coke, Electrode paste, and Dolomitic

limestone. During the last years the use of coal is the most significant, while the use of lignite was zeroed. Laterite and Metallurgical coke are the next more important agents used.

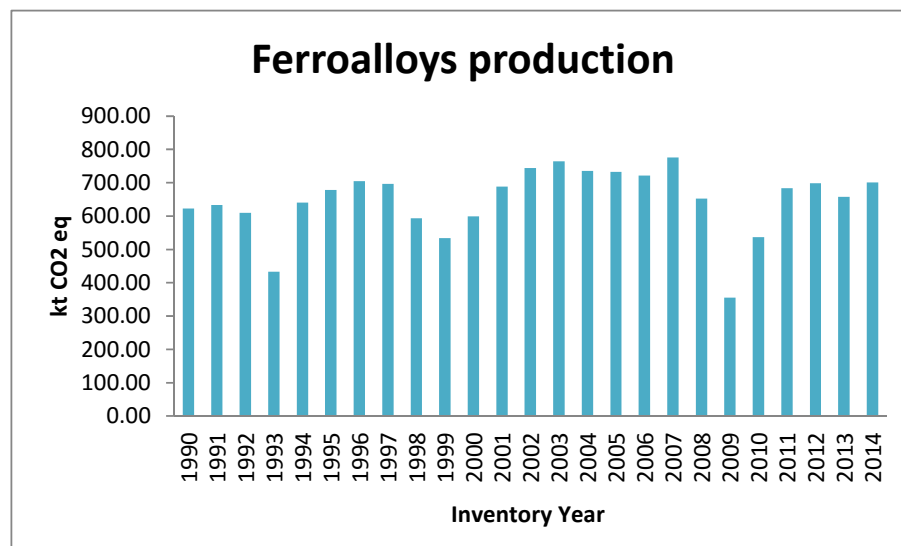


Figure 4.11 *CO₂ emissions (in kt) from Ferroalloys Production for the period 1990 – 2014*

4.12.4 Source-specific QA/QC and verification

In absence of any other data available, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from fuels used as reducing agents are not double counted and the estimation of emissions using the average country-specific EF and the Ni production to make sure that the emissions calculated in both ways do not differ to a high level. It should be also noted that default EF values are not easy to be found in literature for Ni production, making more difficult the estimation with different tiers.

The QC procedures refer to the checking of the IEF in order to ensure that in general the factor is stable. The deviation of the IEFs is attributed to the different percentages of the raw material mixtures throughout the years of the time-series.

4.12.5 Recalculations

No recalculations have been performed during this submission.

4.12.6 Planned improvements

The current submission can be considered satisfactory.

4.13 Aluminium production (CRF Source Category 2.C.3)

4.13.1 Description

Primary aluminium production is responsible for emissions of CO₂ and PFC. Carbon dioxide is produced when, during electrolysis, the carbon of the anode reacts with alumina (Al₂O₃), and also during the anode baking process due to the pitch volatiles combustion and the combustion of baking furnace packing material (coke). Two PFC (CF₄ and C₂F₆) are formed during the phenomenon known as the anode effect, when the aluminium oxide concentration in the reduction cell electrolyte is low.

Emissions of CO₂ and PFC from aluminium production in 2014 (**Table 4.19**) accounted for 2.24% and 0.27%, respectively, of total GHG emissions from *Industrial processes* and GHG emissions excluding *LULUCF*. CF₄ and C₂F₆ emissions in 2014 accounted for 83.295% and 16.71%, respectively, of the PFC emissions (in CO₂ eq.) and 18.60% and 3.73%, respectively, of the total CO₂ emissions derived from Aluminium production.

The average annual rate of increase of CO₂ emissions during the period 1990 – 2014 was 1.14%. Respectively, the average annual rate of increase of PFC emissions is estimated at 2.10%, while emissions have increased by 26.62%, compared to base year emissions (1995). It should be noted that emissions of CO₂ depend directly on aluminium production, while PFC emissions are influenced as well from actions on the restriction of the anode effect.

Table 4.19 CO₂ emissions (in kt) and PFC emissions (in kt CO₂eq) from primary aluminium production for the period 1990 – 2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO ₂ emissions	225.39	229.48	230.64	222.44	207.87	197.12	197.12	199.77	219.99	240.87	244.86	244.05	246.85
PFC emissions	190.26	191.19	187.74	112.94	70.31	62.85	53.73	123.61	151.04	98.23	108.94	67.68	65.10
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
CO ₂ emissions	250.85	250.97	249.08	247.66	249.16	250.32	192.39	207.22	242.03	270.56	276.63	276.87	
PFC emissions	58.09	53.17	52.87	45.28	43.70	55.13	26.21	39.38	45.77	58.41	82.68	79.59	

4.13.2 Methodology

The estimation of emissions from aluminium production is performed in close collaboration with the sole plant operating in Greece and since 2013 ETS verified reports are also provided to the inventory team.

Carbon dioxide emissions from primary aluminium production are calculated using a highly detailed methodology, tracking the carbon content throughout the process. The methodology is based on the 2006 IPCC Tier 3 method, with small interventions that increase the certainty of the estimations. The equations used are described below.

1. Prebake Anode Emissions

$$C_{CO+CO_2}(t) = [(NAC - Waste) * (100 - \%Ash_a - \%S_a)/100] - [C_{inCF_4} + C_{inC_2F_6}]$$

Where:

C_{CO+CO_2} : the carbon content of CO and CO₂ emissions from prebake anode process

NAC: net prebake anode, t

Waste: the quantity of the carbonate sediment that is removed from the basins, t

S_a and Ash_a : the sulphur and ash content in the baked anodes, wt%

and C_{inCF_4} , $C_{inC_2F_6}$: the carbon that is bound by the production of PFCs and does not participate in the CO/CO₂ emissions.

For the distinction of C participating in CO₂, the rate λ is used ($C_{CO} / C_{CO_2} = \lambda * 44 / 28$), based on the measurements of the fuel gases analyzers that operate on a permanent base. The outcome is then multiplied by 44/12 to express the CO₂ emitted.

2. Pitch Volatiles Combustion Emissions

$$CO_2(t) = (GA - H_w - BA - WT) * 44/12$$

Where :

GA: initial weight of green anodes, t

H_w : hydrogen content of GA, t, estimated as $0.005 * GA$

BA: baked anode production, t

WT: Waste tar collected, t, which is considered insignificant.

3. Bake Furnace Packing Material Emissions

$$CO_2(t) = \{ [PC * (100 - \%Ash_a - \%S_a)/100] - [WPC * (100 - \%Ash_b - \%S_b)/100] \} * 44/12$$

Where:

PC: packing coke, t

WPC: Waste packing coke, t

S_a and Ash_a : the sulphur and ash content in packing coke, wt%

S_b and Ash_b : the sulphur and ash content in the waste packing coke, wt%

Data are provided by the plant for years 2005-2012. Since detailed data for the previous years are not available, emissions of years 1990-2004 have been recalculated using the Overlap method in line with the IPCC GPG. It should be noted that the production methodology applied is Centre Worked Prebake with Feed Point System (PFPB methodology). Data since 2013 are provided by the verified ETS reports.

Aluminium production data are directly provided by the plant and are considered confidential. However, publicly available data from the US Geological Survey, the UN Commodity Statistics Database and the Greek Mining Enterprises Association are also used for QA/QC reasons. According to the recommendation made by the previous ERTs, Greece is reporting aluminium production based on these data, although the estimations are based on the more detailed and accurate production quantities provided directly by the plant. It should be mentioned that the reported values are the ones provided by the US Geological Survey, since they cover the whole of the time-series.

PFC emissions estimates are based on anode effect performance by calculating the anode effect overvoltage statistic (Overvoltage method) and are provided directly to the inventory team by the sole plant operating in Greece. This methodology concerns measurements and recordings that are being performed concerning the parameters of the equation used for the CF_4 emission's calculation, namely the overvoltage and the aluminium production process current efficiency. The EF is estimated based on Eq. 3.11 of Chapter 3/GPG ($EF = \text{Over-Voltage Coefficient} \cdot AEO/CE$). The Over-Voltage Coefficient value used by the plant is 1.16 (the updated default one of 2006 IPCC Guidelines), while the Anode Effect Overvoltage (AEO) and Current Efficiency (CE) are measured for each series of electrolytic cells (there are three series).

The C_2F_6 emissions are then calculated by using the following formula:

$$C_2F_6 = 0.1 \cdot CF_4$$

4.13.3 Uncertainties and time-series consistency

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 AD and 6% for EF). All the data and EF are plant-specific and the methodology takes into account the smelter-specific operating conditions.

Emissions have been calculated in the same way throughout the time series. The IEF regarding PFCs emissions is not stable throughout the time-series, mainly because PFCs emissions are not directly associated to the aluminium production but to the anode effect.

The trend of the emissions is depicted in the **Figure 4.12**. PFC emissions from primary aluminium production presented a continuous decrease from 1990 to 1996. Then and for a four years period (1997 – 2000) emissions almost doubled compared to 1996. Since 2001, this trend changes again and emissions were about the same as in 1995 – 1996. The next increase has happened in 2008, followed by an intense decrease by 23.14% in 2009 and an increase from 2010 to 2014, which is in line with the reported production levels. However, PFC emissions decreased in 2014 by -3.74% since 2013.

According to the Greek QA/QC procedures, information has been provided by the plant, concerning the above mentioned trend. This information includes the following:

- ↳ During the period 1993-1998, one aluminium series did not operate leading to the decrease of PFCs emissions (it should be mentioned that the plant disposes three operating aluminium series. All the aluminium series were in place in 1990 and continue to be operating since).
- ↳ During 1998-2000, the plant was facing some operational problems.
- ↳ Since 2000, the accuracy is improved by estimating the over voltage in mV.
- ↳ The difference between 2000 and 2001 is attributed in the exemption of negative overvoltage values.
- ↳ Since 2001 the production process has been significantly improved leading to a decrease in emissions.
- ↳ The plant has also communicated that the increased emissions of 2008 is attributed to the operational crisis of the electrolysis procedure in August-September of the same year. The problem has been caused by the grain size of alumina, and was resolved in during the next year.
- ↳ The decrease in emissions both for CO₂ and PFCs in 2009 is related with the economical recession, influencing all industrial sectors of the country, while during the next two years an increase took place.
- ↳ The decrease of total emissions in 2014 accounted for 0.79% since 2011 and 14.24% since 1990.

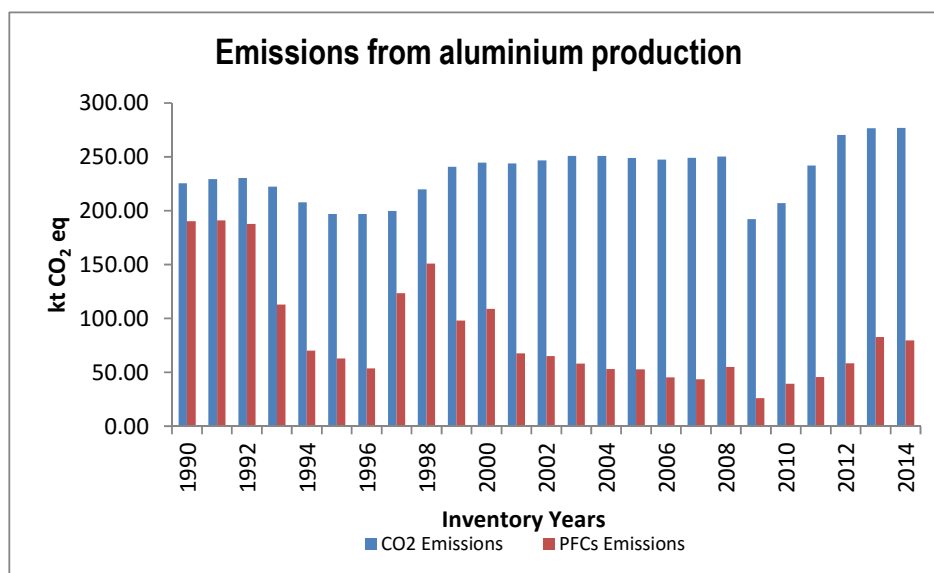


Figure 4.12 *CO₂ and PFCs emissions (in ktCO₂ eq) from aluminium production for the period 1990 – 2014*

4.13.4 Source-specific QA/QC procedures and verification

In the recent years, the estimations of emissions from aluminium production are being conducted in close cooperation with the respective Greek plant, enabling the improvement of the transparency of the inventory, for both CO₂ and PFCs emissions.

Moreover, additional information, such as the Environmental Study and other reports provided by the plant, has enabled the inventory team to better understand the operating situation of the aluminium series and anode effect. In that context, the plant has informed the inventory team on the internal QA/QC procedures undertaken, which include the internal archiving of information, compatible with the Quality Management Procedure of their Internal Quality System (certified to ISO 9001). It should be also noted that, according to information received by the plant, in 2003 the methodology used for the PFCs emissions' calculation has been approved by independent auditors of the Pricewaterhouse Coopers (PwC). In addition, the detailed information provided for the years 2005-2012 has been also verified by accredited verifiers and since 2013 all information are verified under the ETS system.

The Inventory Team's source specific QA/QC procedures include the following:

- The archiving of the all information received in line with the procedures of the QC system.
- Comparison of the emission factors with the default ones and communication with the plant, if needed in order to ensure the quality of the emissions.
- Collection of information / explanation of the trend of the time series, in cooperation with the above mentioned plant.

As a supplementary QA/QC test the IEF of the PFCs has been compared to the default reported in the IPCC Guidelines. The two values are quite close to the default values reported in the study of the Canadian aluminium plants, for Centre Worked Prebaked Technology (*Revised 1996 IPCC Guidelines*).

External sources are being used as alternative information providers in order to validate the production reported by the plant. These sources include the Greek Mining Enterprises Association, and the United Nations Industrial Commodity Statistics Database. Data have been also sought in the US Geological Survey and they are the same as the ones reported by the Greek Mining Enterprises Association. As already reported during previous reviews there has been a pressure on Greece to publish the confidential data reported by plant. In the 2010 and 2011 reviews Greece has also been recommended to report the publicly available data instead of the plant specific ones. In order to resolve this issue, and respecting the accuracy principle of the inventory, the plant specific production data is being used and the publicly available information is reported to help understand the timeseries trend. During the 2012 in country review the publicly available production data which are reported have been approved by the review team as there were minor differences with the confidential plant specific data.

The IEF of the CO₂ has also been compared to the default one. The average factor of the years for which detailed information is available, namely 2005-2014 is 1.53 t/t Al, in the range of the default values of 1.5 (1996 IPCC Guidelines) and 1.6 (2006 IPCC Guidelines).

4.13.5 Recalculations

No recalculation of this subcategory has been performed during this submission.

4.13.6 Planned improvements

In general, the current submission can be considered quite satisfactory.

4.14 Lead Production (CRF Source Category 2.C.5)

4.14.1 Description

CO₂ emissions from Lead production in 2014 (*Table 4.20*), account for 0.08% of total GHG emissions from *Industrial Processes* and for 0.01% of total national emissions (without *LULUCF*). Lead production does not constitute a key source category.

Emissions in 2013 have decreased by 75.90% from 1990 and decreased by 2.84% since 2012.

Table 4.20 CO₂ emissions (in kt CO₂) from lead production for the period 1990 – 2014

Year	Lead production (kt)	CO ₂ Emissions (kt)
1990	26.20	13.62
1991	30.71	15.97

1992	27.96	14.54
1993	28.81	14.98
1994	28.40	14.77
1995	20.40	10.61
1996	11.54	6.00
1997	19.30	10.04
1998	18.00	9.36
1999	22.00	11.44
2000	18.24	9.48
2001	28.62	14.88
2002	29.30	15.24
2003	6.00	1.84
2004	4.00	0.80
2005	7.00	2.36
2006	14.50	6.26
2007	19.00	8.60
2008	34.31	14.32
2009	27.03	10.85
2010	22.20	8.34
2011	26.59	10.63
2012	28.06	11.39
2013	27.44	11.07
2014	26.26	10.46

4.14.2 Methodology

According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO₂ emissions from lead production. CO₂ emissions from lead production are estimated according to the following equation (default methodology, IPCC 2006):

$$E = DS \cdot EF_{DS} + ISF \cdot EF_{ISF} + S \cdot EF_S$$

where, E =CO₂ emissions from lead production, (t), DS = quantity of lead produced by Direct Smelting, (t), EF_{DS} = emission factor for Direct Smelting, (t CO₂/t lead product), ISF = quantity of lead produced from the Imperial Smelting Furnace, (t), EF_{ISF} = emission factor for Imperial Smelting Furnace, (t CO₂/t lead product), S = quantity of lead produced from secondary materials, (t), EF_S = emission factor for secondary materials, (t CO₂/t lead product).

The following are noted in relation to the application of the above equation:

- For all the years the emission factor used is the default emission factor suggested by the IPCC Guidelines (IPCC, 2006) based on 80% ISF and 20% DS. The default EF equals to 0.52 t of CO₂/ t lead. In addition, concerning Treatment of Secondary Raw Materials the default emission factor used equals to 0.2 t of CO₂/ t lead.

- Lead production activity data for the years 1990-2014 derive from international sources (US Geological Survey) as there is a completeness in data availability since 1990.

4.14.3 Uncertainty and time-series consistency

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 EF 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.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data in line with IPCC guidelines. In the case of lead production, the default methodology has been used for the whole time-series.

The trend of the time-series can be seen in **Figure 4.13**. As it can be seen from this Figure, the CO₂ emissions timeseries present fluctuations. More specifically, for the years 2003-2005 there was a low level of CO₂ emissions resulting from a low level in production. In 2008 there was an intense increase in emission equal to 66.55% compared to 2007. For the years 2008 to 2010 there was a decrease in emissions as a result of the economic recession in the country, followed by fluctuations in emissions. Finally, in 2014 there was a slight decrease in emissions compared to 2013 equal to 5.52%.

Since the same emission factor has been used for all the years of the time series the changes of the emissions indicate the general change of the production level.

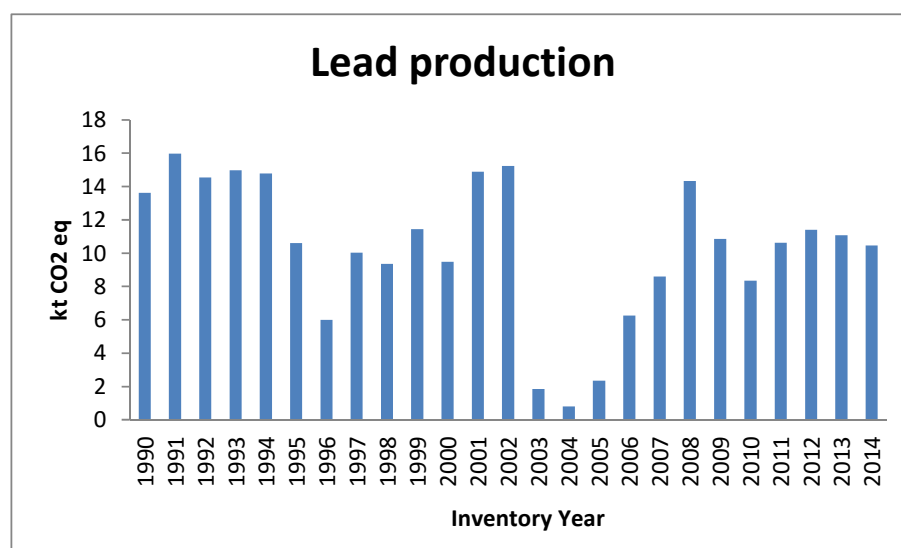


Figure 4.13 *CO₂ emissions (in kt) from Lead Production for the period 1990 – 2014.*

4.14.4 Source-specific QA/QC and verification

Lead production source category was first included in the Greek inventory in 2015 submission according to the 2006 IPCC Guidelines.

According to the QA/QC procedures, all the information received archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

4.14.5 Recalculations

No recalculations have been performed during the 2016 submission.

4.14.6 Planned improvements

Communication with the specific plants related to lead production in Greece is being encouraged in order to be able to have more detailed data in order to improve the Tier of the methodology.

4.15 Zinc Production (CRF Source Category 2.C.6)

4.15.1 Description

CO₂ emissions from zinc production in 2014, account for 0.53% of total GHG emissions from *Industrial Processes* and for 0.06% of total national emissions (without *LULUCF*). Zinc production does not constitute a key source category. Emissions in 2014 have increased by 43.06% from 1990 and by 13.55% since 2013.

The emissions from Zinc production are summarized in *Table 4.21*.

Table 4.21 *CO₂ emissions (in kt CO₂) from zinc production for the period 1990 – 2014*

Year	Zinc production (kt)	CO ₂ Emissions (kt)
1990	26.70	45.92
1991	39.00	67.08
1992	26.20	45.06
1993	24.85	42.75
1994	17.20	29.58
1995	14.50	24.94
1996	13.60	23.40
1997	17.80	30.62
1998	29.10	50.05
1999	19.62	33.74
2000	20.34	34.98
2001	20.46	35.19
2002	30.00	51.60
2003	30.40	52.29
2004	0.00	NO
2005	1.30	2.24
2006	16.41	28.23
2007	18.00	30.96
2008	20.30	34.92
2009	18.13	31.18
2010	19.97	34.34
2011	39.13	67.30
2012	41.82	71.94
2013	33.64	57.86
2014	38.20	65.70

4.15.2 Methodology

According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO₂ emissions from zinc production. CO₂ emissions from zinc production are estimated according to the following equation (default methodology, IPCC 2006):

$$E = Zn \cdot EF_{\text{default}}$$

where, E is CO₂ emissions, Zn is the zinc production, and EF_{default} is the default emission factor.

The following are noted in relation to the application of the above equation:

- For all the years the emission factor used is the default emission factor suggested by the IPCC Guidelines (IPCC, 2006) based on weighting of known emission factors (60% Imperial Smelting, 40% Waelz Kiln). The default EF equals to 1.72 t of CO₂/t zinc.

- Zinc production activity data for the years 1990-2014 derive from international sources (US Geological Survey) as there is a completeness in data availability since 1990.

4.15.3 Uncertainty and time-series consistency

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 EF has been used that is prone to be different from the actual value. As regards to the AD accuracy, the uncertainty value accounts mainly from the uncertainty of the produced zinc quantity.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data inline with IPCC guidelines. In the case of zinc production, the default methodology has been used for the whole time-series.

The trend of the time-series can be seen in *Figure 4.14*.

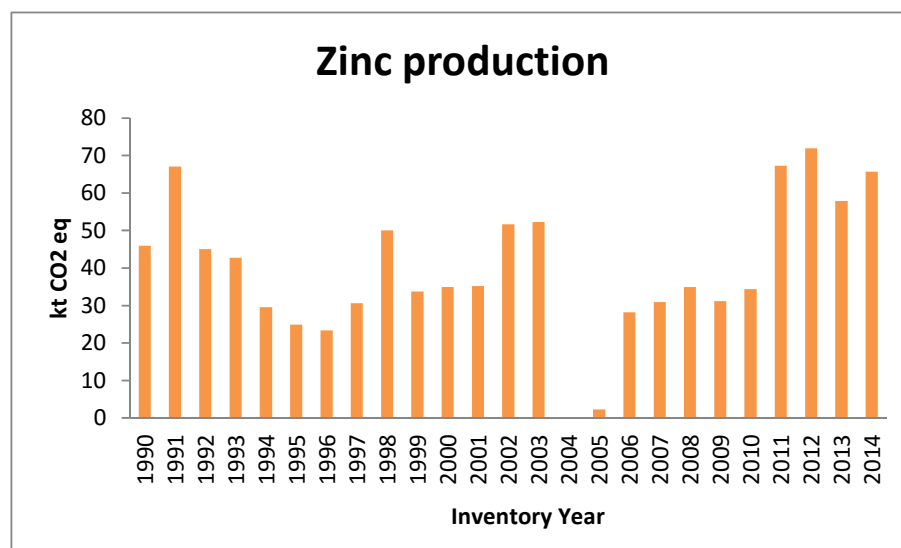


Figure 4.14 *CO₂ emissions (in kt) from Zinc Production for the period 1990 – 2014.*

As it can be seen from this Figure, the CO₂ emissions timeseries present fluctuations. More specifically, for 2004 there was a cease in production and in 2005 a very low production level leading to low CO₂ emissions. In 2011 an intense increase in emissions was noticed reaching 95.96% compared to 2010 level, while in 2012 the maximum value in CO₂ emissions was reached (71.94 kt CO₂). Finally, in 2013 emissions decreased by 19.57% since 2012 and in 2014 they increase by 13.55% since 2013.

Since the same emission factor has been used for all the years of the time series the changes of the emissions indicate the general change of the production level.

4.15.4 Source-specific QA/QC and verification

Zinc production source category was first included in the Greek inventory in 2015 submission according to the 2006 IPCC Guidelines.

According to the QA/QC procedures, all the information received is archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

4.15.5 Recalculations

No recalculations have been performed during this submission.

4.15.6 Planned improvements

Communication with the specific plants related to Zinc production in Greece is being encouraged in order to be able to have more detailed data in order to improve the Tier of the methodology.

4.16 Lubricant Use (CRF Source Category 2.D.1)

4.16.1 Description

Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be subdivided into (a) motor oils and industrial oils, and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate. The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions, included in the IPPU sector.

CO₂ emissions from lubricant use in 2014 (*Table 4.21*), accounted for 0.23% of total GHG emissions from *Industrial Processes* and for 0.0.3% of total national emissions (without *LULUCF*). Lubricant use does not constitute a key source category. Emissions in 2013 have decreased by 71.21% from 1990 and increased by 8.57% since 2012.

The emissions from Lubricant Use are summarized in *Table 4.22*.

Table 4.22 CO₂ emissions (in kt CO₂) from Lubricant Use for the period 1990 – 2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO ₂ emissions	77.83	50.71	51.30	50.12	50.71	43.63	39.50	47.17	30.66	37.73	33.02	46.58	31.84
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
CO ₂ emissions	37.73	41.27	47.17	71.93	60.14	40.68	27.12	23.58	21.82	20.64	22.40	28.30	

4.16.2 Methodology

CO₂ emissions are calculated according to the following Equation with aggregated default data for the limited parameters available and the ODU factor based on a default composition of oil and greases in total lubricant figures (in TJ units):

$$CO_2 \text{ Emissions} = LC \cdot CC_{\text{lubricant}} \cdot ODU_{\text{lubricant}} \cdot 44/12$$

where, $CO_2 \text{ Emissions}$ = CO₂ emissions from lubricants, (t CO₂), LC = total lubricant consumption, (TJ), $CC_{\text{lubricant}}$ = carbon content of lubricants (default), (t C/TJ = kg C/GJ), $ODU_{\text{lubricant}}$ = ODU factor (based on default composition of oil and grease, fraction), $44/12$ = mass ratio of CO₂/C.

The IPCC Default ODU factor for total lubricants that was used is 0.2, assuming 90% lubricating oil consumption and 10% grease consumption and rounded to one significant digit. The CC for lubricants was considered the default carbon content of 20.0 kg C/GJ (on a Lower Heating Value basis), as suggested in the 2006 IPCC guidelines and the NCV was 40.2TJ/kt.

Concerning the activity data for the years 1990-2014 they derive from the energy balance in close collaboration with the Energy sector experts in order to avoid double counting.

4.16.3 Uncertainty and time-series consistency

The uncertainty of both the activity data is and the EF for the CO₂ emissions estimation 5%, on the basis that the activity data derive from the energy balance and the EF is the default one suggested by the 2006 IPCC Guidelines.

The time-series of the CO₂ emissions show important fluctuations. In 2006 a maximum in emissions was reached while for the recent years emissions experience a strong decrease that was very intense for 2012 (**Figure 4.15**). However, in 2013 the CO₂ emissions were reported slightly higher compared to 2012, which is connected to the similar lubricants quantity acquired by the national energy balance. In particular, in 2013 the CO₂ emissions appeared an increase by 8.57% since 2012, followed by an increase in 2014 compared to 2013 equal to 26.32%.

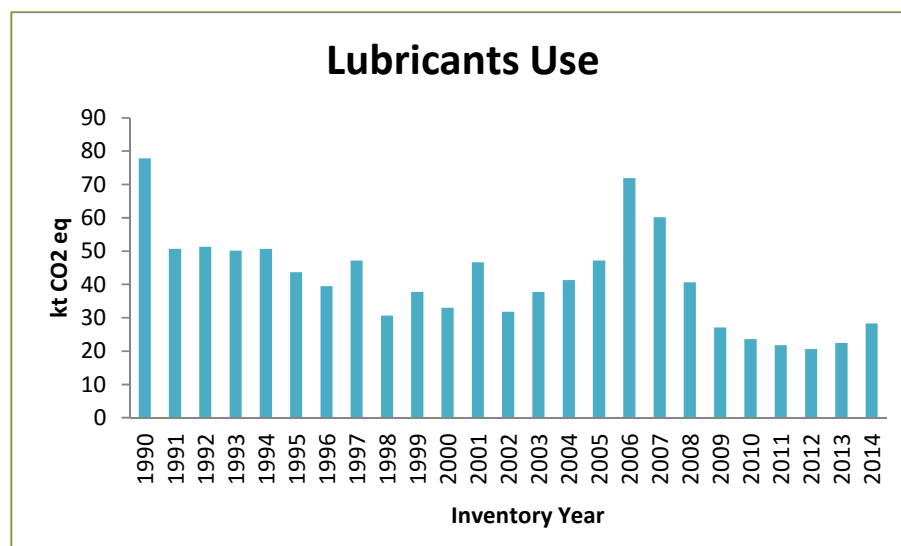


Figure 4.15 *CO₂ emissions (in kt) from Lubricant Use for the period 1990 – 2014.*

4.16.4 Source-specific QA/QC and verification

As there is absence of other data availability, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from lubricant use are not double counted. It should be also noted that lubricant quantity data are not easy to be found in literature, making more difficult the emissions estimation with different tiers. Activity data as it is formerly mentioned are acquired from the national Energy Balance and the EF used is the default one according to the 2006 IPCC Guidelines.

4.16.5 Recalculations

No recalculations have been performed during this submission.

4.16.6 Planned improvements

This submission can be considered quite satisfactory.

4.17 Paraffin Wax Use (CRF Source Category 2.D.2)

4.17.1 Description

Paraffin waxes included in this category are separated from crude oil during the production of light lubricating oils. Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants).

CO₂ emissions from Paraffin Waxes Use in 2014 (**Table 4.22**), account for 0.004% of total GHG emissions from *Industrial Processes* and for 0.0005% of total national emissions (without *LULUCF*). Paraffin Wax use does not constitute a key source category. Emissions in 2014 have decreased by 70.53% from 1990 and by 14.16% since 2013.

The emissions from Paraffin Wax Use are summarized in **Table 4.23**.

Table 4.23 *CO₂ emissions (in kt CO₂) from Paraffin Wax use for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO ₂ emissions	1.77	1.77	2.36	2.36	1.77	1.18	1.18	0.59	0.59	0.59	0.59	0.59	0.34
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
CO ₂ emissions	0.23	0.59	0.21	0.27	0.34	0.45	0.50	0.38	0.38	0.50	0.61	0.52	

4.17.2 Methodology

CO₂ emissions are calculated according to the following equation with aggregated default data for the limited parameters available:

$$CO_2 \text{ Emissions} = PW \cdot CC_{wax} \cdot ODU_{wax} \cdot 44/12$$

where, $CO_2 \text{ Emissions}$ = CO₂ emissions from paraffin wax use, (t CO₂), PW = total wax consumption, (TJ), CC_{wax} = carbon content of wax (default), (t C/TJ = kg C/GJ), ODU_{wax} = ODU factor for paraffin wax(fraction), 44/12 = mass ratio of CO₂/C.

According to the IPCC 2006 Guidelines (Tier 1) it can be assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2. The CC for the waxes was considered the default carbon content of 20.0 kg C/GJ (on a Lower Heating Value basis), as suggested in the 2006 IPCC guidelines and the NCV was 40.2TJ/kt.

Concerning the activity data for the years 1990-2014 they derive from the energy balance in close collaboration with the Energy sector experts in order to avoid double counting.

4.17.3 Uncertainty and time-series consistency

The uncertainty of both the activity data and the EF for the CO₂ emissions estimation 5%, on the basis that the activity data derive from the energy balance and the EF is the default one suggested by the 2006 IPCC Guidelines.

The time-series of the CO₂ emissions show important fluctuations. For the years after 1997 low CO₂ emissions are reported until the recent years (**Figure 4.16**). In particular, a decrease of 25% was reported for the years 1993 to 1994, followed by a decrease by 33.33% for the years 1994 to 1995 and 50% from 1996 to 1997. For 2013 there was a slight decrease in emissions compared to 2011, followed by a decrease by 14.16% in 2014 compared to 2013 emissions.

All activity data are acquired by the national balance. After a personal communication with the National Statistical Authority the inventory team was informed that AD are confidential since the number of plants producing paraffin waxes is lower than three. Therefore the small number of plants operating in Greece is also the reason for the emissions' fluctuations.

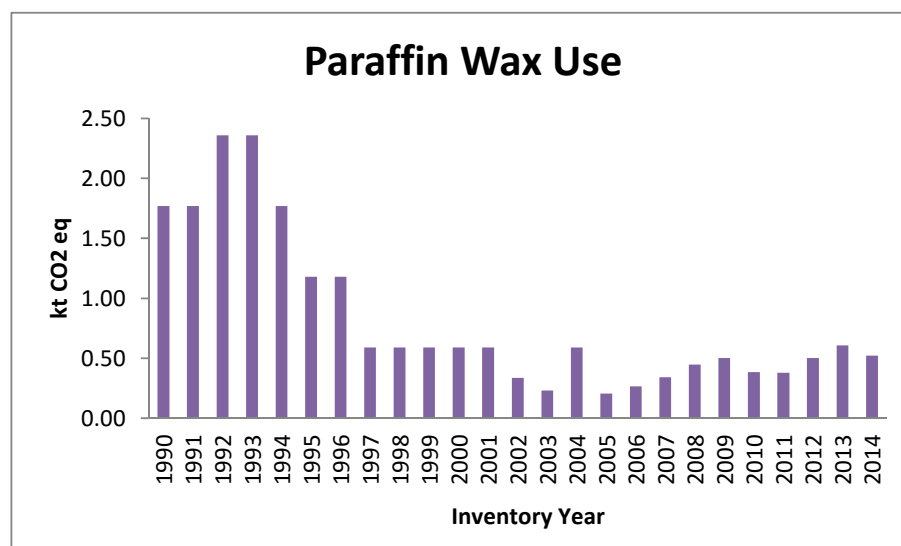


Figure 4.16 *CO₂ emissions (in kt) from Paraffin Wax Use for the period 1990 – 2014.*

4.17.4 Source-specific QA/QC and verification

In absence of other data availability, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from paraffin wax use are not double counted. It should also be mentioned that data availability from other sources, such as literature review, studies, etc. is limited, making more difficult the emissions estimation with higher tiers. Activity data as it is formerly mentioned are acquired from the national Energy Balance and the EF used is the default one according to the 2006 IPCC Guidelines.

4.17.5 Recalculations

No recalculations have been performed during this submission.

4.17.6 Planned improvements

The inventory team has already collected imports and exports data for the paraffin waxes category, including petroleum jelly and other waxes, such as ozokerite. The inventory team is putting a strong effort to collect production data in order to present more detailed AD. However, less than 3 plants operate in Greece and confidentiality issues arise not allowing data to be published. Therefore, these AD will be presented as soon as they become available, in one of the next NIR submissions.

4.18 Solvent Use (CRF Source Category 2.D.3)

4.18.1 Description

Most solvents are part of a final product, e.g. paint, and will sooner or later evaporate to the atmosphere. This evaporation of solvent and other products containing volatile organic compounds represents a major source of NMVOC emissions that, once released into the atmosphere, will react with reactive molecules (mainly HO-radicals) or high energetic light to finally form CO₂. According to the IPCC Guidelines, the following applications are included in this source category:

- Paint application
- Degreasing and Dry Cleaning

Solvent use does not constitute a key source category. Total NMVOC emissions in 2014 have increased by 7.86% from 1990 and decreased by 0.54% since 2012.

The emissions from Solvent Use are summarized in *Table 4.24*.

Table 4.24 NMVOC emissions (in kt) from Solvent Use for the period 1990 – 2014

Year	Population of Greece (1000s)	NMVOC Emissions from paint application (kt)	NMVOC Emissions from Degreasing and Dry Cleaning (kt)
1990	10256.35	10.26	3.08
1991	10339.91	10.34	3.10
1992	10470.96	10.47	3.14
1993	10567.19	10.57	3.17
1994	10666.53	10.67	3.20
1995	10740.61	10.74	3.22
1996	10806.43	10.81	3.24
1997	10885.3	10.89	3.27
1998	10950.41	10.95	3.29
1999	11007.19	11.01	3.30
2000	11044.66	11.04	3.31
2001	11069.01	11.07	3.32
2002	11098.09	11.10	3.33
2003	10998.90	11.00	3.30
2004	11037.74	11.04	3.31
2005	11073.71	11.07	3.32
2006	11112.11	11.11	3.33
2007	11143.78	11.14	3.34
2008	11182.22	11.18	3.35
2009	11190.65	11.19	3.36

2010	11183.516	11.18	3.36
2011	11123.392	11.12	3.34
2012	11123.034	11.12	3.34
2013	11062.508	11.06	3.32
2014	10926.807	10.93	3.28

4.18.2 Methodology

Concerning Paint application, data availability concerning the use of products containing solvents for "Vehicle manufacture and Vehicle refinishing" is limited and as a result the respective emissions are not estimated. Emissions from "Domestic use and construction" are estimated on the basis of population figures and default emission factors from CORINAIR.

Concerning Emissions from Degreasing and Dry Cleaning the estimates are given only for the dry cleaning sector. These estimates are based on population figures and default emission factors from CORINAIR that is applicable to all types of dry cleaning equipment.

In particular, according to the IPCC 2006 Guidelines the methodologies for estimating NMVOC emissions can be found in the EMEP/CORINAIR Emission Inventory Guidebook 2013. The default emission factors used are 1kg/inhabitant/year for paint application and 0.3kg/inhabitant/year for dry cleaning. The AD concerning the Greek Population are obtained by EUROSTAT and they are updated yearly.

4.18.3 Uncertainty and time-series consistency

The uncertainty of the activity data is 6% and the EF for the CO₂ emissions estimation is 3%. As reported in the 2006 IPCC Guidelines usually for this source category only small annual changes are expected. The changes in emissions are following the changes in population of Greece. The population of Greece is increasing year by year reaching a maximum value in 2009 (11,190,650 inhabitants). For the most recent years a decrease in population is presented leading to a decrease in emissions, namely 2.36% since 2009 and 1.23% since 2013.

4.18.4 Recalculations

No recalculation has been performed during this submission.

4.18.5 Planned improvements

The possibility (a) to collect the necessary activity data for the whole time period (1990 to date) in order to estimate the emissions from all possible sources in Greece and (b) to develop national emission factors, representative for the practices followed and weather conditions, is being examined.

4.19 Product Uses as Substitutes for ODS (CRF Source Category 2.F.1 to 2.F.6)

4.19.1 Description

According to the 2006 IPCC Guidelines there are six categories accounting for emissions from the use of ODS substitutes. In specific, emissions of f-gases are generated during the manufacturing, operation/maintenance and final disposal of the following materials/equipment:

- Refrigerating and air conditioning equipment (2.F.1)
- Foam Blowing Agents (2.F.2)
- Fire Protection (2.F.3)
- Aerosols (2.F.4)
- Solvent uses (2.F.5)
- Other applications (2.F.6)

In order to obtain a reliable estimation of f-gases emissions, the collection of detailed data for all the activities mentioned above (e.g. number of refrigerators, type and amount of refrigerant used by each market label, substitutions of refrigerants that took place the late years etc.) is required. The availability of official data in Greece is limited and, therefore, in some cases the estimations presented hereafter involve the application of country specific methodologies.

In order to resolve any remaining completeness issues, and given the fact that there has not been any opposite indication for the use of the PFCs in Fire Extinguishers and f-gases in Solvent Uses up to now, in September 2010 Greece has decided to use information from inventories of neighbouring countries. In specific for Solvent uses the inventory of Italy has been used while for Fire Extinguishers the inventories of Italy, Spain and Portugal have been used, on the grounds that the climatic and socio-economic conditions between Greece and these Countries are quite similar.

Emissions from ODS substitutes constitute a key category in the Greek inventory system by level and trend assessment. Emissions from ODS in 2014 (**Table 4.25**) accounted for 47% of total GHG emissions from *Industrial Processes and Product Use* and for 5.73% of total national emissions (without *LULUCF*). The average annual rate of emissions' increase for the period 1995 – 2014 is estimated at 31.98%. The significant increase of emissions, observed in the timeseries, is attributed to the increased emissions from Refrigerating and air conditioning equipment and especially from commercial and industrial applications of refrigeration mostly.

Also there is an increase in the use of air conditioning equipment, because of the living standards improvement and the restriction in CFCs use, according to the provisions of the Montreal Protocol for ozone depleting substances. Emissions from refrigeration and air conditioning equipment are by far the more important subcategory, contributing by 95.21% to the emissions from ODS substitutes, while emissions from Foam blowing agents are at the second place (3.26% contribution to the

emissions from ODS substitutes in the 2014 inventory). **Figure 4.17** shows the contribution from each subcategory to the total emissions from ODS substitutes.

Table 4.25 *F-gases emissions (in Kt CO₂ eq) per gas from ODS Substitutes for the period 1990 - 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
HFC-23	NO	NO	NO	NO	NO	NO	NO	6.64	14.54	23.22	36.49	47.09	61.40
HFC-32	NO	NO	NO	NO	NO	0.03	0.22	0.73	1.45	2.45	4.78	9.23	15.15
HFC-125	NO	NO	NO	NO	NO	6.10	12.12	24.10	39.46	57.46	90.44	137.29	198.05
HFC-134a	NO	NO	NO	0.10	0.16	27.34	52.43	95.30	149.77	215.02	305.89	427.11	547.39
HFC-143a	NO	NO	NO	NO	NO	8.92	16.44	30.21	47.21	65.88	95.11	127.57	168.30
HFC-152a	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.78	51.22
HFC-227ea	NO	NO	NO	NO	NO	NO	NO	NO	NO	3.17	4.37	5.89	7.57
PFC-116	NO	NO	NO	NO	NO	NO	NO	2.02	4.43	7.08	13.32	16.43	23.18
TOTAL				0.10	0.16	42.38	81.21	159.01	256.88	374.29	550.40	773.40	1,072.26
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
HFC-23	78.66	90.89	103.87	114.65	171.78	186.46	190.76	221.65	196.32	220.06	222.78	180.55	
HFC-32	24.38	36.24	48.77	63.42	79.69	95.41	110.41	133.11	164.13	206.95	279.77	306.06	
HFC-125	280.48	381.28	529.08	639.15	804.19	946.15	1,070.21	1,283.25	1,495.19	1,791.55	2,194.69	2,373.39	
HFC-134a	677.57	825.17	1,166.96	1,343.16	1,525.19	1,741.52	1,809.97	1,864.24	1,884.16	1,847.38	1,960.28	1,877.90	
HFC-143a	214.72	266.35	377.70	409.08	500.06	561.97	597.83	693.47	723.09	790.29	793.33	818.00	
HFC-152a	81.63	88.67	105.66	133.60	141.14	152.37	155.26	159.96	162.36	167.08	158.40	159.04	
HFC-227ea	9.80	12.91	16.29	19.40	23.08	26.47	29.69	32.99	36.40	38.47	40.97	43.19	
PFC-116	31.18	34.68	38.64	41.93	59.35	63.82	65.13	90.06	64.76	89.36	89.88	55.05	
TOTAL	1,398.43	1,736.20	2,386.97	2,764.38	3,304.49	3,774.17	4,029.26	4,478.73	4,726.41	5,151.14	5,740.10	5,813.18	

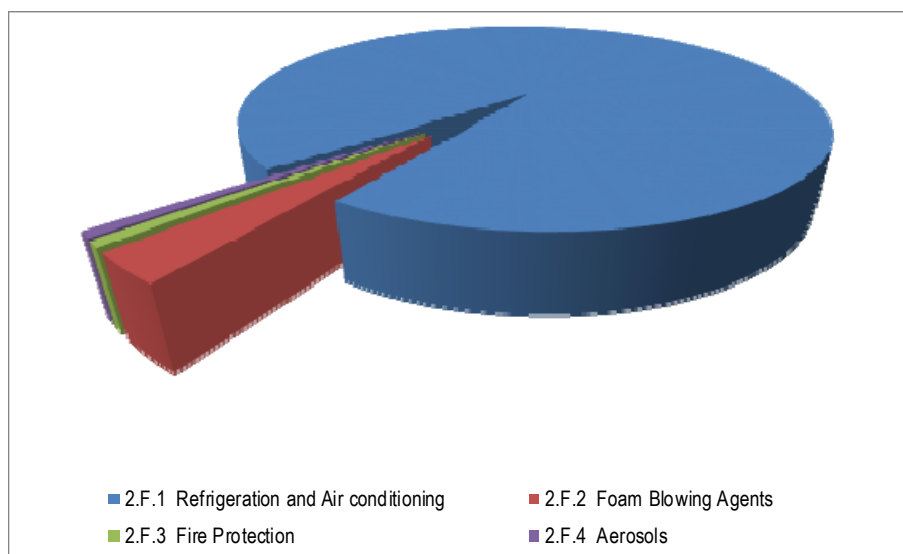


Figure 4.17 *F Gases emissions distribution from ODS substitutes in 2014*

The demand of A/C equipment is highly dependent on the climate conditions. Generally, the raise of the annual mean temperature and the occasional extreme heat waves increase the demand. However, in the last years the economic recession (decrease of consumers' incomes, decrease in consumer loans, credit cards etc.) plays a strong role in the market. The construction activity is another factor that also affects the demand for air conditioner equipment. The sales are also driven by the need to replace the old existing equipment with new less energy consuming products. The replacement depends on the product life, which is usually a factor of the quality and the conditions of use. It should be mentioned that in 2009 the Ministry of Development & Competitiveness (former: Minister for the Economy, Competitiveness and Shipping) motivate consumers to replace their old equipment within the framework of an action called "Changing A/C Equipment". More than 140,000 "old equipment" were replaced. Moreover, the occasionally observed increases in international oil prices, along with the recent increase in fuel consumption tax lead the consumer to choose A/C equipment for heating purposes. The value of refrigerating equipment can have a positive or negative effect on demand. Usually the competition between importing and producing companies and the competitive pricing can drive the sales of products.

The National Association of Refrigeration Importing and Trading Companies has provided, among others, information for the introduction of f-gases in the Greek market. Depending on the data availability, 1995 has been considered the f-gas introduction year for most subcategories in stationary refrigeration and air conditioning, while 1993 has been used as the first year of f-gases use in domestic refrigeration. In any case Greece is using 1995 as base year, and therefore this does not cause any problem to the time series. With regards to transport refrigeration, 2000 has been selected as the first year, based on previous expert judgement performed by the National Association of Refrigerating and Cooling Technicians.

On the basis of the same information the use of f-gases covers the whole refrigeration, mobile air-conditioning and stationary air-conditioning market. It should be noted that as regards transport refrigeration usually the import concerns already used vehicles; therefore the import of each year is corresponded to a 2-5 year previous manufacture.

As regards to the rest of the categories, the use of f-gases in MDIs has been in place since 1995, according to information received by the National Organization of Medicines, while emissions from foam blowing and fire extinguishers have been more recent (2001 and 1999 respectively).

4.19.2 Methodology

Refrigeration and air-conditioning

F-gases emissions are estimated based on the Tier 2a methodology described in the IPCC Good Practice Guidance. This is a bottom-up approach based on detailed equipment data and emission factors representing various types of leakage per equipment category. It should be noted that the application of the Tier 1 methodology (calculation of potential emissions based on imports, exports and domestic consumption of each gas) and Tier 2b (calculation of actual emissions based on detailed sales data per gas and activity) is not possible for the time being, as the available information is not reported in the way required by these methodologies.

Total emissions are calculated as the sum of **assembly** emissions (emissions associated with product manufacturing, even if the products are eventually exported), **operation** emissions that include annual leakage from equipment stock in use (regardless of where they were manufactured) as well as servicing emissions and **disposal** emissions that include the amount of refrigerant released from scrapped systems, regardless of where they were manufactured, according to the following equation:

$$E_c = DOM \cdot CH \cdot k$$

$$E_o = \left(\sum_{t_0}^T (DOM + IMP - EXP)_t \cdot CH \right) \cdot x$$

$$E_D = (DOM + IMP - EXP)_{T-n} \cdot CH \cdot y \cdot (1 - z) - DES$$

The sources of emissions included in the category refrigeration and air conditioning equipment, are the following:

- ↳ Refrigeration
 - Residential applications
 - Other commercial applications (incl. Industrial)
 - Small commercial applications
 - Transport refrigeration

- ✎ Air conditioning
 - Split unit systems and semi-central systems.
 - Central air conditioning – Chillers
 - Other applications of central air conditioning
 - Mobile air conditioning

Regarding the activity data (number of equipment) the following should be mentioned:

- Data residential refrigeration equipment flows for the period 1993 – 2009 are provided by market surveys (ICAP 2000, 2002, 2006, 2008, 2010). For 2010-2014 emissions are estimated using the trend of the more recent years 2005-2009 as the respective survey has not been published up to the time of writing of the current report.
- Data on the commercial and industrial refrigeration equipment flows are determined based on ElStat data. Refrigerated show cases and counters are included in the category of large commercial applications while the rest refrigeration equipment (except residential refrigeration) is considered as small commercial installations.
- Data on the number of transport refrigeration for 2000-2014 are provided by the Ministry of Infrastructure, Transport and Networks and by the Association of Motor Vehicle Importers Representatives.
- Data on the air conditioning equipment flows for the period 1993 – 2013 are provided by market surveys (ICAP 2000, 2002, 2003, 2005, 2008, 2009, 2011, 2013), while for 2014 emissions are estimated using the trend of the more recent years 2009-2013 as the respective survey has not been published up to the time of writing of the current report. .
- Data on the number of new vehicles are provided by the Ministry of Infrastructure, Transport and Networks and by the Association of Motor Vehicle Importers Representatives.

The National Association of Refrigeration Importing and Trading Companies (President and members) and the companies related to the sales of equipment containing f-gases, are determined **the refrigerant blends that are in the market** and **their percentage distribution** along with **f-gases penetration** for each application. More specific, the Inventory Team has been first been informed by the President of the Association of Refrigeration Importing & Trading Companies on the refrigerant blends that are in the market (or have been during the inventory timeseries). An excel form sent out to all members of the Association asking for the quantities imported, exported and sold per blend and year. About 50% of the companies have filled and sent back the reports for the year 2014, indicating the quantities sold in national market, whether they have been obtained by the national market or imported, and exported, and also the years on which each blend has been circulated. Based on the data provided, **the percentage distribution** of each blend has been determined. Moreover, a form sent out annually, to the companies producing/importing/exporting refrigeration and air conditioning equipment in Greece. The response of the companies has been rather reluctant in a way that, for the time being, the data can be used only as indicative for incompleteness reasons (25% of the companies has responded with filled in reports or provision of “no use” information). It should be noted however, that given the intrinsic complexity of the time-series and the market, the sample can be considered quite representative and the reported information has been used additionally to the one provided by the gas importing companies. The **used blends for each application** and **f-gases penetration** derived from the information derived from the National Association of Refrigerating and Cooling Technicians in conjunction to the data

provided from National Association of Refrigeration Importing and Trading Companies and the members, and the Companies related to the sales of equipment containing f-gases.

The values of the basic parameters used for the estimation of emissions, as well as the type of refrigerant used in each category are based on expert judgement performed by members of the National Association of Refrigerating and Cooling Technicians, in combination with the default values provided in the IPCC GPG. With reference to the blends used in each application, additional information has been provided by the President of the National Association of Refrigeration Importing and Trading Companies and cross-checked by the conclusions made from the reporting of the equipment companies.

The percentage contribution of each blend has been determined based on information provided by the importing companies, as described above. The resulted distribution for the years 1995-2014 is presented in **Figure 4.18**.

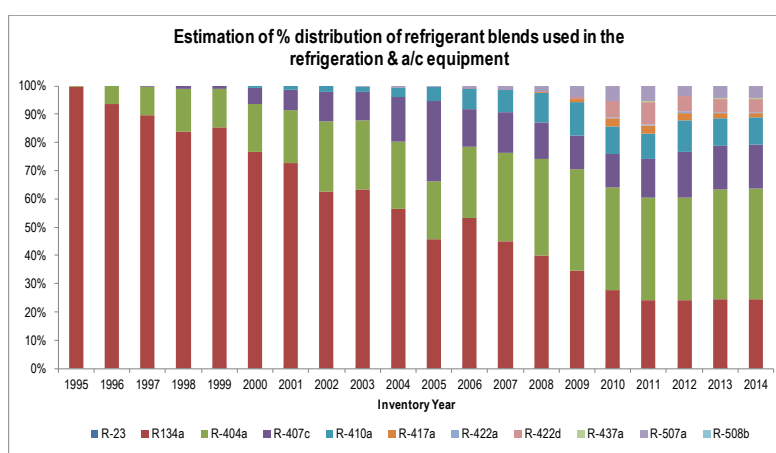


Figure 4.18 *Distribution of refrigerant blends in the Greek market, 1995-2014*

The structure of the emissions from each sub-source for 2014 is presented in **Figure 4.19**.

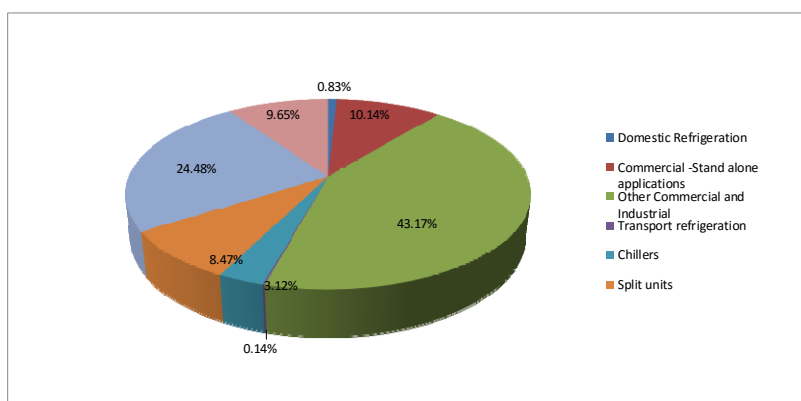


Figure 4.19 *Contribution of each sub-source for 2.F.1 for 2014*

Total F-gases emissions from the above mentioned applications are presented in **Table 4.26** for the period 1993-2014.

Table 4.26 *F-gases emissions (in kt CO₂ eq) from refrigeration and air conditioning equipment for the period 1993 – 2014*

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Domestic refrigeration	0.10	0.16	0.26	0.39	0.58	0.76	0.95	1.11	1.24	1.36	1.44
Commercial-Stand Alone Appl.	0.00	0.00	1.20	3.00	6.47	10.93	14.25	19.31	29.14	39.19	58.32
Other Commercial-Industrial Appl.	0.00	0.00	36.98	68.49	134.23	215.02	303.74	420.58	541.85	678.55	842.05
Transport Ref	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.91	1.65	2.41
Chillers	0.00	0.00	0.08	0.16	0.33	0.79	1.72	3.17	7.26	13.99	22.31
Split-Units	0.00	0.00	0.25	0.49	1.17	2.39	4.73	12.45	29.19	40.24	54.67
Other Applications of Central AC	0.00	0.00	0.13	0.33	0.74	2.03	4.61	11.58	25.52	55.19	103.65
MAC	0.00	0.00	3.44	8.30	15.46	24.92	41.06	77.41	127.17	174.80	221.79
TOTAL	0.10	0.16	42.35	81.17	158.97	256.84	371.08	546.00	762.28	1,004.97	1,306.650
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Domestic refrigeration	1.51	1.57	1.59	1.67	9.85	13.73	26.42	39.52	45.70	46.20	45.71
Other Commercial-Stand Alone Appl.	82.78	110.27	142.07	181.40	219.35	248.69	299.99	372.66	407.48	486.36	561.45
Commercial-Large Applic.	1000.15	1421.28	1498.76	1855.72	2042.33	2119.17	2334.82	2338.86	2448.23	2482.30	2389.35
Transport Ref	3.15	3.95	4.87	5.97	7.81	8.58	9.21	8.87	8.40	8.10	7.78
Chillers	32.40	43.35	54.96	67.63	81.90	96.40	109.19	131.47	150.38	162.52	172.69
Split-Units	73.39	101.27	133.05	167.95	206.09	245.45	286.69	324.88	371.40	416.19	468.83
Other Applications of Central AC	156.58	210.06	266.86	326.31	389.83	439.50	522.77	667.60	897.71	1,303.78	1,354.64
MAC	284.31	343.26	403.23	455.80	521.58	601.18	627.70	594.89	566.57	557.71	534.30
TOTAL	1,634.265	2,235.034	2,505.386	3,062.451	3,478.740	3,772.700	4,216.781	4,478.762	4,895.868	5,463.160	5,534.743

With regards to Residential Refrigeration, according to the data provided by ICAP SA, the majority of the equipment concerns small capacities (lower than 150 L), with a contribution oscillating between 22 and 35% during the years 2003-2008. Other important categories include combinations of refrigerators and freezers characterized by individual external doors, residential refrigerators with compression of a capacity above 340 L and also refrigerators of medium capacity (between 250-340 L). The respective contribution percentages in 2008 were 18.87%, 15.96% and 20.23%. Based on the data provided by the equipment companies the majority of the equipment does not contain R-134a (R600 is being used instead). Especially for the in country produced equipment, the one Greek company active in this area has affirmatively reported the non-use of f-gases in domestic refrigeration equipment. This has been also crosschecked with an information material provided online by the Greenpeace's national website.

With respect to Commercial and Industrial equipment, small applications refer to stand alone equipment mainly used in mini markets and other food trade, private and public companies, restaurants, etc. The main blends used are R134a, R407c and R410a, after 2001. It should be mentioned that R410a is used in new equipment only, while the other two gases are also used in retrofit, for the replacement of R-12 and R-22 respectively. Other commercial and industrial applications refer to refrigerants used for chemical and food production processes. With regards to Industrial applications, penetration is considered quite limited due to the important use of NH₃ as a refrigerant (especially in chemical industries aka fertilizer companies). The blends used in this case vary importantly and are increased in the recent years (R422a, R422d and R437a have been all reported to be used after 2006). It should be noted that the last three cases the blends are used only in retrofit and therefore do not have emissions from assembly. R23 and R508b are also reported in low quantities, being used in very low temperatures (deep freezing applications in hospitals).

With reference to a/c equipment, the following can be noted:

- The in country production which mainly refers to central A/C units, chillers and fan coils present a decreasing trend over the last years (1995-2012) with an average annual rate of decrease at 14%. In 2012 the total production was almost 4,550 units significantly decreased from 2009 (~11,000 units).
- The majority of Imports regards split units (about 91% for 2012). Total Imports of a/c equipment are characterized by a general increasing trend in the years 1995-2007, while imports in 2008 are at the same level with 2007 (increase of 0.9%). Imports in 2009 were significantly reduced as a result of the reduced in country demand. It is also noted that an important percentage of the imported a/c units is re-exported in other countries (mainly Balkans and Turkey). In addition, in 2012 the imports were not decreased; in fact imports were increased at about 2.25%.
- The exports timeseries generally present intense fluctuations. The last four years (2009-2012) the trend is a decreasing one. In fact, in 2012 exports decreased 2.70%.

- Domestic sales in chillers decreased 8% at 2012 (1,150 units). The consumption of Central A/C Units in 2012 decreased 12.19% from 2011. Finally, fan coils follow the same pattern, showing a decrease of 13.51% in 2012 comparing to 2011. Domestic consumption of split units increased 6.5% compared 2012 to 2011 while the consumption of semi-central A/C equipment present an increment of 7.10% since last year.
- Chillers: Domestic sales for the period 1994-2010 presented intense fluctuations. In specific sales in the period 1994-2002 presented an increment with an annual rate of increase at 13.10%. Especially after 2000 the observed increment was due to the development of the infrastructures sector in the years close to the Olympic Games of 2004. In the following years the trend is decreasing, being at the about the same levels for the years 2005-2008, while important decrease is observed in 2009-2012 (-11.70%). Chillers of efficiency up to 14 RT are estimated to be responsible for 50% of the market in 2012, while chillers with scroll compressor covered 87% versus chillers with screw compressor that covered the 12.60% of the market in the same year. Chillers with reciprocating compressor cover a very low percentage of the market.
- Central A/C Units are characterized by an increasing trend in the years 1995-2003 with an average rate of increase at 13%, which is then followed by a decrease in the next years (annual decrease rate 16.30%). The majority of the country's production and consumption refers to small size units (<8000 m³/h). In addition, the domestic consumption mainly covered by the in country production rather than the imports (because of the large volume of the units they are not considered to be profitable). In 2012 the Greek market is 12,19% lower than the previous year.
- The consumption of Fan coils present fluctuation for the examined period. In 2012 the decrement was in sales was 13.5% comparing to 2011.
- Split units (single- and multi-, lower than 24,000 BTU) & semi-central units (split units above 24,000 BTU and limited number of packaged and VRV systems): In the Greek market, this category shows an increasing trend until 2000 (average annual rate of change 23.4%), with some variations in some years for the period 2001-2005. Then and for the years 2006-2008 sales were increased due to the favorable climate conditions. In the last two years imports in this category show a decreasing trend. The decrease at 2009 was 17% for split units, and would have been lower had it not been for the "Changing A/C Equipment" program that has been implemented by the Ministry of Development & Competitiveness (former: Minister for the Economy, Competitiveness and Shipping) in 2009. The consumption of split and semicentral systems was reduced by 25.45% from 2009 to 2010, while in 2009 they were already lower by 23.00% with respect to 2008 levels. The intense decrease in 2010 (25.45 %) observed in Greek market, depicting the decrease of the average household income, while the relatively mild climatological conditions of June-July 2010 also contributed. Split units presented a slight increment in 2012 (6.50%) mainly due to the high temperatures in the

Summer of 2012 and the new European Directive concerning the imports of such an equipment.

The trend concerning A/C equipment refers to the movement of the Greek market based on the production, sales, imports and exports of the units. However emissions in each year concern the use of the corresponding equipment, and therefore the effects of these facts are made visible in the following years of the inventory.

Foam blowing agents

Emissions from foam blowing refer to emissions from hard foam production. The implemented methodology is described by the equation 3.38 of the IPCC GPG:

$$\begin{aligned} \text{Emissions from closed-cell foam} = & [(\text{Total HFCs and PFCs used in manufacturing of new closed-cell foam in year } t) \cdot (\text{first-year Loss emission factor})] \\ & + [(\text{Original HFC or PFC charged blown into closed-cell foam manufacturing between year } t \text{ and year } t-n) \cdot (\text{annual loss emission factor})] \\ & + [(\text{Decommissioning losses in year } n) - (\text{HFC or PFC destroyed})] \end{aligned}$$

In order to perform the estimation of the emissions, data have been collected using information by the questionnaires filled by the four industries of the sector for this reason. According to the information received by the respective companies the Greek market is mainly covered by the products produced in Greece. In general, the industries reported that they do not make any use of PFCs, while one of the industries has also reported the use of other (proprietary) Blowing Agents (PBA) than HFCs. The consumption of foam products containing HFCs has begun in Greek market in 2001 and all the HFCs used concerns the manufacturing of XPS panels. HFC-134a has been used for the period 2000-2001 by one plant, while all the other plants of the sector use HFC-152a. The observed fluctuation in the emission trend (*Figure 4.20*) is due to the different operation periods of the companies.

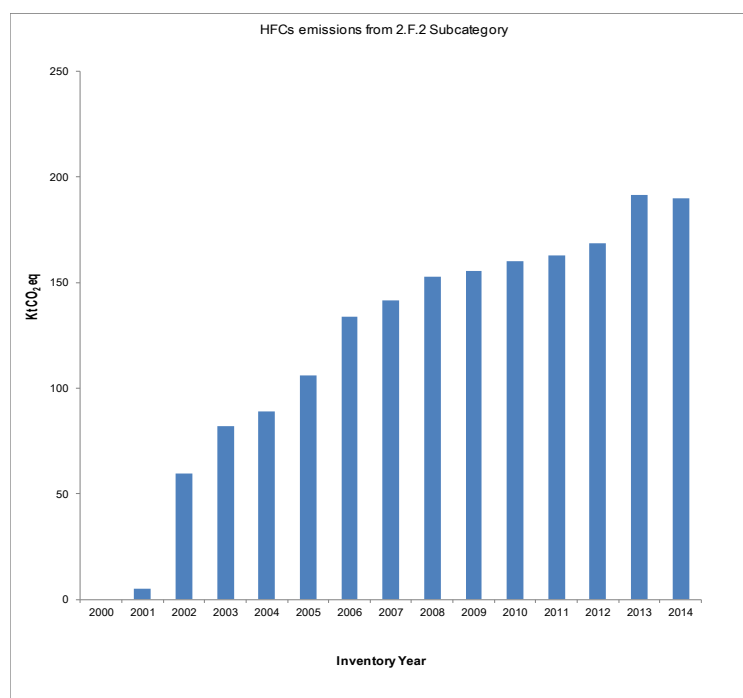


Figure 4.20 HFCs emissions from 2.F.2 Subcategory

From the four companies that report in the Greek system only one has mentioned, apart from XPS production, imports of XPS foams (average of 2.6 % of company's sales). In this case the HFCs emitted from the imported products have been already taken into account in the calculations performed in the previous years. The other companies have explained to the Inventory Team that they are either concentrated only on production or that they do import products that, however, do not contain HFCs. In the 2012 in Country Review the ERT have recommended to continue to collect further information on imports of foam products containing HFCs. In line with this the Inventory Team has tried to contact the PanHellenic Association of Insulating Companies. However, the Association does not provide the required data, probably due to the lack of such data. The inventory team in order to be consistent with the 2012 improvement plan and the ERT recommendations, in 2014 conducted for the first time all the members of the Associations, asked them to fill an excel form with the amount of imported and exported quantities of foam products containing HFCs. Despite the fact that the response was not very high the Inventory Team kept sending them the excel forms and try to inform them and encourage them, in order to overcome their confidentiality issues. Over 30% of the members, have responded, for the time being, thus, the data can be used only as indicative for incompleteness reasons. However, the members that responded reported that they either they do not import foam products because they fulfil their needs from the Greek market (products produced in Greece that have been counted in the inventory) or they import foam products free of HFCs' which contains other (environmentally friendly) gases such as air as cell gas. It should be noted that given the intrinsic complexity of the time-series and the market, the sample can be considered quite representative and the reported information has been considered adequate by the Inventory Team, thus the imports of foam products in Greece are calculated from the reported data from one of the companies which apart from producing also mention imports of foam products containing HFCs.

For the first year's emissions for HFC-134a and HFC-152a the emission factors 25% and 50% respectively have been applied, while the annual loss emission factors were 0.75% and 25% respectively. Both values are the default suggested in the 2006 IPCC Guidelines.

Emissions of foam blowing agents are presented in **Table 4.27**.

Table 4.27 *HFCs emissions (in kt CO₂eq) from foam blowing agents for the period 1995 – 2014*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
First Year Emissions (HFC-134a)	2.33	8.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	31.74	28.53
Annual Emissions (HFC-134a)	0.07	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.35	1.30	2.16
First Year Emissions (HFC-152a)	1.86	33.52	42.63	33.11	33.40	40.89	32.29	29.01	21.27	17.31	13.14	11.91	2.15	1.86
Annual Emissions (HFC-152a)	0.93	17.69	39.00	55.56	72.26	92.70	108.85	123.36	133.99	142.65	149.22	155.17	156.25	157.18
TOTAL	5.19	59.68	81.95	88.98	105.97	133.91	141.46	152.68	155.57	160.27	162.67	168.57	191.44	189.73

Fire protection

According to the 2006 IPCC Guidelines, emissions should be estimated using the following equation:

$$\begin{aligned} \text{Emissions} = & \text{Annual sales of HFCs/PFCs for Fire Protection} \\ & - (\text{HFCs/PFCs used to Charge new fire protection equipment} \\ & - \text{HFCs or PFCs originally used to charge retiring fire protection equipment}) \end{aligned}$$

Although it is good practice to use the above mentioned equation, data in Greece are very scarce and the specific methodology could not be implemented. However, in order to improve the completeness of the inventory, a country-specific estimation of the emissions has been performed, based on the assumption that the use of HFCs in fire equipment in Greece is similar to the one of other Mediterranean countries (Italy, Portugal, Spain), taking into account the country's population.

More specifically the assumption made concludes that since 1999 the use of HFC-227ea for fire protection equipment has been made. The estimated emissions are presented in **Table 4.28**.

Table 4.28 *HFC-227ea emissions (in kt CO₂eq) from fire protection equipment for the period 1999 – 2014*

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
HFC-227ea	3.17	4.37	5.89	7.57	9.80	12.91	16.29	19.40	23.08	26.47	29.69	32.99	36.40	38.47	40.97	43.19

Aerosols

More aerosol packages contain hydrocarbons as propellants, but in a small fraction of the total HFCs and PFCs may also be used as propellants or solvents. Emissions from aerosols usually occur shortly after the production while 100% of the chemical is emitted. According to 2006 IPCC Guidelines, the 5 main sources of aerosols are:

- Metered Dose Inhalers (MDIs)
- Personal Care Products
- Household Products
- Industrial Products and
- Other General Products

Emissions are estimated using the following equation:

- Emissions in year t = [(Quantity of HFC and PFC contained in aerosol products sold in year t) · (EF)]
- + [(Quantity of HFC and PFC contained in aerosol products in year (t-1)) · (1 – EF)]

Data derive of the National Organization of Medicines and the Hellenic Aerosol Association, while plant-specific questionnaires have been sent to all the known private companies of the sector, based on information received by the President of the Hellenic Aerosol Association. The characteristics of the categories can sum up to the following:

Regarding MDIs:

- The use of HFC-134a in manufactured and imported metered dosed inhalers is quite common. Most of the emissions concern imported material, while there are three MDIs brands that have been produced in the country.
- According to the information received by the National Organization of Medicines, the quantity of HFC-134a by piece oscillates between 25 and 75 mg, while the usual quantity is between 47-55 mg.
- The assumption of the total emission of the HFC-134a during the first year after sale has been made. This assumption is in line with the IPCC GPG.

As regards to other aerosol products:

- there is only one plant that has reported the use of HFC-134a. The respective manufacturing process covers the inventory years 2005-2012. The plant has also reported the production, exports and zero imports of the respective products (products that contain HFCs) for all the years of the time-series. The consumption to production ratio oscillates between 67 and 100%, being 66.93% for 2012. In the past emissions have been estimated using this ratio, but in 2011 the plant has informed the inventory team on the average actual charge per piece (70 g/piece). This information in combination with the production and export statistical data is considered more precise than the previous methodology (derivation and use of production/consumption rate).

Emissions from this category can be viewed in *Table 4.29*.

Table 4.29 *HFC-134a emissions from Aerosols/MDIs (in kt CO₂ eq) for the period 1995 - 2014*

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
HFC-134a Emissions	0.032	0.038	0.035	0.035	0.036	0.036	0.040	0.038	0.035	0.036	29.686
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014		
HFC-134a Emissions	105.679	77.501	116.282	71.299	68.684	48.570	48.228	44.532	45.514	105.679	77.501

Emissions in this subcategory are emissions from MDIs and one aerosol product. The increment observed in the MDIs emissions is important in the recent years, mainly due to the inclusion of new MDIs brands in the recent years. The observed fluctuation in the emissions can attributed mostly to the aerosol emissions. Thus, the peak in emission trend in 2005 is due to the fact that the production of aerosol product began in 2005. The variation in the emission trend between 2005 and 2008 can be attributed to the fluctuation in the production and export levels of 2005-2008 in aerosol product that affect the consumption. In 2009 to 2012 emissions experience a strong decline

which is attributed to the corresponding decrease of aerosols being sold, moreover, the decrease in the production of aerosol product was almost 25%.

4.19.3 Uncertainty and time-series consistency

The uncertainty related to emissions from ODS substitutes is generally characterized by high values. In order to improve the estimation, the uncertainty has been estimated for each subcategory separately, while the category's uncertainty value is the combination of the individual estimations.

For the refrigeration and A/C equipment (CRF 2.F.1) the activity data uncertainty has been estimated at 100% whereas an EF uncertainty of 150% is used, due to the fact that the emission factors are selected based on expert's opinion (National Association of Refrigerating and Cooling Technicians) but being in the default range suggested by the 2006 IPCC Guidelines.

In the rest three categories (foam blowing agents, aerosols and fire protection) the uncertainty associated is quite lower. More specifically, in the foam blowing agents subcategory (2.F.2) the uncertainty values suggested by the 2006 IPCC Guidelines have been used. Therefore, activity data uncertainty is at about 40%, which is the proposed value for regional estimates. As regards to the uncertainty associated with the emission value, the value of 50% has been chosen, mainly because the default values have been chosen while no data are available in order to develop country specific values. As regards to aerosol products, the activity data derive from a National Organization and the estimated uncertainty value used is at 15%, whereas the emission factor used has been characterized by a typical uncertainty of 5%. It should be noted that the National Organization of Medicines provided the inventory team with detailed data (brand name, charge and consumption per year) of MDIs sold per year. Finally in the Fire Protection the uncertainty of the activity data amounts to 60%, accounting for the absence of data, while the EF used is the default one and therefore is characterized by an uncertainty of 10%. It should be noted that even though the activity data in the 2.F.3 category are based on assumptions, the countries have been used so as to have common characteristics with Greece with respect to socioeconomical, geographical and climate conditions.

As regards to time-series consistency, the methodology used is the same for the whole time series, while the main data providers remain also the same.

In **Figure 4.21** the trend of 2.F.1 category is presented. As regards the chart, the general trend is increasing.

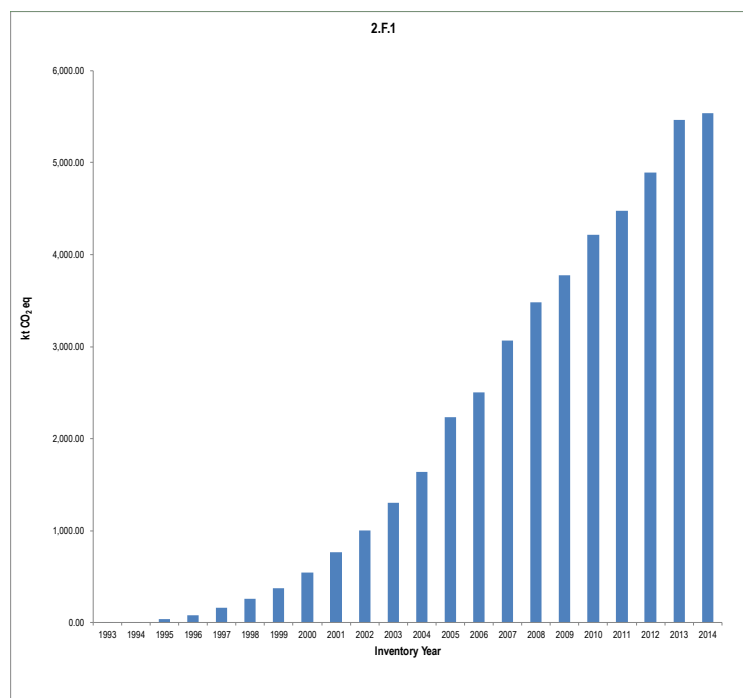


Figure 4.21 HFCs emissions from 2.F.1 for the period 1993-2014 (in kt CO₂ eq)

In Figures 4.22 and 4.23, the trend of each subcategory is also presented.

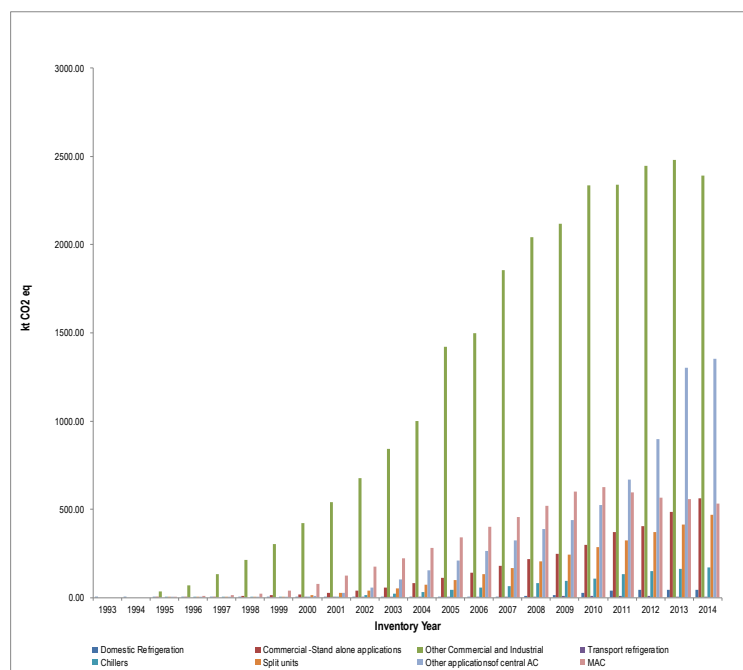


Figure 4.22 HFCs emissions from Refrigeration and A/C equipment for the period 1993-2014 (in kt CO₂ eq)

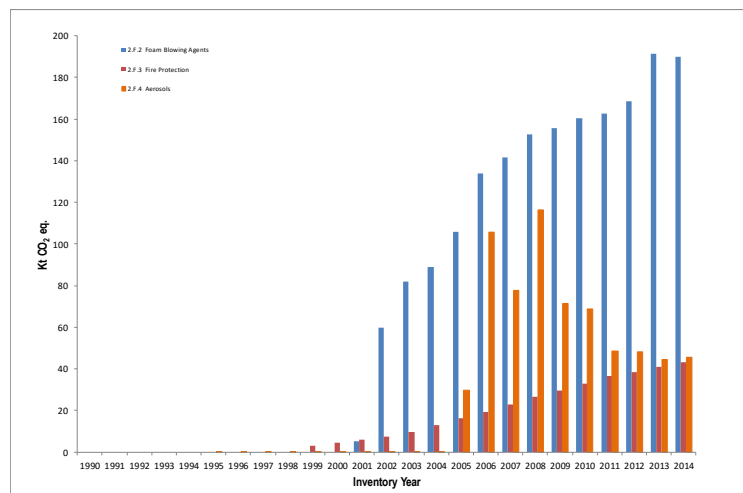


Figure 4.23 *HFCs emissions from Foam blowing, Fire extinguishers and Aerosols/MDIs for the period 1990-2014 (in kt CO₂ eq)*

Regarding the first chart in each subcategory the trend is similar to the general trend. Production and import levels in 2011-2014 show reductions in some subcategories, which is attributed to the financial recession, however, due to the high inertia of the Sector (equipment bought in one year continues to emit gases in the years to follow up to its final disposal) this is not fully depicted in the emissions. However in some cases (commercial refrigeration, chillers, split units, mobile A/C) in 2014 production and imports have slightly increased or either on the same levels with 2013. In any case the f-gases penetration percentage is quite lower in the recent years, following the intense use of R600. One trait that is also important is that part of the equipment has reached its lifetime and therefore is considered to be disposed. The recycling amount of gases, according to the gathered data is quite low, this means that the increase of emissions can attributed also to the disposal procedures in some subcategories. At the same time however, this will lead to their removal from the next year and therefore the total effect is quite counterbalanced.

The second chart refers to emissions from the other subcategories of the ODS substitutes sector. Concerning the MDIs/aerosol emissions, although the increment in the MDIs emissions is important in the recent years, mainly due to the inclusion of new MDIs brands in the recent years, the total trend is a decreasing one mainly due to aerosol emissions. The observed fluctuation in the emissions can also be attributed to the aerosol emissions. Thus, the peak in emission trend in 2005 is due to the fact that the production of aerosol product began in 2005. The variation in the emission trend between 2005 and 2008 can be attributed to the fluctuation in the production and export levels of 2005-2008 in aerosol product. In 2009 and 2010 emissions experience a strong decline which continues in 2011 - 2014 and attributed to the corresponding decrease of aerosols being sold. As regards to emissions from foam blowing, the observed fluctuation is due to the fact that there are only three companies using HFCs and the trend depends on the substitution of HFCs with other blowing agents and on the different year of first use of HFCs for the production process.

It can be observed in any case that the trend was a increasing one until 2013 with a slight increament in 2014.

4.19.4 Source-specific QA/QC and verification

Source specific QA/QC procedures have been performed whenever available. However it is important to note that in most cases this is not feasible due to the absence of official data or even data sources. The estimation using data from different sources has been feasible only in the case of aerosols and MDIs, since data have been collected by the National Organization of Medicines and private pharmaceutical companies as well, enabling the inventory team to perform cross-checking procedures. Also, the Hellenic Aerosols Association has provided a gross estimation of the HFCs level used that is in line with the plant specific information, enabling the inventory team to draw the conclusion that this subcategory is complete.

Other QA/QC procedures include the examination and verification of the trend. This has been performed and the results have been already presented in the previous paragraph (4.14.3). As it can be concluded from the previous, the trend is not easily cross-checked due to the high inertia of the sector (the input data of each year are responsible for the emissions in the following years).

Additional QA/QC procedures involved the update of the working files. This has been performed and checked in the internal qa/qc procedures of the Inventory System and various errors have been corrected. The new files are considered to be more complete and user-friendly, whereas default values are provided for the EFs so as to additionally check the expert judgments.

4.19.5 Recalculations

In the current submission minor recalculations have been performed in 2F1 subcategory (2007-2013) due to updated recycling data.

4.19.6 Planned improvements

There are no planned improvements for this category for the time being.

4.20 Electrical equipment (CRF Source Category 2.G.1)

4.20.1 Description

The use of SF₆, as dielectric, in the transmission and distribution system of electricity, is considered as the main source of SF₆ emissions. Emissions arise in cases of leakages and during the maintenance of sub-stations and circuit breakers, especially when the equipment is old.

4.20.2 Methodology

In the context of the present inventory, emissions are estimated on the basis of information provided by PPC regarding losses in the transmission and the distribution system. The data provided cover the period 1995 – 2013. Emissions estimates are being performed on the basis of

the quantity of SF₆ consumed during the year, by the Directorate of Strategy and Planning of the PPC. According to the information received by the Public Power Corporation (PPC), the methodology is the same for the reported emissions from both transmission and distribution activities, and it actually refers to direct measurements of the SF₆ used to fill in any escape of the gas. The measurement procedure involves the weighting of the compressed SF₆ cylinder before and after the filling of the equipment. The difference in the weight corresponds to the kg of SF₆ that has escaped (and therefore needed to be re-filled). PPC has kindly informed the inventory team that in 2009 a new SF₆ mass-flow meter has been purchased in the department of Distribution, in order to ensure the higher accuracy of the weighting. As regards to the rest of the emission, namely for the years 1990 – 1994, they are estimated (by the inventory team) by means of a linear extrapolation.

SF₆ emissions from electrical equipment are presented in **Table 4.30**. Emissions in 2014 have been increased by 68.03% from 1990, whereas they have decreased from 2013 by 4.46%. The contribution of emissions from electrical equipment in total emissions (incl. & excl. LULUCF) is insignificant (lower than 0.00 % for the whole time-series).

Table 4.30 *SF₆ emissions (in kg) from electrical equipment for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SF ₆ emissions	2.93	3.02	3.11	3.20	3.29	3.42	3.51	3.56	3.60	3.69	3.81	3.88	4.06	4.06	4.26	6.16	7.98	9.46	7.18	5.02	5.86	5.13	5.05	5.15	4.92

In 2013 centralized review, the ERT strongly recommends that Greece provide additional information on the method used to estimate SF₆ emissions in its next annual submission, in order to improve the transparency of its reporting. The emissions refer to the escape of the gas due to old, used insulating parts of equipment (mainly gaskets) and, far more rarely, to a failure of the system. In the first case the insulating parts have to be changed. In the second case, the SF₆ has to be removed in pressurised cylinders and then be re-filled to the equipment (after the fixing of the latter). Any fluctuation to the time-series depicts the maintenance issues that have risen, according to the information received from PPC, in the particular year. In general fluctuations are more intense in the Transmission system (375kg in 2007 versus 280 kg in 2008). The contact persons in the Transmission system have indicated that many times experience is used as a driver and therefore, a particular type of gasket that has been reported for unsuccessful insulating operation has been replaced in the systems, leading to a decrease of the escaped SF₆ in the next year.

4.20.3 Uncertainty and time-series consistency

The uncertainty concerning the activity data is estimated at 50%. Regarding the EF, the estimated uncertainty 20% and is close to the default one suggested in the IPCC GPG.

The time-series is in general consistent, since the activity data is collected by the same provider for all the inventory years, apart 1990-1994 where the linear extrapolation method has been used.

Any fluctuation to the time-series depicts the maintenance issues that have risen in the particular year as has been analytically explained above.

4.20.4 Source-specific QA/QC and verification

For the time being the available data do not permit the implementation of any source-specific QA/QC procedure. QA/QC verification could be performed using information of the GIS providers in Greece; however the issue is quite complicated because the filling of new equipment may be performed from different companies than the ones that cover the filling of equipment in use. The total quantities are only available by PPC and this is why the verification from external sources is not easy to be performed.

For the time being, all the available information is kept in the Input File of the inventory, according to the Greek QA/QC plan.

4.20.5 Recalculations

In the current submission no recalculations have been performed.

4.20.6 Planned improvements

Any gaps in activity data time series will be filled in as soon as new data become available.

4.21 N₂O from Product Uses (CRF Source Category 2.G.3)

4.21.1 Description

Evaporative emissions of nitrous oxide (N₂O) can arise mainly by:

- Medical applications and
- Use as a propellant in aerosol products.

According to 2006 IPCC Guidelines it is *good practice* to estimate and report N₂O emissions from these sources.

N₂O for anaesthetic use is supplied in steel cylinders containing a minimum of 98 percent N₂O. N₂O is used during anaesthesia for two reasons: a) as an anaesthetic and analgesic and as b) a carrier gas for volatile fluorinated hydrocarbon anaesthetics such as isoflurane, sevoflurane and desflurane.

On the other hand, N₂O is also used as a propellant in aerosol products primarily in food industry. Typical usage is to make whipped cream, where cartridges filled with N₂O are used to blow the cream into foam.

N₂O emissions from Product Uses in 2014 (**Table 4.31**), account for 1.15% of total GHG emissions from *Industrial Processes* and for 0.14% of total national emissions (without *LULUCF*). N₂O emissions from Product Uses does not constitute a key source category. Total N₂O emissions in 2014 have increased by 6.54% from 1990 and decreased by 1.23% since 2013.

Table 4.31 summarizes the N₂O emissions from medical applications and use as a propellant in aerosol products.

Table 4.31 N₂O emissions (in kt) from Product Uses for the period 1990 – 2014

Year	Population of Greece (1000s)	N ₂ O Emissions from medical applications (kt)	N ₂ O Emissions from use as a propellant in aerosol products (kt)
1990	10256.35	0.23	0.22
1991	10339.91	0.23	0.22
1992	10470.96	0.23	0.22
1993	10567.19	0.23	0.23
1994	10666.53	0.24	0.23
1995	10740.61	0.24	0.23
1996	10806.43	0.24	0.23
1997	10885.30	0.24	0.23
1998	10950.41	0.24	0.23
1999	11007.19	0.24	0.24
2000	11044.66	0.24	0.24

2001	11069.01	0.25	0.24
2002	11098.09	0.25	0.24
2003	10998.90	0.24	0.24
2004	11037.75	0.24	0.24
2005	11073.71	0.25	0.24
2006	11112.11	0.25	0.24
2007	11143.78	0.25	0.24
2008	11182.22	0.25	0.24
2009	11190.65	0.25	0.24
2010	11183.52	0.25	0.24
2011	11123.39	0.25	0.24
2012	11123.03	0.25	0.24
2013	11062.51	0.25	0.24
2014	10926,81	0.24	0.23

4.21.2 Methodology

The inventory team in order to provide emissions for these source categories proceeded as follows:

1. The inventory team started by investigating the NIRs and ERT audit reports of other Annex I parties.
2. The ratio of N₂O emissions per population (ktN₂O/1000s capita) for a cluster of Annex I parties was computed. Four European countries were selected: Italy and Spain (which have similarities with Greece as concerns climate etc), Austria and Netherlands (in order to be conservative in the estimation of emissions).
3. The mean value of the above mentioned ratios was calculated.
4. By using the population of Greece as a driver (activity data) and the above calculated ratio as “Emission factor”, the emissions for the whole time series 1990-2013 were estimated.

4.21.3 Uncertainty and time-series consistency

The uncertainty of the activity data is 5% and the EF for the CO₂ emissions estimation is 5%. The methodology used is based on calculation of EFs from other countries and the activity data include population data as provided by EUROSTAT.

Figure 4.24 presents the changes in emissions which are in accordance with the changes in population of Greece. In 2011 and 2012 the emissions are stable while in 2013 there was a decrease in emissions equal to 0.54% since 2012. In 2014 the emissions also decreased by 1.23% compared to 2013 levels.

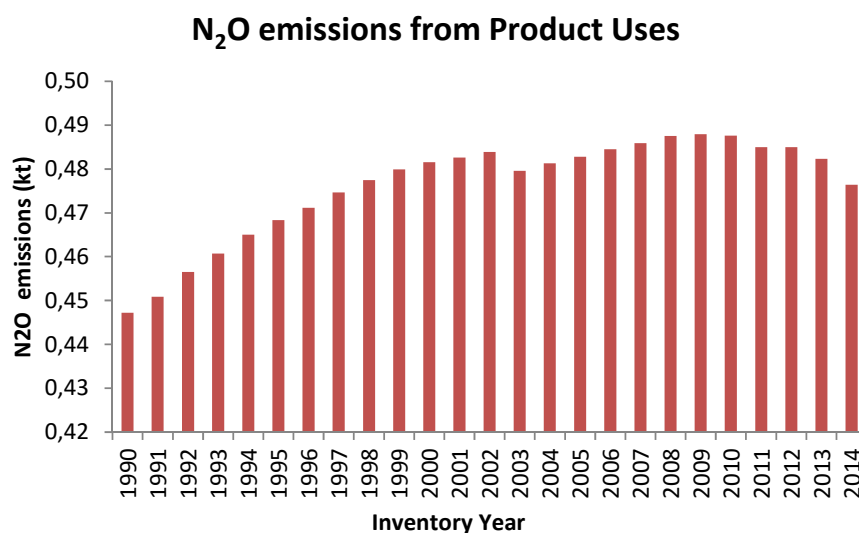


Figure 4.24 *N₂O emissions (in kt) from Product Uses for the period 1990 – 2014.*

4.21.4 Source-specific QA/QC and verification

In absence of other data availability, the QC tests include the annual update and double check of the population data provided by EIAstat and EuroStat. The data provided by Eurostat are available for the whole time series. It should also be mentioned that data availability from other sources, such as literature review, studies, etc. is limited, making more difficult the emissions estimation with higher tiers. Activity data as it is formerly mentioned are acquired from the national Energy Balance and the EF used is the default one according to the 2006 IPCC Guidelines.

4.21.5 Recalculations

No recalculations have been performed during this submission.

4.21.6 Planned improvements

The possibility to calculate N₂O emissions from data of quantity of N₂O supplied that are obtained from manufacturers and distributors of N₂O products is being examined, according to the IPCC guidelines.

4.22 *Other Use of Solvents and Related Activities (CRF Source Category 2.G.4)*

4.22.1 Description

In this category CO₂ and NMVOC emissions from other uses of solvents are included. Namely emissions calculated are emissions from:

- Wood preservation
- Printing industry

- Glue production
- Production and processing of PVC
- Domestic solvent use (except paint application)
- Production of pharmaceutical products
- Fat edible and non edible oil extraction and
- Ink production

4.22.2 Methodology

The emission factors used for some of the activities defined in EMEP CORINAIR and for which it was possible to obtain the corresponding activity data from the Hellenic Statistical Authority, are:

1. For the wood preservation: 24 kg / t of wood preserved.
2. For printing industry, the estimation of emissions was based on the consumption of ink. Printing ink is mostly used for the publishing of newspapers, books and various leaflets. According to the estimations of one publishing organisation, the amount of ink used for the printing of a daily newspaper is approximately 3.7 g of ink. The quantity of ink used for printing books etc. was calculated by subtracting the total quantity used for the newspapers from the total ink consumed. The emission factor applied (500 kg / t ink) is the updated EF from the 2013 EMEP guidebook.
3. Glue production, applied emission factor: 20 kg /t of product
4. Production and processing of PVC: 40 kg / t of product produced or processed.
5. Domestic solvent use (except paint application): 2.7 kg NMVOC/capita/year
6. Production of pharmaceutical products: 14 g /capita.
7. Fat edible and non edible oil extraction: 14 kg NMVOC/ t of seed processed
8. Ink production: 30 kg / t of product.

On the other hand, NMVOC emissions will eventually be oxidised to CO₂ in the atmosphere. These CO₂ inputs are included in the national inventory, as suggested by the 2006 IPCC guidelines. They can be calculated from emissions of NMVOCs by using the calculation principles:

$$\text{Inputs CO}_2 = \text{Emissions NMVOC} \cdot C \cdot 44/12$$

Where C is the fraction carbon in NMVOC by mass. The default C= 0.6 has been used in this submission.

In **Table 4.32** CO₂ emissions (in kt) from Other Uses of Solvents for the whole time series are summarized.

Table 4.32 *CO₂ emissions (in kt) from Other Uses of Solvents for the period 1990 – 2014*

Year	NMVOC Emissions from wood preserva-	NMVOC Emissions from the Printing industry (kt)	NMVOC Emissions from Glue manufacture (kt)	NMVOC Emissions from PVC processing(kt)	NMVOC Emissions from Domestic solvent use (kt)	NMVOC Emissions from Pharmacy (kt)	NMVOC Emissions from Fat edible and non-edible oil	NMVOC Emissions from Ink manufacturing (kt)
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	tion(kt)						extraction (kt)	
1990	16.12	5.69	2.29	1.48	60.92	0.31	15.56	0.10
1991	15.58	5.72	1.59	1.45	61.42	0.32	19.55	0.09
1992	13.33	6.13	1.83	1.48	62.20	0.32	18.54	0.11
1993	8.98	6.16	1.53	0.86	62.77	0.32	20.13	0.10
1994	9.97	6.19	1.66	1.56	63.36	0.33	13.49	0.10
1995	10.37	6.22	1.94	1.39	63.80	0.33	6.30	0.20
1996	7.34	6.25	2.04	1.70	64.19	0.33	6.93	0.27
1997	8.13	6.28	2.09	1.80	64.66	0.33	6.19	0.29
1998	5.91	7.61	2.37	1.86	65.05	0.33	7.44	0.30
1999	10.88	8.16	2.26	1.97	65.38	0.34	7.26	0.17
2000	8.72	8.66	2.77	2.10	65.61	0.34	5.55	0.19
2001	6.56	9.99	2.72	2.08	65.75	0.34	7.31	0.19
2002	6.20	7.22	3.14	2.17	65.92	0.34	6.32	0.19
2003	6.91	9.43	2.90	1.93	65.33	0.34	8.07	0.19
2004	6.96	12.06	3.68	1.64	65.56	0.34	6.98	0.19
2005	6.06	9.38	3.45	1.45	65.78	0.34	8.13	0.19
2006	6.37	9.02	3.65	2.05	66.01	0.34	8.17	0.19
2007	6.79	8.54	4.02	2.32	66.19	0.34	8.31	0.18
2008	5.74	8.18	3.30	2.67	66.42	0.34	7.35	0.20
2009	4.81	8.00	2.88	1.66	66.47	0.34	6.23	0.22
2010	4.72	7.05	3.44	1.21	66.43	0.34	9.93	0.25
2011	4.64	4.60	2.65	0.74	66.07	0.34	8.81	0.28
2012	4.18	3.09	1.96	0.66	66.07	0.34	8.75	0.21
2013	4.06	2.11	1.52	0.81	65.71	0.34	11.33	0.27
2014	3.93	2.54	1.03	0.81	64.91	0.33	10.75	0.26

4.22.3 Uncertainty and time-series consistency

The uncertainty of the activity data and the EF for the CO₂ emissions estimation is 5%. As reported in the 2006 IPCC Guidelines usually for this source category only small annual changes are expected.

The fluctuations in NMVOC emissions are attributed either in the Greek population or the production level of each solvent category. The general trend in all cases presents a decrease in emissions during the last years, due to the economic recession. Especially for printing industry a maximum value was presented in 2004 which could be connected with the organization of the Olympic games in Greece during that year.

4.22.4 Source-specific QA/QC and verification

In absence of other data availability, the QC tests include the annual update and double check of the population data provided by ElStat and EuroStat. The data provided by Eurostat are available for the whole time series. It should be noted that activity data provided by ElStat for year 2014 are provisional and they will be updated as soon as new data become available.

4.22.5 Recalculations

CO₂ emissions deriving from the oxidation of NMVOC were included in the whole sub-category. Followingly, the difference in the emissions for the year 2014 are presented compared to the previous submission, as well as the Impact of recalculation on total emissions excluding and including LULUCF, respectively.

Difference (CO ₂ -eq, kt)	Impact of recalculation on total emissions excluding LULUCF %	Impact of recalculation on total emissions including LULUCF %
86.16	0.085%	0.088%

4.22.6 Planned improvements

There are no planned improvements for this category for the time being.

5. Agriculture (CRF sector 3)

5.1 Overview

In this chapter, GHG emissions estimates from the sector *Agriculture* are presented and the calculation methodologies per source category are described.

According to the IPCC Guidelines, the following source categories are included in this sector:

- ↳ Enteric fermentation
- ↳ Manure management
- ↳ Rice cultivation
- ↳ Agricultural soils
- ↳ Field burning of agricultural residues

The remainder of this chapter is organised as follows. Paragraph 5.1 continues with the presentation of emissions trends from agriculture, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for agriculture. Then (Paragraphs 5.2 – 5.6) detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source category is presented.

5.1.1 Emissions trends

GHG emissions from *Agriculture* decreased by 14.2% between 1990 and 2016 (**Figure 5.1**), with an average annual rate of decrease of 0.6. The steep decrease observed for the years 1993 and 1994 is due to the cut backs in public incentives for the use of synthetic fertilizers.

Emissions from *Agriculture* and especially N₂O emissions from agricultural soils are characterized by intense fluctuations during the period 1990 – 2014. The annual variations of agricultural production and the amount of synthetic fertilizers applied are the main causes for these fluctuations. Agricultural production data were derived from the Hellenic Statistical Authority (ELSTAT), while confirmed data for the quantities of synthetic fertilizers applied in soils derive for the first time from the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers (PHAPFPD).

Agriculture is responsible for methane and nitrous oxide emissions. Emissions per gas from agriculture are presented in **Table 5.1**.

Table 5.1 *GHG emissions (in kt CO₂ eq) per gas from Agriculture, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	60	58	56	44	41	45	46	44	44	42	38
CH ₄	5018	5027	4959	4957	4897	5029	5047	5057	5041	5103	4979
N ₂ O	5107	5125	4929	4387	4293	4491	4539	4447	4447	4383	4212
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO ₂	37	36	35	36	32	30	34	29	25	30	26
CH ₄	4943	4991	4884	4860	4849	4875	4858	4831	5005	5059	5043
N ₂ O	4153	4128	4021	4085	3889	3787	3922	3748	3630	3856	3669
Year	2012	2013	2014								
CO ₂	25	26	26								
CH ₄	5037	5071	5045								
N ₂ O	3634	3688	3672								

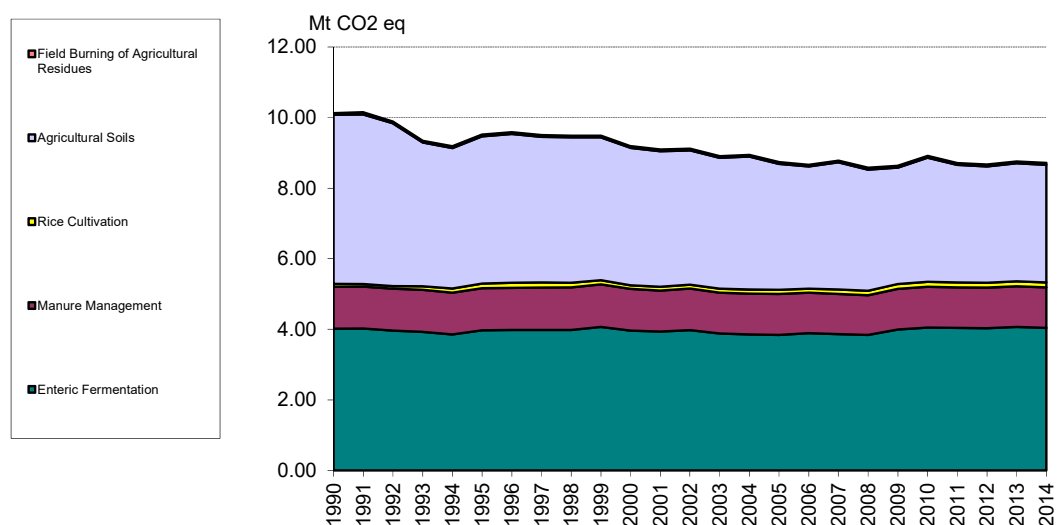


Figure 5.1 *Total GHG emissions (in kt CO₂ eq) from Agriculture for the period 1990 – 2014*

Methane represents the main GHG from *Agriculture*, with a contribution ranging from 49% to 60%. Methane emissions in 2014 increased by 0.5 compared to 1990 levels with an average annual rate of decrease estimated at 0.02%.

Enteric fermentation is the main source of emissions from *Agriculture* (**Figure 5.2**), accounting for 39.4% - 46.4% of the total emissions from the sector.

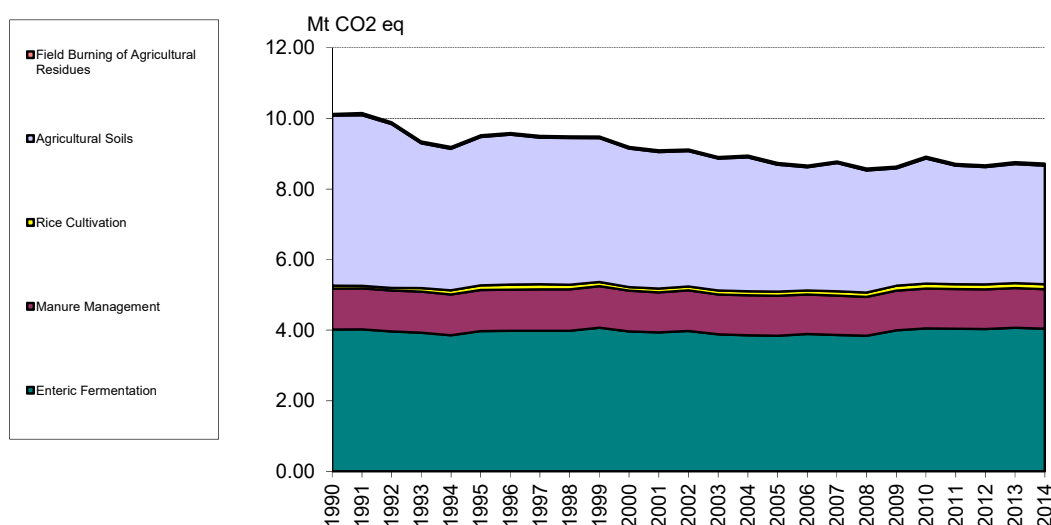


Figure 5.2 *GHG emissions (in kt CO₂ eq) from Agriculture per source category, for the period 1990 – 2014*

5.1.2 Methodology

The calculation of GHG emissions from *Agriculture* is based on the methodologies and emission factors suggested by the 2006 IPCC Guidelines.

Data on animal population, agricultural production and cultivated areas used for the emissions calculation were provided by the ELSTAT, while data on the amount of synthetic fertilizers applied to soils derive from Pan-Hellenic Association of Professional Fertilizers Producers & Dealers..

The methodology applied for the calculation of emissions per source category is briefly presented in **Table 5.2**, while a detailed description is given in the corresponding paragraphs (Paragraphs 5.2 – 5.6).

Key categories

If enteric fermentation is considered as a common source, following the suggestion by IPCC Guidelines (2006), this source is determined as a key category. However, after the

recommendations of 2010 centralized ERT review the emissions from enteric fermentation were disaggregated by the significant animal types. The consequences of this improvement were the determination of enteric fermentation of non dairy cattle, sheep and other animal as key categories sources while the enteric fermentation of dairy cattle source were determined as non key category sources.

Table 5.2 *Methodologies for the estimation of emissions from Agriculture*

	CH ₄		N ₂ O	
	Method	Emission factor	Method	Emission factor
Enteric fermentation - Dairy cattle	T2	CS, D		
Enteric fermentation – Non dairy cattle	T2	CS, D		
Enteric fermentation – Sheep	T2	CS, D		
Enteric fermentation – Other animal	T1	D		
Manure management	T2, T1	CS, D	D	D
Rice cultivation	D	D		
Agricultural soils			D, T1, T1a, T1b	CS, D
Field burning of agricultural residues	D	D	D	D

T1, T2, T1a and T1b: IPCC methodology Tier 1, 2, 1a and 1b respectively

D: IPCC default methodology and emission factor, CS: Country specific emission factor

Agricultural soils (animal production, indirect emissions and direct emissions) are key categories. (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations) The key categories from agricultural sector (excluding LULUCF) are presented **Table 5.3**.

Table 5.3 *Key categories from the Waste sector (excluding LULUCF)*

Source category	Gas	Level assessment	Trend assessment
Enteric fermentation – Sheep	CH ₄	☒	
Enteric fermentation - Non Dairy Cattle	CH ₄	☒	
Enteric fermentation – Other animal	CH ₄	☒	
Manure Management	N ₂ O	☒	
Direct emissions	N ₂ O	☒	☒
Animal production	N ₂ O	☒	☒
Indirect emissions	N ₂ O	☒	☒

According to the IPCC Good Practice Guidance, emissions from key categories should be estimated using the most rigorous methodologies. In the case of enteric fermentation, Tier 2

methodology is applied for enteric fermentation of non dairy cattle, for dairy cattle and for sheep. Tier 2 methodology is being used for non dairy cattle and dairy cattle for the first time in this submission. For the rest of the animal the improvement of of emissions estimation's methodology is planning, especially for the most important of these, like goats.

Concerning agricultural soils both simple and detailed methodologies (Tier 1) as well as their combination are proposed, depending on data availability.

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV.

5.1.3 Completeness

Table 5.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in agriculture.

Table 5.4 *Agriculture – Inventory completeness*

	CO ₂	CH ₄	N ₂ O
A. Enteric fermentation		☒	
B. Manure management		☒	☒
C. Rice cultivation		☒	
D. Agricultural soils			
1. Direct emissions		NE	☒
2. Animal production		NE	☒
3. Indirect emissions		NE	☒
F. Field burning of agricultural residues		☒	☒

NE: Not estimated

Methane emissions from agricultural soils are not estimated since appropriate methodologies have not been developed yet.

5.2 Enteric fermentation (CRF Source Category 3A)

5.2.1 Description

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.

Enteric fermentation (CH₄ emissions) of sheep and other animal are key categories. As already mentioned, the Tier 2 methodology is applied for the estimation of methane emissions from enteric fermentation of cattle and sheep, according to the recommendation of the IPCC Guidelines. The Tier 1 methodology and the default emission factors suggested by the IPCC Guidelines are used for the rest of the animal species.

Methane emissions from enteric fermentation in 2014 account for 46% of total GHG emissions from *Agriculture* and for 4% of total national emissions (excluding *LULUCF*). The average annual rate of decrease of emissions from enteric fermentation for the period 1990 – 2014, is estimated at 0.02% (decrease by 0.59% in 2014 compared to 1990). Emissions from enteric fermentation are presented in **Table 5.5**.

Table 5.5 CH₄ emissions (kt) from enteric fermentation for the period 1990 – 2014

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ emissions (kt)	160.69	160.92	158.51	157.14	154.26	158.95	159.28	159.36	159.37	162.73	158.59
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ emissions (kt)	157.49	159.08	155.27	154.21	153.61	155.60	154.60	153.71	159.78	162.02	161.61
Year	2012	2013	2014								
CH ₄ emissions (kt)	161.36	162.66	161.63								

5.2.2 Methodology

Enteric fermentation of dairy cattle

Methane emissions from the enteric fermentation of dairy cattle are estimated according to the Tier 2 IPCC methodology, as it is described in the IPCC Good Practice Guidance.

The calculation of the emission factors for each activity is based on the following equation:

$$EF_i = \frac{GE_i \cdot Ym_i \cdot 365}{55.65}$$

where i is the activity, EF_i is the estimated emission factor for CH₄ (kg CH₄/head/yr), GE_i is the gross energy intake (MJ/head/day) and Ym is the methane conversion rate which is the fraction of the gross energy in feed converted to CH₄.

The calculation of gross energy for sheep is based on the following equation:

$$GE = \left[\frac{(NE_m + NE_a + NE_l + NE_p)}{(NE_{ma}/DE)} + \frac{(NE_g)}{(NE_{ga}/DE)} \right] / \left[\frac{DE}{100} \right]$$

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NE_{ma}/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NE_{ga}/DE is the similar ratio for growth.

The number of dairy cattle used for the calculation of methane emissions is a three-year average centred at the year of reference and it is presented in **Table 5.6** for the period 1990-2014. In the same table the annual average milk production (for 365 days) is presented as it is provided by the EL.STAT., the only available official milk production data, while milk production yield during suckling estimated at 0.6 kg/day (estimated for 365 days).

The average bodyweight of dairy cattle is estimated at 600 kg.. For the estimation of net energy for dairy cattle activity, it was considered that they are confined to a small area thus no energy is required to acquire feed ($C_a = 0$). Default values for Ym from IPCC Guidelines were utilized.

Table 5.6 *Number of dairy cattle in 1000s (three-year average) for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy cattle (1000s)	210	214	203	219	168	192	184	184	172	154	180
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Dairy cattle (1000s)	172	152	149	157	153	149	158	137	128	144	130
Year	2012	2013†	2014†								
Dairy cattle (1000s)	132	133	137								

† Provisional data

As it is presented in the Table 5.6, provisional data are used for some years given the fact that no official data have been issued by the EL.STAT. In order to meet the recommendation of the 2013 ERT review, it must be mentioned that the provisional data are based on the trend of the previous years (development of first order equations: animal population versus year). Taking into consideration that significant fluctuations on the historical data are not observed, it is assumed that the data for the years that there are no official data will follow the trend of the last five to ten years. As presented during the 2012 in country review, the data assumed in the past differed from the official data issued during the next years, less than 2%, i.e. less than the uncertainty of the official data which is 5%.

Finally, in **Table 5.7** information regarding gross energy (Gei) is presented.

Table 5.7 *Gross energy (GE) for dairy cattle for the period 1990 - 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GE (MJ/head/day)	217	216	225	224	245	236	240	239	246	256	243
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
GE (MJ/head/day)	248	264	260	261	270	272	262	280	288	273	286
Year	2012	2013	2014								
GE (MJ/head/day)	284	283	280								

Enteric fermentation of other cattle

Similar with the dairy cattle, methane emissions from the enteric fermentation of other cattle are estimated according to the Tier 2 IPCC methodology, as it is described in the 2006 IPCC Guidelines.

The characterization and classification of other cattle was based on data from ELSTAT and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues. The population of other cattle for each sub-category is presented in **Table 5.8** for the period 1990-2014.

The calculation of the emission factors for each activity is based on the equation presented above for the dairy cattle. In **Table 5.9** parameters used for the estimation of emissions from other cattle is presented as well as the gross energy (Ge) and the emissions factors (EFs) for the 2014. Portion of female cattle, >2 year old, giving birth is estimated at 0.9 while milk production yield estimated at 0.08 kg/day (estimated for 365 days), based on official data provided by ELSTAT. and milk production yield during suckling estimated at 1.0 kg/day (estimated for 365 days). Milk fat content is estimated at 4% while for the estimation of net energy for other cattle activity, it was considered that they are confined in areas with sufficient forage requiring modest energy expense to acquire feed. ($C_a = 0.17$). Default values for Y_m from IPCC Guidelines were utilized.

Table 5.8 *Number of other cattle (in 1000s) for each sub-category (three-year average), for the period 1990 – 2014*

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
< 1 year											
For slaughter as calves	110	91	103	85	53	61	60	58	38	111	50
Females	67	62	55	52	55	65	51	57	56	44	57
Males	45	41	39	37	57	63	57	57	62	47	57
1-2 years											
Females	55	54	50	52	39	44	45	47	41	49	41
Male	65	66	60	51	46	53	59	57	54	67	50
> 2 year											
Females	132	148	126	104	115	118	128	128	144	159	117
Males	8	6	8	5	5	7	8	6	10	16	12
Total	483	469	442	387	370	410	408	411	405	492	383
Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
< 1 year											
For slaughter as calves	45	63	65	68	72	72	65	64	94	71	66
Females	33	44	41	40	39	40	44	38	41	55	69
Males	5	7	5	5	8	10	7	6	33	56	56

1-2 years												
	Females	45	55	56	58	53	59	57	56	63	70	73
	Males	38	48	5	6	8	8	8	7	65	66	52
> 2 year												
	Females	142	157	169	171	166	190	169	190	177	200	213
	Males	13	13	7	7	9	9	12	10	21	17	21
Total		322	386	348	356	355	389	361	371	494	535	551
Sub-categories		2012	2013	2014								
< 1 year												
For slaughter as calves		75	74	73								
	Females	70	70	71								
	Males	58	69	70								
1-2 years												
	Females	76	75	74								
	Males	55	48	38								
> 2 year												
	Females	198	216	211								
	Males	21	21	21								
Total		553	574	557								

† Provisional data

Table 5.9 *Mean Weight, Gross energy (Gei), CH₄ conversion rate (Ym) value and emissions factor (EFs) for each subcategory of other cattle for 2014*

	Mean Weight (kg)	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) KgCH ₄ /head/yr
< 1 year				
For slaughter as calves	200	92.2	0.065	39.3
	Females	180	95.8	40.8
	Males	230	107.2	45.7
1-2 years				
	Females	450	145.8	62.1
	Males	500	158.7	67.7
> 2 year				
	Females	550	174.5	74.4
	Males	750	209.9	89.5
Average	408	141.7	0.065	60.4

Enteric fermentation of sheep

Methane emissions from the enteric fermentation of sheep are estimated according to the Tier 2 IPCC methodology, as it is described in the IPCC Good Practice Guidance. For the calculation of the net energy required for each animal sub-category and activity, the appropriate in each case factors suggested in the IPCC Good Practice Guidance were used. The calculation of the emission factors for each animal sub-category and activity is based on the following equation:

$$EF_i = \frac{GE_i \cdot Ym_i \cdot 365}{55.65}$$

where i is the activity, EF_i is the estimated emission factor for CH₄ (kg CH₄/head/yr), GE_i is the gross energy intake (MJ/head/day) and Ym is the methane conversion rate which is the fraction of the gross energy in feed converted to CH₄.

The calculation of gross energy for sheep is based on the following equation:

$$GE = \left[\frac{(NE_m + NE_a + NE_l + NE_p)}{(NE_{ma}/DE)} + \frac{(NE_g + NE_{wool})}{(NE_{ga}/DE)} \right] \cdot [DE/100]$$

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

NE_{wool} is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NE_{ma}/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NE_{ga}/DE is the similar ratio for growth.

The characterization and classification of sheep was based on data from ELSTAT and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues. The estimation of sheep population for each sub-category is presented in **Table 5.10**.

The average bodyweight of sheep at weaning is estimated at 15 kg while the average weights of female and male mature sheep (>1 year) are estimated at 53 kg and 70 kg respectively.

The average milk production for domestic and in flock and for nomadic sheep was re-estimated equal to 0.30 kg/day and 0.27 kg/day respectively estimated for 365 days for 2012, utilizing the only available official milk production data provided by the EL.STAT (Recommendations by the 2013 ERT).

The milk production of mothers during suckling estimated at 0.12 kg/day (for 365 days). Wool production is estimated for all the mature sheep at 4 kg/sheep/year.

Due to lack of data concerning the births of lambs the following assumption was adopted. It was considered that all milked mature sheep give birth. Some of the milked sheep give single birth while the other one give a double such the total number of lambs to be equal with these obtained by the ELSTAT as born.

Default methane conversion rates (Y_m) which correspond to high digestibility were selected from the 2006 IPCC Good Practice. In **Table 5.11** information regarding gross energy (Gei), CH₄ conversion rate (Y_m) values and emissions factors (EFs) for each subcategory of sheep (such as grazing, lactation and growth) is presented for 2014.

Table 5.10 *Number of sheep (in 1000s) for each sub-category (three-year average), for the period 1990 – 2014*

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milking ewes											
Milk production	5235	5254	5239	5263	5321	5361	5378	5370	5398	5411	5435
Only suckling	394	395	394	396	400	404	405	404	406	407	409
Other female sheep > 1 year	732	734	732	736	744	749	752	751	755	756	760
Males > 1 year old	394	395	394	396	400	404	405	404	406	407	409
Female lambs	1524	1530	1525	1532	1549	1561	1566	1564	1572	1575	1582
Male lambs	381	382	381	383	387	390	391	391	393	394	396
Born sheep	8352	8482	8627	8660	8704	8820	8837	8866	8863	8918	8949
Total	8660	8692	8666	8706	8802	8869	8896	8884	8930	8951	8991
Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Milking ewes											
Milk production	5517	5476	5442	5336	5315	5338	5378	5373	5399	5339	5333
Only suckling	415	412	410	402	400	402	405	404	406	402	402
Other female sheep > 1 year old	771	765	761	746	743	746	752	751	755	746	745
Males > 1 year old	415	412	410	402	400	402	405	404	406	402	402
Female lambs	1606	1594	1584	1554	1547	1554	1566	1564	1572	1554	1552
Male lambs	402	399	396	388	387	389	391	391	393	389	389
Born sheep	9033	9034	9049	9029	8994	9001	8998	9008	9052	8990	9033
Born sheep Total	9127	9058	9002	8827	8792	8830	8897	8889	8931	8832	8822

Sub-categories	2012†	2013†	2014†
Milking ewes			
Milk production	5328	5325	5321
Only suckling	401	401	401
Other female sheep > 1 year old	744	744	743
Males > 1 year old	401	401	401
Female lambs	1551	1550	1549
Male lambs	388	388	388
Born sheep	8981	8972	8954
Total	8813	8808	8802

† Provisional data

The duration of lamb's growth is estimated at 315 days, which correspond to the period between effective weaning and one year of age, suckling lasts 50 days, while pregnancy lasts 147 days.

Table 5.11 *Gross energy (Gei), CH₄ conversion rate (Ym) value and emissions factor (EFs) for each subcategory of sheep for 2014*

	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) KgCH ₄ /head/yr
Female lamb	17.3	0.045	5.1
Female sheep - milking ewes	25.5	0.065	10.9
Female sheep – other	20.2	0.065	8.6
Male lamb	22.1	0.045	6.5
Male sheep	26.1	0.065	11.1
Average	23.5	0.062	9.5

Methodology for enteric fermentation for the other animals

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 country specific emission factor.

The application of this methodology requires livestock population data and emission factors per animal species. Population data were obtained from the ELSTAT. Emission factors used were the ones suggested by 2006 IPCC Guidelines.

The number of animals used for the calculation of methane emissions (**Table 5.12**) is a three-year average centred at the year of reference.

Table 5.12 *Number of animals (in 1000s) by category (three-year average), for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Buffalo	0.769	0.939	0.888	0.902	0.692	0.7	0.735	0.788	0.865	0.877	0.975
Goats	5334	5336	5365	5378	5444	5525	5570	5600	5615	5614	5639
Horses	45	42	40	38	36	35	33	32	31	30	29
Mules and ashes	187	173	161	150	140	130	121	115	107	101	96
Swine	996	986	1001	1014	1009	994	987	998	999	973	964
Poultry	28282	28843	28818	29256	29379	29059	29157	29583	29704	30727	31010
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Buffalo	1.009	1.024	1.11	1.29	1.237	1.389	1.643	1.764	1.785	1.908	2.017
Goats	5667	5669	5621	5509	5422	5402	5346	5275	5216	5155	5094
Horses	29	28	28	27	27	27	28	28	27	27	27
Mules and ashes	89	84	79	73	69	64	60	56	50	46	41
Swine	934	940	937	940	949	902	892	880	884	875	867
Poultry	28714	30088	29134	30587	31566	31599	31949	29141	29111	29079	29048
Year	2012†	2013†	2014†								
Buffalo	2.126	2.243	2.352								
Goats	5089	5084	5079								
Horses	27	27	27								
Mules and ashes	40	40	40								
Swine	866	865	864								
Poultry	29016	28985	29011								

† Provisional data

5.2.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ emissions of enteric fermentation sector as % of total emissions is estimated by 0.8%. The uncertainty associated with activity data is 5% according to uncertainty given by NSSG for the livestock population data. On the other hand, the uncertainty associated with emission factors is 30% as it is estimated according to Good Practice Guidance. The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.2.4 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures followed in the enteric fermentation source are:

1. Cross checking information provided by the National Statistical Service of Greece and by the Ministry of Rural Development regarding the animal population and the agricultural crop production.
2. Animal population is also checked by comparison with two different works provided by the ELSTAT. The first one is annual statistical survey while the second one is a census of livestock population. The results of the first one were used for the estimation of emissions for cattle while the results of the other for the rest of animals.
3. Comparison of information regarding animal population, agricultural crop production and emissions factors with this of other neighbour countries.
4. Estimations were checked with several calculation tools such as emissions trends and sum deviations.

5.2.5 Recalculations

No recalculations were performed.

5.2.6 Planned improvements

The possibility of applying Tier 2 methodology for the estimation of methane emissions from the enteric fermentation of goats is under examination. Moreover, updated data for the population of animals is expected to be disposed in the next submission.

5.3 Manure management (CRF Source Category 3B)

5.3.1 Description

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.

CH₄ and N₂O from manure management in 2014 accounted for 9.4% and 3.72% of total GHG emissions from *Agriculture* respectively, and for 0.81% and 0.32% of total national emissions respectively (without *LULUCF*). CH₄ emissions in 2014 decreased by 7.04% compared to 1990 levels, with an average annual rate of decrease estimated at 0.29% for the period 1990 - 2014. N₂O emissions in 2014 decreased by 6.4% compared to 1990 levels, with an average annual rate of decrease estimated at 0.27%. CH₄ and N₂O emissions from manure management for the period 1990 – 2014 are presented in **Table 5.13**.

Table 5.13 *CH₄ and N₂O emissions (in kt) from manure management, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ (kt)	35.38	35.28	35.36	35.59	35.26	35.47	35.38	35.59	35.60	35.34	35.10
N ₂ O (kt)	1.02	1.03	1.02	1.01	1.01	1.03	1.03	1.04	1.05	1.09	1.03
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ (kt)	34.49	34.62	34.23	34.13	34.19	33.54	33.34	32.89	33.24	33.19	32.93
N ₂ O (kt)	1.00	1.05	1.01	1.02	1.04	1.05	1.02	1.02	1.08	1.09	1.10
Year	2012	2013	2014								
CH ₄ (kt)	32.90	32.96	32.89								
N ₂ O (kt)	1.09	1.10	1.09								

5.3.2 Methodology

Manure management systems per animal species

The shares of manure management systems per animal species are presented in **Table 5.14** considering 100% conditions of temperate climate region for Greece.

Country-specific data for all the animal categories are considered for the allocation of manure to animal waste management systems per animal species was followed.

Table 5.14 **Manure management systems**

Manure management systems	Anaerobic lagoon	Liquid systems	Daily spread	Solid storage and dry lot	Pasture/ range/ paddock	Other system
Dairy cows	0%	5.52%	0%	86.48%	8%	0%
Other cattle	0%	0%	3%	64%	33%	0%
Buffalo	0%	0%	3%	64%	33%	0%
Poultry	0%	0%	0%	100%	0%	0%
Sheep	0%	0%	0%	10%	90%	0%
Swine	0%	90%	0%	10%	0%	0%
Horses	0%	0%	0%	0%	100%	0%
Mules and ashes	0%	0%	0%	0%	100%	0%
Goats	0%	0%	0%	10%	90%	0%

Dairy Cattle

For the estimation of the dairy cattle manure management systems' allocation, information received by several agricultural experts was utilized:

- the Ministry of Rural Development and Food,
- the Greek Regions with high population of animals (Ipiros, Thessalia etc.),
- the Hellenic statistical Authority (EL.STAT.) and
- the Technological Educational Institute of Thessaloniki.

According to this information:

- In old farms and in farms with small population of animals (<30), only solid management practice is performed using manure piles.
- In new units with high population of dairy cattle (>30) manure is either stored in piles or separation of liquid-solid is performed. Solid is stored to piles, while liquid is stored to tanks.
- Where liquid-solid separation of manure is performed, in about 40% of the total dairy cattle farms, 15% of solid is drifted by the liquid, and thus, this solid part of manure is treated under liquid conditions.
- **8% of the total produced manure from the dairy cattle remains in pasture / range / paddock.**

Therefore, the produced manure that is managed in liquid systems is:

$$f_{\text{solid}} = 40\% * 15\% = 6\%$$

Given that 8 % of the animal remains in pasture / range / paddock the real solid treated in liquid systems is:

Solid manure treated in liquid systems = 6 %* 92% of total solid produced manure or

Solid manure treated in liquid systems = 5.52 % of total solid produced manure

While the rest (94% * 92% = **86.48%** of total solid produced manure) is treated by solid manure management systems (i.e. manure piles).

However, it must be noticed that for the estimation of N₂O emissions the assumption by the IPCC GPG p4.44 that 50% of the nitrogen excreted is in the faeces and 50% is in the urine was utilized, according to.

Since 40 % of the produced manure is separated to liquid and solid, while 15% of solid manure drifts with the liquid, the liquid product of the separation contains 50% of nitrogen excreted, which is in the liquid phase, as well as 7.5% (=15%*50%), which is 15% of the remaining 50% of nitrogen contained in solid. Thus, the fraction (f_N) of nitrogen excretion treated in liquid manure management systems is estimated as follows:

$$f_N = 50\% + 50\% * 15\% = 57.5\%$$

The produced nitrogen excretion that is treated in liquid systems is:

N excretion treated in liquid systems = 40% * 57.5 % *92%*total produced manure or

N excretion treated in liquid systems = 21.16%*total N excretion produced

While the rest of nitrogen excreted is treated by solid manure management systems (i.e. manure piles). Therefore, for the estimation of N₂O emissions the allocation of the manure management systems is modified to 21% liquid systems, 71 % solid systems and 8 % Pasture/ range/ paddock

Other Cattle and Buffalo

The allocation of manure to animal waste management systems of other cattle and buffalo results as follows. Almost the 60% of them, the animal in age of 1 year and older, remain in pasture for about seven months per year while the young animal remain mainly in stall. For the rest of the time, all the other cattle are in stall. Thus, it is estimated that about 33% of the produced manure by other cattle fall in pasture while the rest is mainly managed in Solid storage and dry lot systems.

Swine

The majority of swine in Greece remain in properly designed building infrastructures and their manure is managed with liquid systems according to Greek legislation. A small share of swine's manure, about 10%, is managed with solid systems. This share mainly represents the manure produced by swine live in small production units.

Sheep, goats, poultry

The allocation of manure to animal waste management systems of other animal, like sheep, goats and poultry were reconsidered utilizing information received by several agricultural experts in order to meet the recommendations by the 2012 and 2013 ERTs. The contacted experts are from:

- the Ministry of Rural Development and Food,
- the Greek Regions with high population of animals (Ipiros, Thessalia etc.),
- the Hellenic statistical Authority (EL.STAT.) and
- the Technological Educational Institute of Thessaloniki.

According to this information, almost all the poultry manure is treated with solid practices, while for sheep and goats, only for the 10% of their lives they remain in stables while the other time are in pasture. However, the collection of their manure from the stables is performed only two times per year.

Horses and Mules and ashes

It is estimated that all manure of Horses and Mules and ashes remains in pasture / range / paddock.

CH₄ emissions from manure management

CH₄ emissions from manure management:

- CH₄ emissions from Manure Management;
- N₂O emissions from Manure Management (direct and indirect)

were estimated using IPCC Tier 2 approach for dairy cattle and other cattle and sheep.

For the rest of the animals default methodology is used.

Bo values proposed by IPCC Guidelines and default MCF values provided by IPCC Guidelines for different manure management systems were used.

N₂O emissions from manure management

In order to calculate N₂O emissions from manure management, the default IPCC methodology was used, according to the following equation.

$$E = \sum_S \left(\sum_T \left(N_T \cdot Nex_T \cdot MS_{(T,S)} \right) \right) \cdot EF_S$$

where E is N₂O emissions, T is the animal species index, S is the manure management system index, $N_{(T)}$ is the livestock population, $Nex_{(T)}$ the annual average N excretion per head of species, $MS_{(T,S)}$ the fraction of total annual excretion for each livestock species that is managed in system S , $EF_{(S)}$ is the N₂O emission factor for system S .

The annual nitrogen excretion rates for each livestock category were estimated following the Tier 1 approach proposed by 2006 IPCC Guidelines, Equation 10.30. Country specific data were used for the TAM, typical animal mass for livestock category, for the dairy cattle, other cattle and sheep while for the rest animal categories data were collected by Tables 10A-4 to 10A-9 in Annex 10A.2 utilizing data provided for Europe. Default N excretion rate, $N_{rate(T)}$ was estimated collected data by Table 10.19 for Eastern Europe apart from dairy cattle were data for Western Europe were utilized.

Default emission factors for direct N₂O emissions from manure management were utilized (Table 10.21).

Indirect Emissions from Atmospheric deposition and Nitrogen Leaching and Run-off were estimated based on default methodologies presented by 2006 IPCC Guidelines, Eq. 10.27 and 10.29, and the proposed emission factors, Table 11.3. For the estimation of N losses due to volatilisation from manure management Equation 10.26 was used while N losses due to leaching from manure management systems were estimated with Equation 10.28:

- $Frac_{GasMS}$, percent of managed manure nitrogen for livestock category T that volatilises as NH₃ and NO_x in the manure management system S , data from Table 10.22 were utilized
- For $Frac_{leachMS}$, percent of managed manure nitrogen losses for livestock category T due to runoff and leaching during solid and liquid storage of manure, data from IPCC Guidelines as mean values were utilized.

Managed manure n available for application to managed soils, feed, fuel or construction uses were estimated based on Equation 10.34 while $\text{Frac}_{\text{LossMS}}$, amount of managed manure nitrogen for livestock category T that is lost in the manure management system S, % was calculated based on data from Table 10.23 and the proposed figures from IPCC for the amount of nitrogen from bedding.

5.3.3 Uncertainties and time-series consistency

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% according to uncertainty given by NSSG for the livestock population data. On the other hand, 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% (country specific value) taking into account that in Greece there is a wide variety of management systems used usage. The uncertainty associated with emission factors is 100% as it is estimated according to Good Practice Guidance.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.3.4 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the manure management source are:

1. Investigation for information related to manure management systems applied in Greece per animal species and cross-checking. Information has already sought from the Agricultural University of Athens, the Ministry of Rural Development and Food, the Department of Animal Production at the School of Agriculture Technology (the Technological Educational Institute of Epirus) and the Office of Rural Development of the Prefecture of Thessaloniki and other research institutes.

2. Comparison of information regarding animal population, agricultural crop production and emissions factors with this of other neighbour countries.
3. Estimations were checked with several calculation tools such as emissions trends and sum deviations.

5.3.5 Recalculations

No recalculations were performed.

5.3.6 Planned improvements

The available official information related to manure management systems applied in Greece per animal species is not sufficient to allow for the characterization of the existing situation, especially as new techniques are being introduced. For this reason, the availability of relevant information is examined in collaboration with other research institutes (e.g. Agricultural University). However, difficulties arose while obtaining data due to high number of small units in Greece.

5.4 Rice cultivation (CRF Source Category 3C)

5.4.1 Description

Rice cultivated in Greece is grown in continuously flooded fields. This process results in methane production from anaerobic decomposition of organic matter, and consequently leads to the release of the gas in the atmosphere through the rice plants.

CH₄ emissions from rice cultivation for the period 1990 – 2014 are presented in *Table 5.15*.

Table 5.15 *CH₄ emissions (in kt eq. CO₂) from rice cultivation for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄	0.08	0.07	0.07	0.10	0.12	0.13	0.14	0.15	0.13	0.12	0.10
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄	0.11	0.11	0.11	0.11	0.12	0.11	0.13	0.13	0.14	0.14	0.14
Year	2012	2013	2014								
CH ₄	0.14	0.14	0.14								

CH₄ emissions from rice cultivation in 2014 account for 1.6% of total GHG emissions from Agriculture and for 0.14% of total national emissions (without LULUCF). CH₄ emissions increased by 70.2 % in 2014 compared to 1990, with an average annual rate of increase of 2.9% for the period 1990 - 2014.

The fluctuations in emissions trends are attributed to the annual changes in the amount of the cultivated areas as provided by the HEL.SAT.

5.4.2 Methodology

In order to estimate methane emissions from rice cultivation, the default methodology suggested by the IPCC guidelines was followed. The cultivated areas provided by the NSSG and the emission factor 20 g CH₄/ m² were used for the emissions calculation.

Rice cultivated in Greece is grown in continuously flooded fields without the use of organic amendments and one cropping period is considered annually.

5.4.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ emissions of rice cultivation sector as % of total emissions is estimated by 0.04%. The uncertainty associated with activity data is 2% according to uncertainty given by NSSG for the for the rice cultivation data. On the other hand, the uncertainty associated with emission factors is 40% as it is estimated according to IPCC Rev. 1996. The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.4.4 Recalculations

In this year's inventory, CH₄ emissions were corrected due to error in CRF compilation. The deviation of the emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions from the sector of recalculations are presented in **Table 5.16**.

Table 5.16 *Recalculations of CH₄ emissions from rice cultivation*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference (kt CO ₂ eq)	-283	-254	-253	-348	-408	-450	-493	-501	-452	-402	-343
Impact on Emissions from Agriculture (%)	-5.3	-4.8	-4.9	-6.6	-7.7	-8.2	-8.9	-9.0	-8.2	-7.3	-6.4
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference (kt CO ₂ eq)	-364	-386	-389	-392	-398	-384	-431	-431	-482	-482	-482
Impact on Emissions from Agriculture (%)	-6.9	-7.2	-7.4	-7.5	-7.6	-7.3	-8.1	-8.2	-8.8	-8.7	-8.7
Year	2012	2013									
Difference (kt CO ₂ eq)	-482	-482									
Impact on Emissions from Agriculture (%)	-8.7	-8.7									

5.5 Agricultural soils (CRF Source Category 3D)

5.5.1 Description

Agricultural soils constitute the largest anthropogenic source of nitrous oxide emissions. N₂O is produced naturally in soils through the microbial processes of nitrification and denitrification. Agricultural activities add nitrogen to soils, increasing the amount of N₂O released in the atmosphere. Anthropogenic N₂O emissions from agriculture are produced either directly from nitrogen inputs to soils or indirectly, after the removal of nitrogen from soils. The N₂O emissions sources examined are the following:

- ↳ Pasture, range and paddock (animal production)
- ↳ Direct N₂O emissions
- ↳ Indirect N₂O emissions

Emissions from agricultural soils for the period 1990 – 2014 are presented in **Table 5.17**.

Table 5.17 *N₂O emissions (in kt) from agricultural soils for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Animal production	3.52	3.53	3.51	3.49	3.51	3.56	3.59	3.59	3.61	3.65	3.60
Direct emissions	8.40	8.45	7.97	6.62	6.36	6.80	6.89	6.65	6.62	6.39	6.04
Indirect emissions	4.15	4.14	4.00	3.56	3.48	3.65	3.69	3.61	3.61	3.55	3.42
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Animal production	3.63	3.64	3.59	3.53	3.50	3.52	3.51	3.50	3.55	3.53	3.52
Direct emissions	5.88	5.77	5.58	5.80	5.33	5.04	5.41	4.99	4.60	5.18	4.72
Indirect emissions	3.38	3.35	3.28	3.31	3.15	3.07	3.18	3.03	2.91	3.09	2.93
Year	2012	2013	2014								
Animal production	3.52	3.53	3.51								
Direct emissions	4.64	4.76	4.74								
Indirect emissions	2.91	2.95	2.94								

The reduction of N₂O emissions from agricultural soils is mainly due to the reduction in the use of synthetic nitrogen fertilizers. The decrease in the use of synthetic nitrogen fertilizers could probably be attributed to an increase in organic farming, the price of fertilizer and the impact of initiatives to promote good practice in fertilizer use. Additionally, the annual changes in the amount of fertilizers used and the agricultural production are the basic factors that account for the fluctuation of emissions during the period 1990 – 2014.

5.5.2 Methodology

Animal production

The estimation of N₂O emissions from pasture, range and paddock was based on the methodology used for the calculation of N₂O from manure management (Equation 11.1), using the default factors suggested by IPCC Guidelines (Table 11.1). Nitrogen input from pasture, range and paddock and N₂O emissions for the period 1990 – 2014 are presented in **Table 5.18**.

Direct N₂O emissions from agricultural soils

Direct N₂O emissions from agricultural soils derive from:

- ↳ The use of synthetic fertilizers
- ↳ Animal manure used as fertilizers
- ↳ The cultivation of N-fixing crops
- ↳ Crop residues that remain in soils
- ↳ Organic soils cultivation
- ↳ Sewage sludge used in agriculture (Estimation for first time in the current submission)

For the estimation of N₂O emissions from the use of synthetic fertilizers, Tier 1 methodology suggested by the IPCC Guidelines was applied.

Table 5.18 *Nitrogen input (in kt) and N₂O emissions (in kt) from pasture, range and paddock, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	215.61	215.82	215.13	214.76	216.70	219.30	220.46	220.65	221.53	222.97	221.89
N ₂ O emissions	3.52	3.53	3.51	3.49	3.51	3.56	3.59	3.59	3.61	3.65	3.60
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011

N input	223.82	223.84	221.34	217.26	215.33	216.15	215.57	214.64	216.06	214.36	213.45
N ₂ O emissions	3.63	3.64	3.59	3.53	3.50	3.52	3.51	3.50	3.55	3.53	3.52
Year	2012	2013	2014								
N input	213.12	213.32	212.772								
N ₂ O emissions	3.52	3.53	3.51								

As a part of the nitrogen contained in the fertilizer is volatilised in ammonia and nitrogen oxides, the relevant conversion factor suggested by IPCC Guidelines. The amount of synthetic nitrogen applied to soils and the subsequent N₂O emissions for the period 1990 – 2014 are presented in **Table 5.19**.

Table 5.19 *Synthetic nitrogen applied (in kt) and N₂O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	424.00	408.00	390.00	307.00	286.00	316.00	323.00	307.00	308.00	293.00	270.00
N ₂ O emissions	6.66	6.41	6.13	4.82	4.49	4.97	5.08	4.82	4.84	4.60	4.24
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N input	260.00	253.00	247.00	255.00	224.00	210.00	236.00	201.00	175.00	213.00	181.39
N ₂ O emissions	4.09	3.98	3.88	4.01	3.52	3.30	3.71	3.16	2.75	3.35	2.85
Year	2012	2013	2014								
N input	175.45	182.53	180.9								
N ₂ O emissions	2.76	2.87	2.84								

In 2012 and 2013 ERT reviews, recommendation regarding data providers of the annual synthetic fertilizers consumption was arisen emphasizing in the necessity for the collection data from the EL.STAT as an official organization and secondarily by the PHAPFDP.

It must be referred that EL.STAT. issues only import and export data concerning fertilizers and not data concerning specific nitrogen fertilizers consumption in nitrogen units. Therefore, data only from PHAPFDP is able to be collected instead of utilizing imports and export data of fertilizers and assuming nitrogen content.

As far as the information collection methodology is concerned, as it was explained by the experts from PHAPFDP, more than 98% of the Professional Fertilizers Producers & Dealers in Greece are members of the organization. Therefore, information concerning fertilizers consumption as well as the content of each type of fertilizer in nitrogen is provided directly to the association by their members.

The basic methodology was also applied for the estimation of N₂O emissions from the use of animal manure as a fertilizing agent. Specifically, the total nitrogen excretion from animals was calculated, as in the case of manure management, and then corrected to account for the fraction that volatilises in ammonia and nitrous oxides and the fraction that is deposited in soils through pasture, range and paddock, by using the default emission factors. In **Table 5.20** nitrogen input to soils from animal manure and subsequent N₂O emissions are presented, for the period 1990 – 2014.

Table 5.20 *Nitrogen input to soils from animal manure (in kt) and N₂O emissions (in kt) from animal manure used as fertilizers, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	55.66	55.81	55.70	55.47	55.11	56.07	56.34	56.59	56.87	58.19	56.27
N ₂ O emissions	0.87	0.88	0.88	0.87	0.87	0.88	0.89	0.89	0.89	0.91	0.88
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N input	55.18	56.76	55.03	55.57	56.11	56.23	55.47	54.81	57.02	57.59	57.60
N ₂ O emissions	0.87	0.89	0.86	0.87	0.88	0.88	0.87	0.86	0.90	0.90	0.91
Year	2012	2013	2014								
N input	57.46	57.87	57.45								
N ₂ O emissions	0.90	0.91	0.90								

Estimation of N₂O emissions from the organic soils (0.084 kt) was based on the cultivated area (6.7 kHa, constant for the entire period examined in North Greece) and the updated default emission factor suggested in the IPCC Good Practice Guidance for mid-latitude organic soils. Data for the

areas of organic soils derive from a relevant research conducted by the Soil Science Institute of Athens (SSIA, 2001).

Indirect N₂O emissions from agricultural soils

Indirect N₂O emissions from agricultural soils derive from:

- ↳ Volatilisation of nitrogen included in synthetic fertilizers, animal manure (used as fertilizer) and sewage sludge (used also as fertilizer) as NO_x and NH₃, followed by atmospheric deposition as NO_x, HNO₃ and NH₄ on soils and surface waters and subsequent N₂O formation.
- ↳ Leaching and runoff of nitrogen contained in applied fertilizers (synthetic, animal manure and sewage sludge).

For all sources of N₂O emissions, the Tier 1 methodology suggested by IPCC Good Practice Guidance has been applied (Equations 11.9 and 11.10). The activity data on the amount of nitrogen from synthetic fertilizers, animal manure and sewage sludge are those used for the calculation of direct emissions. The emission factors used are the default ones suggested by IPCC (Table 11.3). The emission factor for atmospheric deposition reflects the fraction of nitrogen that volatiles as ammonia and nitrous oxides, while for leaching and runoff it reflects the fraction of nitrogen that leaks from synthetic fertilizers and animal manure. The amount of nitrogen deposited and the indirect N₂O emissions for the period 1990 – 2014 are presented in **Table 5.21**

For the estimation of the fraction of nitrogen that volatilizes as NH₃ and NO_x from the input to soils due to the application of sewage sludge in agriculture, the default value suggested by the IPCC Good Practice Guidance, i.e. 20%, was used.

Table 5.21 *Deposited nitrogen (in kt) and indirect N₂O emissions (in kt) from agricultural soils, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atmospheric deposition											
N deposited	96.65	95.13	93.17	84.75	82.96	86.68	87.66	86.15	86.48	85.53	82.63
N ₂ O emissions	1.52	1.49	1.46	1.33	1.30	1.36	1.38	1.35	1.36	1.34	1.30
Leaching/Runoff											
N deposited	223.54	224.55	215.10	189.25	184.88	193.94	195.99	191.47	191.26	187.24	180.33
N ₂ O	2.63	2.65	2.54	2.23	2.18	2.29	2.31	2.26	2.25	2.21	2.13

emissions

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Atmospheric deposition											
N deposited	81.80	81.42	79.97	80.07	76.69	75.48	77.81	73.99	72.12	75.69	72.35
N ₂ O emissions	1.29	1.28	1.26	1.26	1.21	1.19	1.22	1.16	1.13	1.19	1.14
Leaching/Runoff											
N deposited	177.84	175.73	171.40	174.35	164.68	159.43	166.35	158.12	151.07	161.58	152.46
N ₂ O emissions	2.10	2.07	2.02	2.05	1.94	1.88	1.96	1.86	1.78	1.90	1.80
Year	2012	2013	2014								
Atmospheric deposition											
N deposited	71.72	72.55	72.19								
N ₂ O emissions	1.13	1.14	1.13								
Leaching/Runoff											
N deposited	150.88	153.23	152.78								
N ₂ O emissions	1.78	1.81	1.80								

5.5.3 Uncertainties and time-series consistency

The combined uncertainty of N₂O emissions of direct emissions as % of total emissions is estimated by 5.5%. The uncertainty associated with activity data is estimated 20% according to uncertainty given by NSSG for the crop production and the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers for the synthetic fertilizers consumed in the country while the uncertainty associated with emission factors is 200 % (country specific value).

The combined uncertainty of N₂O emissions of indirect emissions as % of total emissions is estimated by 0.9%. The uncertainty associated with activity data is 20% according to uncertainty given by NSSG for the crop production while the uncertainty associated with emission factors is 50 % as it is estimated according to Good Practice Guidance.

The combined uncertainty of N₂O emissions of animal production as % of total emissions is estimated by 1.5%. The uncertainty associated with activity data is 50% (country specific value) taking into account that in Greece there is a wide variety of management systems used usage while the uncertainty associated with emission factors is 100 % as it is estimated according to Good Practice Guidance.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.5.4 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the agricultural soils source are:

1. Cross checking information provided by the National Statistical Service of Greece and by the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers regarding the amount of synthetic fertilizers. Moreover, data provided by FAO for the period 1990-2002 were compared with these provided by PHAPFPD,
2. Comparison of activity data and emissions factors with these of other neighbour countries.
3. Estimations were checked with several calculations tools such as emissions trends and sum deviations.

5.5.5 Recalculations

No recalculations were performed.

5.6 Field burning of agricultural residues (CRF Source Category 3F)

5.6.1 Description

The generation of crop residues is a result of the farming practices used. Disposal practices for residues include ploughing them back into the ground, composting, landfilling and burning on-site. According to the IPCC Good Practice Guidance, 10% constitutes an indicative value of the residues burned annually on the field. Burning of agricultural residues is responsible for emissions of CH₄, N₂O, CO and NO_x.

CH₄ and N₂O emissions from field burning of agricultural residues for the period 1990 – 2014 are presented in *Table 5.22*.

Table 5.22 *GHG emissions (in kt) from field burning of agricultural residues, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ emissions	1.37	1.91	1.56	1.49	1.63	1.52	1.50	1.52	1.42	1.40	1.48
N ₂ O emissions	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ emissions	1.51	1.46	1.36	1.51	1.53	1.40	1.37	1.65	1.57	1.55	1.60
N ₂ O emissions	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Year	2012	2013	2014								
CH ₄ emissions	1.63	1.64	1.67								
N ₂ O emissions	0.04	0.04	0.04								

5.6.2 Methodology

For the estimation of CH₄ and N₂O emissions from field burning of agricultural residues the default methodology has been applied. In order to calculate the biomass that is burned agricultural production per crop (as in the sector of agricultural soils) and the default factors related to the residues to crop product ratio, the dry matter fraction and the oxidation factor, as well as to the fraction of residues burned were used.

5.6.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ emissions of field burning of agricultural sector as % of total emissions is estimated by 0.01%. The combined uncertainty of N₂O emissions of field burning of agricultural sector as % of total emissions is estimated by 0.003%. The uncertainty associated with activity data is 20% according to uncertainty given by NSSG for the crop production data while

the uncertainty associated with emission factors is 20% as it is estimated according to Good Practice Guidance.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.6.4 Recalculations

No recalculations were performed.

5.7 Urea application (CRF Source Category 3H)

5.7.1 Description

Adding urea to soils during fertilisation leads to a loss of CO₂ that was fixed in the industrial production process. Urea (CO(NH₂)₂) is converted into ammonium (NH₄⁺), hydroxyl ion (OH⁻), and bicarbonate (HCO₃⁻), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO₂ and water.

CO₂ Urea application for the period 1990 – 2014 are presented in *Table 5.23*.

Table 5.23 *GHG emissions (in kt) from Urea application, for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ emissions	60	58	56	44	41	45	46	44	44	42	38
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO ₂ emissions	37	36	35	36	32	30	34	29	25	30	26
Year	2012	2013	2014								
CO ₂ emissions	25	26	26								

5.7.2 Methodology

For the estimation of CO₂ emissions from Urea application the default methodology suggested in IPCC Guidelines has been applied. The emission factors used are the default ones suggested by IPCC Guidelines.

5.7.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ emissions of field burning of agricultural sector as % of total emissions is estimated by 0.01%. The combined uncertainty of N₂O emissions of field burning of agricultural sector as % of total emissions is estimated by 0.003%.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

5.7.4 Recalculations

No recalculations were performed.

6. Land Use, Land Use Change and Forestry (CRF sector 4)

6.1 Overview

In this chapter emissions and removals of greenhouse gases from the sector *Land Use, Land Use Change and Forestry* are presented, and methodologies used to estimate emissions / removals by each source / sink category are described. Emissions and removals from this sector have been calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use (henceforth in this chapter 2006 GL AFOLU), in accordance with the decision 24/CP.19, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (henceforth KP Supplement) and the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (henceforth in this chapter GPG LULUCF), adopted at COP9 (Decision 13/CP.9). The GPG LULUCF introduced new categories for estimating and reporting emissions and removals of CO₂ and other greenhouse gases, based on six top-level land-use² categories:

- ↳ Forest land
- ↳ Cropland
- ↳ Grassland
- ↳ Wetlands
- ↳ Settlements
- ↳ Other land

The 2005 inventory submission included the results of Greece's first attempt to comply with the reporting requirements of Decision 13/CP.9 for the LULUCF sector. Carbon stock changes in the five carbon pools (Aboveground Biomass, Belowground Biomass, Dead Wood, Litter and Soil Organic Matter) and emissions of non-CO₂ gases were assessed and reported. Specific quality assurance and quality control procedures were followed in the preparation of this inventory, uncertainties were estimated and key categories were identified. However, GHG emissions and removals for several land use and land use change categories were not estimated until the 2010 submission. The 2010 submission incorporated some major improvements undertaken by Greece in order to improve accuracy and completeness of the reported estimates, to minimize uncertainties and to be compliant with the reporting requirements of both UNFCCC and the KP, while from 2015 and onwards the national inventory report is following methodologies provided in the 2006 GL AFOLU, and KP Supplement.

The remainder of this chapter is organized as follows. Paragraph 6.1 continues with an overview of the LULUCF sector with a presentation of emission / removal levels and trends, a brief discussion

² The names of these land categories are a mixture of land cover (e.g., Forest land, Grassland, Wetlands) and land use (e.g., Cropland, Settlements) classes, however, for convenience, they are here referred to as land-use categories.

on the methodology used in this inventory, an assessment of the completeness of the GHG inventory for the LULUCF sector and the presentation of recalculations and improvements undertaken since the previous submission. Then, in the next two chapters, relevant information on the land-use definitions and the classification system used as well as information on approaches used for representing land areas is given. Finally, in Paragraphs 6.4 to 6.10 detailed information (descriptions, references and sources of specific methodologies, assumptions, emission factors and activity data used and the rationale for their selection) on each category is presented.

6.1.1 Emissions/Removals trends

The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2014. The sink capacity of the LULUCF sector fluctuates between 1.47 Mt CO₂ eq and 3.30 Mt CO₂ eq, showing an increasing trend. This is the result of the decrease of the sink capacity of the Cropland category on the one hand, and the increase of the sink capacity of the Forest Land category on the other.

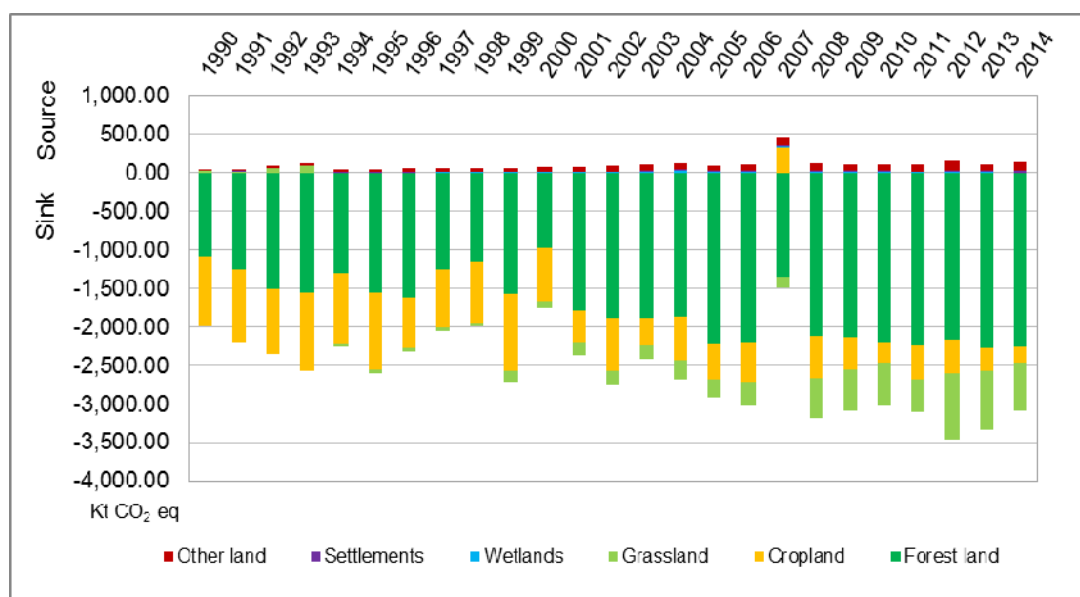


Figure 6.1 Net GHG emissions / removals (in kt CO₂ eq) from the Land Use, Land Use Change and Forestry sector by category for the period 1990 – 2014

CO₂ is the main greenhouse gas emitted to and removed from the atmosphere following carbon stocks changes in different carbon pools. Non-CO₂ greenhouse gases (CH₄ and N₂O) and indirect GHG (NO_x and CO) are released in relatively small quantities when biomass is burnt.

As shown in **Figure 6.1**, both Forest Land and Cropland (with the exception of the year 2007) categories act as net carbon sinks during the period 1990 – 2014. Emissions / removals from the Forest Land category are the result of the balance mainly in biomass increment from forest growth and biomass loss due to fellings and wildfires. Net removals from the Forest Land show an upward trend that is attributed mainly to the reduction in fellings and the afforestation programmes started in 1994. The sink capacity of Forest Land has increased from 1.08 Mt CO₂ eq in 1990 to 2.2 Mt CO₂ eq in 2014.

Removals from Cropland, fluctuate between 0.2-1.1 Mt CO₂ eq yr⁻¹ (except 2007 where the category acts as a source). Grassland category appears as a sink from 1994 – 2014 mainly due to conversion of Cropland to Grassland, while emissions from that category are primarily the result of conversion of Forest land to Grassland and changes in vegetation type, as well as, the result of wildfires. Wetlands, Settlements and Other Land categories are small sources of CO₂ when Forest land and Grassland are converted to these land uses. Emissions / removals per gas and category from LULUCF are presented in **Table 6.1**.

Table 6.1 GHG emissions/removals (in kt) from the Land Use, Land Use Change and Forestry sector by category and gas for the period 1990-2014

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Net CO ₂ emissions / removals (in kt)													
A. Forest Land	-1139.19	-1272.89	-1560.71	-1616.19	-1350.79	-1582.93	-1629.86	-1303.15	-1268.52	-1581.68	-1133.51	-1799.48	-1881.95
B. Cropland	-908.07	-951.01	-852.15	-1006.95	-931.02	-1011.36	-655.03	-738.49	-812.46	-993.60	-680.18	-432.41	-685.14
C. Grassland	0.22	0.20	5.74	53.00	-51.93	-58.20	-68.48	-74.07	-86.57	-141.34	-167.53	-171.21	-199.33
D. Wetlands	NE,NO	NE,NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51	0.74	2.37
E. Settlements	6.08	7.80	4.79	5.22	6.01	4.03	14.44	5.72	5.39	8.52	13.21	8.95	10.28
F. Other Land	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15	64.23	69.89
G. HWP	-324.95	-307.72	-183.86	-399.92	-381.21	-321.32	-341.01	230.78	127.56	18.48	-201.08	-48.45	-197.90
CH ₄ emissions (in kt)													
A. Forest Land	1.86	0.71	2.05	2.14	1.87	1.23	0.51	1.49	4.66	0.30	5.74	0.61	0.06
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	0.63	0.53	1.61	1.13	1.18	0.50	0.54	0.81	1.59	0.18	2.48	0.50	0.09
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWP													
N ₂ O emissions (in kt)													
A. Forest Land	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.04	0.00	0.00
B. Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Grassland	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.00
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00
G. HWP													
TOTAL LULUCF (kt CO ₂ eq)	-2278.78	-2477.46	-2457.21	-2852.22	-2599.92	-2895.13	-2612.06	-1771.74	-1817.38	-2624.89	-1884.85	-2347.64	-2877.68

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Net CO ₂ emissions / removals (in kt)												
A. Forest Land	-1881.22	-1872.31	-2233.40	-2223.37	-1553.82	-2145.86	-2160.55	-2232.78	-2244.96	-2183.77	-2267.76	-2266.85
B. Cropland	-367.50	-561.39	-448.47	-499.55	327.64	-551.27	-430.60	-255.68	-448.59	-446.61	-311.06	-316.65
C. Grassland	-178.22	-259.27	-236.89	-325.98	-282.90	-523.27	-543.10	-556.98	-430.47	-874.96	-776.25	-850.53
D. Wetlands	1.37	26.30	3.10	4.23	3.58	2.82	2.82	2.61	2.59	2.85	2.52	0.09
E. Settlements	24.46	15.37	21.03	17.98	18.51	16.99	14.79	13.86	12.36	24.32	13.38	11.33
F. Other Land	69.09	77.69	69.91	82.51	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47
G. HWP	-256.72	-234.47	-253.35	-275.48	-438.76	-74.69	-262.42	-335.77	-296.44	56.06	90.97	93.27
CH ₄ emissions (in kt)												
A. Forest Land	0.09	0.23	0.19	0.57	7.59	1.18	1.29	0.55	0.23	0.87	0.07	0.04
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	0.13	0.31	0.16	0.25	5.14	0.54	0.54	0.10	0.48	0.87	0.57	0.33
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWP												
N ₂ O emissions (in kt)												
A. Forest Land	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00
B. Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Grassland	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.00
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00
G. HWP												
TOTAL LULUCF (kt CO ₂ eq)	-2582.97	-2793.47	-3068.53	-3197.24	-1474.02	-3129.32	-3239.88	-3260.71	-3301.96	-3246.83	-3148.45	-3236.67

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

6.1.2 Methodology

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: Agriculture, Forestry, and Other Land Use, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, and the IPCC Good Practice Guidance for LULUCF.

Activity data and country specific emission / removal factors were obtained from the EL.STAT. (Hellenic Statistical Authority), the Ministry of Environment and Energy (MEEN) and relevant studies of research bodies. References to all sources are given in the description of the methodology used in each category.

The methodology applied for the calculation of emissions per source / sink category is summarised in **Table 6.2**, while a detailed description is given in the respective chapters for each category.

Table 6.2 *Methodology for the estimation of emissions / removals from the LULUCF sector*

IPCC Source / Sink Categories	CO ₂		CH ₄		N ₂ O	
	Method	Emission factor	Method	Emission factor	Method	Emission factor
A. Forest Land						
A1. Forest Land remaining Forest Land	T1,T2	CS, D	T1	D	T1	D
A2. Land converted to Forest Land	OTH,T1	OTH,D	T1	D	T1	D
B. Cropland						
B1. Cropland remaining Cropland	T1,T2	CS, D	NA	NA	NA	NA
B2. Land converted to Cropland	T1,T2	CS, D	NA	NA	T1	D
C. Grassland						
C1. Grassland remaining Grassland	T2	CS	T1	D	T1	D
C2. Land converted to Grassland	T1,T2	CS, D	NA	NA	NA	NA
D. Wetlands						
D1. Wetlands remaining Wetlands						
D2. Land converted to Wetlands	T1,T2	CS, D	NA	NA	NA	NA
E. Settlements						
E1. Settlements remaining Settlements						
E2. Land converted to Settlements	T1,T2	CS, D	NA	NA	NA	NA
F. Other Land						
F1. Other Land remaining Other Land						
F2. Land converted to Other Land	T1,T2	CS, D	NA	NA	NA	NA
G. Harvested wood products	T2	D	NA	NA	NA	NA

T1, T2: IPCC methodology Tier 1 and Tier 2 respectively

CS: Country specific methodology and emission factor

OTH: Other

D: IPCC default methodology and emission factor

In this inventory, the IPCC default land use transition period of 20 years was used in the estimation process of carbon stock changes in mineral soils related to land use changes, with the only exception to be that in Land converted to Wetlands. Following previous ERT's recommendation and in order to increase transparency the transition period that has been applied to estimate carbon stock changes in each land use change category is presented below:

<u>LULUCF</u>	<u>Transition period</u>	<u>KP-LULUCF</u>	<u>Transition period</u>
<u>Land converted to Forest land</u>		<u>Art. 3.3. Afforestation/Reforestation</u>	
<i>Cropland converted to Forest land</i>	<i>20 years</i>	<i>Cropland converted to Forest land</i>	<i>20 years</i>
<u>Land converted to Cropland</u>		<u>Art. 3.3. Deforestation</u>	
<i>Forest land converted to Cropland</i>	<i>20 years</i>	<i>Forest land converted to Cropland</i>	<i>20 years</i>
<i>Grassland converted to Cropland</i>	<i>20 years</i>	<i>Forest land converted to Wetlands</i>	<i>10 years³</i>
<u>Land Converted to Wetlands</u>		<i>Forest land converted to Settlements</i>	<i>20 years</i>
<i>Forest land converted to Wetlands</i>	<i>10 years³</i>	<i>Forest land converted to Other land</i>	<i>20 years</i>
<i>Grassland converted to Wetlands</i>	<i>10 years³</i>		
<u>Land converted to Settlements</u>			
<i>Forest land converted to Settlements</i>	<i>20 years</i>		
<i>Grassland converted to Settlements</i>	<i>20 years</i>		
<u>Land converted to Other land</u>			
<i>Forest land converted to Other land</i>	<i>20 years</i>		
<i>Grassland converted to Other land</i>	<i>20 years</i>		

Key categories

Key categories – a term introduced by the GPG LULUCF to expand key source concept and cover both source and sink categories – have been determined following the Tier 1 method. The key categories in the *LULUCF* sector determined by this analysis are presented in **Table 6.3** (see Paragraph 1.5 for a complete presentation of the results of the key category analysis and Annex I for the presentation of the relevant calculations).

Table 6.3 *Key categories in the LULUCF sector*

IPCC source / sink category	Greenhouse Gas	Level assessment	Trend assessment
Forest Land remaining Forest Land	CO ₂	☒	☒
Cropland remaining Cropland	CO ₂		☒
Conversion to Grassland	CO ₂	☒	☒
Harvested Wood Products	CO ₂		☒

³ According to Appendix 3a.3 of the GPG LULUCF (Tier 1), 10 years is the time period for which emissions from soil organic matter pool have been assumed to occur after flooding took place.

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV. However, it is noted that uncertainties in estimates from this sector are possibly higher than those reported, since uncertainties introduced by assumptions made and categories or pools not estimated have not been considered.

6.1.3 Completeness

The **Table 6.4** below summarizes the completeness of the inventory for the sector Land use, Land Use Change and Forestry.

Table 6.4 *Land Use, Land Use Change and Forestry – Completeness of emissions / removals inventory*

IPCC source / sink categories	CO ₂	CH ₄	N ₂ O
A. Forest Land			
1. Forest Land remaining Forest Land	☒	☒	☒
2. Land converted to Forest Land	☒	☒	☒
B. Cropland			
1. Cropland remaining Cropland	☒	NO	NO
2. Land converted to Cropland	☒	NO	☒
C. Grassland			
1. Grassland remaining Grassland	☒	☒	☒
2. Land converted to Grassland	☒	NO	NO
D. Wetlands			
1. Wetlands remaining Wetlands			
2. Land converted to Wetlands	☒	NO	NO
E. Settlements			
1. Settlements remaining Settlements			
2. Land converted to Settlements	☒	NO	NO
F. Other Land			
1. Other Land remaining Other Land			
2. Land converted to Other Land	☒	NO	NO
G. Harvested wood products	☒	NO	NO

NO: Not Occurring

6.1.4 Category-specific QA/QC procedures

Category specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan. The special procedures followed in the LULUCF sector are:

- Investigation of more information related to cropland management practices applied in Greece.

- Comparison of information regarding the emissions factors with this of other neighbor countries.
- Cross checking information provided by the Forest Service of each prefecture and by the central Forest Service regarding the area of wildfires, and the land use changes.
- Cross checking information provided by the Hellenic Statistical Authority.
- Estimations were cross checked several times with the aim of assuring the accuracy of the results.

The most important results of the internal audits are:

- Need to seek additional sources of information regarding cropland areas and management practices in Greece.
- Need to seek additional sources of information regarding grassland areas and management practices in Greece.
- More detailed description in the NIR of methods, activity data and emission factors used for the estimation of emissions/removals from different sources/sinks, and better implementation of the annotated NIR, in order to further improve transparency.
- Better use of Notation keys in the CRF tables.
- More efforts need to be done in order to collect country specific data with the aim of increasing the Tier level of estimations of emissions/removals resulting from carbon stock changes in the various carbon pools in key land use categories.
- Investigation of the process chain of HWPs in the country, the end-use, discard rates with a view to developing country specific emission factors for the necessary estimations.

6.1.5 Recalculations and improvements

In the current submission, several recalculations have been performed mainly due to the application of methodologies proposed by 2006 GL AFOLU and the new global warming potentials values (GWPs), in accordance with the updated UNFCCC reporting guidelines as contained in decision 24/CP.19. More specifically, the recalculations and improvements performed refer to:

- Complete reconstruction of the land use, land-use change matrices for the period 1990 – 2014, following also ERT's recommendation. Inclusion in the NIR of a complete set of both annual and 20-years land use, land-use change matrices for the period 1990 – 2014. This development resulted in a change of the total country area. Further, the total country area equals the sum of all land use categories, correcting any inconsistencies detected in the previous submission.

- Update of the Forest Management Plans database and inclusion of data from the more recent Forest Management Plans that resulted in recalculations in the whole time series in the "Forest land remaining Forest land" category.
- Recalculations of non-CO₂ emissions from wildfires in Forest land remaining Forest land category (use of updated data).
- Reporting for the first time on activity data for Grassland converted to Forest land category (natural forest expansion) following ERT's recommendation.
- Use of the most updated emission factors from a neighboring country (i.e. Italy), for the estimation of carbon stock changes in living biomass in Cropland converted to Forest land category.
- Estimation and reporting for the first time of CO₂ and non-CO₂ greenhouse gas emissions resulted from dead organic matter pool (dead wood and litter) subject to wildfires in forest land category.
- Update and fulfillment of the Land Use Change Database.
- Recalculations for Cropland category, due to the application of the new IPCC guidelines.
- Recalculations for the whole time series for Forest land and Grassland categories converted to other land use categories.
- Correction in the use of notation keys in CRF tables.

6.2 Land-use definitions and classification systems used and their correspondence to the LULUCF categories

The forest definition of Greece in this inventory is the same used in the previous inventories, and adopted also in the framework of the Kyoto Protocol. The threshold values for tree crown cover, land area and tree height are:

- i. 25% minimum tree crown.
- ii. 0.3 hectares minimum land area.
- iii. 2 metres tree height, or the potential to achieve it.

Cropland category includes all annual and perennial crops as well as temporary fallow land.

Grassland includes rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed it without human intervention. Pastures that have been fertilised or sown are considered as cropland.

As wetlands is classified land that is covered or saturated by water for all or the greatest part of the year (e.g. lakes, reservoirs, marshes), as well as river bed (including torrent beds) and that does not fall into the forest land, cropland, grassland or settlements categories.

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in other land-use categories.

The category of "Other land" includes all land areas that do not fall into any of other land-use categories (e.g. rocky areas, bare soil, mine and quarry land).

Below, the land use and land-use change matrices for the period 1990 to 2014 are presented. They are presented both as annual and 20-years matrices, while in the next chapter the necessary information on the way they have been developed is given.

Table 6.5 *Annual and 20-years land use, and land-use change matrices (areas in ha)*

	from/to	1990						Total 1989
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1989	Forestland	3,359,072	0	1	0	6	107	3,359,186
	Cropland	0	3,944,197	3	NO	NO	NO	3,944,200
	Grassland	3,993	3	4,794,919	0	448	231	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	0	265,280	265,280
Total 1990		3,363,065	3,944,200	4,794,923	299,600	530,775	265,618	13,198,180
	from/to	1991						Total 1990
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1990	Forestland	3,363,018	0	0	0	16	31	3,363,065
	Cropland	0	3,944,194	6	NO	NO	NO	3,944,200
	Grassland	3,925	5	4,790,673	0	171	148	4,794,923
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,775	NO	530,775
	Other land	NO	NO	NO	NO	2	265,616	265,618
Total 1991		3,366,943	3,944,200	4,790,679	299,600	530,964	265,794	13,198,180
	from/to	1992						Total 1991
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1991	Forestland	3,366,751	1	2	2	13	174	3,366,943
	Cropland	0	3,941,195	3,005	NO	NO	NO	3,944,200
	Grassland	4,071	4	4,786,321	0	66	218	4,790,679
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,964	NO	530,964
	Other land	NO	NO	NO	NO	1	265,794	265,794
Total 1992		3,370,822	3,941,200	4,789,328	299,602	531,043	266,185	13,198,180
	from/to	1993						Total 1992
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1992	Forestland	3,369,962	1	767	0	17	74	3,370,822
	Cropland	0	3,919,487	21,713	NO	NO	NO	3,941,200
	Grassland	4,738	12	4,784,369	32	42	135	4,789,328
	Wetlands	NO	NO	NO	299,602	NO	NO	299,602
	Settlements	NO	NO	NO	NO	531,043	NO	531,043
	Other land	NO	NO	NO	NO	1	266,184	266,185
Total 1993		3,374,700	3,919,500	4,806,849	299,634	531,104	266,393	13,198,180
	from/to	1994						Total 1993
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1993	Forestland	3,374,616	0	4	1	20	58	3,374,700
	Cropland	2,400	3,912,598	4,502	NO	NO	NO	3,919,500
	Grassland	1,562	2	4,805,039	1	84	161	4,806,849
	Wetlands	NO	NO	NO	299,634	NO	NO	299,634
	Settlements	NO	NO	NO	NO	531,104	NO	531,104
	Other land	NO	NO	NO	NO	1	266,392	266,393
Total 1994		3,378,579	3,912,600	4,809,545	299,636	531,209	266,611	13,198,180
	from/to	1995						Total 1994
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1994	Forestland	3,378,295	2	189	0	13	79	3,378,579
	Cropland	3,200	3,906,093	3,307	NO	NO	NO	3,912,600
	Grassland	962	5	4,808,488	0	24	65	4,809,545
	Wetlands	NO	NO	NO	299,636	NO	NO	299,636
	Settlements	NO	NO	NO	NO	531,209	NO	531,209
	Other land	NO	NO	NO	NO	0	266,611	266,611
Total 1995		3,382,457	3,906,100	4,811,984	299,636	531,247	266,755	13,198,180
	from/to	1996						Total 1995
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1995	Forestland	3,357,606	5	963	3	86	523	3,359,186
	Cropland	5,600	3,906,065	32,535	NO	NO	NO	3,944,200
	Grassland	19,251	30	4,778,486	33	836	957	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	5	265,275	265,280
Total 1996		3,382,457	3,906,100	4,811,984	299,636	531,247	266,755	13,198,180
	from/to	1997						Total 1971
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1971	Forestland	3,359,072	0	1	0	6	107	3,359,186
	Cropland	0	3,944,197	3	NO	NO	NO	3,944,200
	Grassland	3,993	3	4,794,919	0	448	231	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	0	265,280	265,280
Total 1990		3,363,065	3,944,200	4,794,923	299,600	530,775	265,618	13,198,180
	from/to	1998						Total 1972
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1972	Forestland	3,359,025	0	1	0	22	138	3,359,186
	Cropland	0	3,944,191	9	NO	NO	NO	3,944,200
	Grassland	7,918	8	4,790,670	0	620	379	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	2	265,278	265,280
Total 1991		3,366,943	3,944,200	4,790,679	299,600	530,964	265,794	13,198,180
	from/to	1999						Total 1973
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1973	Forestland	3,358,833	2	3	2	35	312	3,359,186
	Cropland	0	3,941,187	3,013	NO	NO	NO	3,944,200
	Grassland	11,989	12	4,786,312	0	686	596	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	2	265,278	265,280
Total 1992		3,370,822	3,941,200	4,789,328	299,602	531,043	266,185	13,198,180
	from/to	2000						Total 1974
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1974	Forestland	3,357,973	3	770	2	52	386	3,359,186
	Cropland	0	3,919,474	24,726	NO	NO	NO	3,944,200
	Grassland	16,727	23	4,781,353	32	728	731	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	4	265,276	265,280
Total 1993		3,374,700	3,919,500	4,806,849	299,634	531,104	266,393	13,198,180
	from/to	2001						Total 1975
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1975	Forestland	3,357,890	3	774	3	72	444	3,359,186
	Cropland	2,400	3,912,571	29,229	NO	NO	NO	3,944,200
	Grassland	18,289	25	4,779,543	33	812	892	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	5	265,275	265,280
Total 1994		3,378,579	3,912,600	4,809,545	299,636	531,209	266,611	13,198,180
	from/to	2002						Total 1976
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1976	Forestland	3,357,606	5	963	3	86	523	3,359,186
	Cropland	5,600	3,906,065	32,535	NO	NO	NO	3,944,200
	Grassland	19,251	30	4,778,486	33	836	957	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	5	265,275	265,280
Total 1995		3,382,457	3,906,100	4,811,984	299,636	531,247	266,755	13,198,180

	from/to	1996						Total 1995
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1995	Forestland	3,382,073	1	79	5	143	156	3,382,457
	Cropland	3,000	3,898,696	4,404	NO	NO	NO	3,906,100
	Grassland	1,263	2	4,810,501	0	23	196	4,811,984
	Wetlands	NO	NO	NO	299,636	NO	NO	299,636
	Settlements	NO	NO	NO	NO	531,247	NO	531,247
	Other land	NO	NO	NO	NO	4	266,751	266,755
Total 1996		3,386,336	3,898,700	4,814,983	299,641	531,416	267,104	13,198,180
	from/to	1996						Total 1997
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1997	Forestland	3,357,222	7	1,041	8	228	679	3,359,186
	Cropland	8,600	3,898,661	36,939	NO	NO	NO	3,944,200
	Grassland	20,514	33	4,777,002	33	859	1,153	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	9	265,271	265,280
Total 1996		3,386,336	3,898,700	4,814,983	299,641	531,416	267,104	13,198,180
	from/to	1997						Total 1996
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1996	Forestland	3,386,203	0	0	0	10	122	3,386,336
	Cropland	6,000	3,883,499	9,201	NO	NO	NO	3,898,700
	Grassland	0	1	4,814,556	22	54	351	4,814,983
	Wetlands	NO	NO	NO	299,641	NO	NO	299,641
	Settlements	NO	NO	NO	NO	531,416	NO	531,416
	Other land	NO	NO	NO	NO	2	267,102	267,104
Total 1997		3,392,203	3,883,500	4,823,757	299,663	531,482	267,574	13,198,180
	from/to	1997						Total 1978
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1978	Forestland	3,357,089	7	1,042	8	238	802	3,359,186
	Cropland	14,600	3,883,460	46,140	NO	NO	NO	3,944,200
	Grassland	20,514	33	4,776,575	55	912	1,504	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	11	265,269	265,280
Total 1997		3,392,203	3,883,500	4,823,757	299,663	531,482	267,574	13,198,180
	from/to	1998						Total 1997
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1997	Forestland	3,392,112	1	2	0	15	73	3,392,203
	Cropland	1,800	3,866,199	15,501	NO	NO	NO	3,883,500
	Grassland	181	0	4,823,165	93	38	280	4,823,757
	Wetlands	NO	NO	NO	299,663	NO	NO	299,663
	Settlements	NO	NO	NO	NO	531,482	NO	531,482
	Other land	NO	NO	NO	NO	34	267,541	267,574
Total 1998		3,394,093	3,866,200	4,838,669	299,756	531,568	267,894	13,198,180
	from/to	1998						Total 1979
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1979	Forestland	3,356,998	7	1,044	8	253	875	3,359,186
	Cropland	16,400	3,866,159	61,641	NO	NO	NO	3,944,200
	Grassland	20,695	34	4,775,984	148	950	1,784	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	45	265,235	265,280
Total 1998		3,394,093	3,866,200	4,838,669	299,756	531,568	267,894	13,198,180
	from/to	1999						Total 1980
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1980	Forestland	3,356,876	9	1,050	8	291	951	3,359,186
	Cropland	20,400	3,854,656	69,144	NO	NO	NO	3,944,200
	Grassland	20,695	35	4,775,600	148	1,053	2,063	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	64	265,216	265,280
Total 1999		3,397,971	3,854,700	4,845,794	299,756	531,728	268,230	13,198,180
	from/to	2000						Total 1999
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1999	Forestland	3,397,788	0	0	0	78	105	3,397,971
	Cropland	2,377	3,848,198	4,125	NO	NO	NO	3,866,200
	Grassland	1,685	2	4,843,726	100	169	112	4,845,794
	Wetlands	NO	NO	NO	299,756	NO	NO	299,756
	Settlements	NO	NO	NO	NO	531,728	NO	531,728
	Other land	NO	NO	NO	NO	3	268,228	268,230
Total 2000		3,401,850	3,848,200	4,847,851	299,856	531,977	268,445	13,198,180
	from/to	2001						Total 2000
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2000	Forestland	3,401,659	2	0	0	38	151	3,401,850
	Cropland	1,176	3,838,998	8,026	NO	NO	NO	3,848,200
	Grassland	2,893	0	4,844,693	9	83	173	4,847,851
	Wetlands	NO	NO	NO	299,856	NO	NO	299,856
	Settlements	NO	NO	NO	NO	531,977	NO	531,977
	Other land	NO	NO	NO	NO	1	268,444	268,445
Total 2001		3,405,729	3,839,000	4,852,719	299,865	532,099	268,768	13,198,180
	from/to	2002						Total 2001
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2001	Forestland	3,405,557	1	1	18	38	114	3,405,729
	Cropland	2,302	3,832,697	4,002	NO	NO	NO	3,839,000
	Grassland	1,748	2	4,850,570	0	143	256	4,852,719
	Wetlands	NO	NO	NO	299,865	NO	NO	299,865
	Settlements	NO	NO	NO	NO	532,099	NO	532,099
	Other land	NO	NO	NO	NO	1	268,767	268,768
Total 2002		3,409,607	3,832,700	4,854,572	299,883	532,282	269,136	13,198,180
	from/to	2003						Total 2002
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2002	Forestland	3,409,264	2	13	16	218	95	3,409,607
	Cropland	1,544	3,810,997	20,160	NO	NO	NO	3,832,700
	Grassland	2,678	3	4,851,423	5	237	226	4,854,572
	Wetlands	NO	NO	NO	299,883	NO	NO	299,883
	Settlements	NO	NO	NO	NO	532,282	NO	532,282
	Other land	NO	NO	NO	NO	1	269,136	269,136
Total 2003		3,413,486	3,811,001	4,871,595	299,904	532,737	269,457	13,198,180
	from/to	2003						Total 1984
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1984	Forestland	3,355,988	14	1,064	42	663	1,416	3,359,186
	Cropland	27,798	3,810,945	105,457	NO	NO	NO	3,944,200
	Grassland	29,700	42	4,765,075	262	1,685	2,830	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	69	265,211	265,280
Total 2003		3,413,486	3,811,001	4,871,595	299,904	532,737	269,457	13,198,180

		2004						Total 2003
from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land		
2003	Forestland	3,413,207	0	7	20	85	167	3,413,486
	Cropland	1,829	3,803,684	5,488	NO	NO	NO	3,811,001
	Grassland	2,329	10	4,867,817	1,132	147	161	4,871,595
	Wetlands	NO	NO	NO	299,904	NO	NO	299,904
	Settlements	NO	NO	NO	NO	532,737	NO	532,737
	Other land	NO	NO	NO	NO	7	269,450	269,457
Total 2004		3,417,364	3,803,695	4,873,312	301,056	532,976	269,777	13,198,180

		2005						Total 2004
	from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2004	Forestland	3,417,261	0	0	0	62	42	3,417,364
	Cropland	2,325	3,775,447	25,923	NO	NO	NO	3,803,695
	Grassland	1,657	1	4,871,171	9	398	77	4,873,312
	Wetlands	NO	NO	NO	301,056	NO	NO	301,056
	Settlements	NO	NO	NO	NO	532,976	NO	532,976
	Other land	NO	NO	NO	NO	0	269,777	269,777
Total 2005		3,421,243	3,775,447	4,897,094	301,064	533,436	269,896	13,198,180

		2006						Total 2005
from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land		
2005	Forestland	3,421,089	0	1	13	58	81	3,421,243
	Cropland	1,296	3,760,145	14,006	NO	NO	NO	3,775,447
	Grassland	2,737	2	4,893,767	7	264	318	4,897,094
	Wetlands	NO	NO	NO	301,064	NO	NO	301,064
	Settlements	NO	NO	NO	NO	533,436	NO	533,436
	Other land	NO	NO	NO	NO	0	269,895	269,896
Total 2006		3,425,121	3,760,147	4,907,774	301,085	533,758	270,295	13,198,180

		2007						Total 2006
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2006	Forestland	3,424,637	0	2	4	81	397	3,425,121
	Cropland	0	3,702,452	57,696	NO	NO	NO	3,760,147
	Grassland	4,363	7	4,903,034	4	163	203	4,907,774
	Wetlands	NO	NO	NO	301,085	NO	NO	301,085
	Settlements	NO	NO	NO	NO	533,758	NO	533,758
	Other land	NO	NO	NO	NO	2	270,292	270,295
Total 2007		3,429,000	3,702,458	4,960,732	301,093	534,005	270,893	13,198,180

		2008						Total 2007
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2007	Forestland	3,428,842	0	2	0	75	80	3,429,000
	Cropland	0	3,693,809	8,649	NO	NO	NO	3,702,458
	Grassland	4,037	1	4,956,253	0	123	318	4,960,732
	Wetlands	NO	NO	NO	301,093	NO	NO	301,093
	Settlements	NO	NO	NO	NO	534,005	NO	534,005
	Other land	NO	NO	NO	NO	2	270,891	270,893
Total 2008		3,432,878	3,693,810	4,964,904	301,093	534,205	271,289	13,198,180

		2009						Total 2008
	from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2008	Forestland	3,432,799	0	39	0	13	27	3,432,878
	Cropland	0	3,685,348	8,462	NO	NO	NO	3,693,810
	Grassland	3,958	2	4,960,734	0	122	88	4,964,904
	Wetlands	NO	NO	NO	301,093	NO	NO	301,093
	Settlements	NO	NO	NO	NO	534,205	NO	534,205
	Other land	NO	NO	NO	NO	0	271,289	271,289
Total 2009		3,436,757	3,685,350	4,969,236	301,093	534,341	271,404	13,198,180

		2010						Total 2009
	from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2009	Forestland	3,436,721	0	5	0	2	29	3,436,757
	Cropland	0	3,670,916	14,434	NO	NO	NO	3,685,350
	Grassland	3,914	14	4,964,980	0	250	78	4,969,236
	Wetlands	NO	NO	NO	301,093	NO	NO	301,093
	Settlements	NO	NO	NO	NO	534,341	NO	534,341
	Other land	NO	NO	NO	NO	0	271,404	271,404
Total 2010		3,440,635	3,670,930	4,979,419	301,093	534,593	271,511	13,198,180

		2011						Total 2010
	from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2010	Forestland	3,440,585	0	0	0	8	42	3,440,635
	Cropland	0	3,566,283	104,647	NO	NO	NO	3,670,930
	Grassland	3,929	17	4,975,386	0	82	5	4,979,419
	Wetlands	NO	NO	NO	301,093	NO	NO	301,093
	Settlements	NO	NO	NO	NO	534,593	NO	534,593
	Other land	NO	NO	NO	NO	0	271,511	271,511
Total 2011		3,444,514	3,566,300	5,080,033	301,093	534,683	271,558	13,198,180

		2004						Total 1985
from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land		
1985	Forestland	3,355,709	14	1,071	62	748	1,583	3,359,186
	Cropland	29,627	3,803,628	110,945	NO	NO	NO	3,944,200
	Grassland	32,028	53	4,761,296	1,394	1,832	2,991	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	76	265,204	265,280
Total 2004		3,417,364	3,803,695	4,873,312	301,056	532,976	269,777	13,198,180

		2005						Total 1986
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1986	Forestland	3,355,605	14	1,071	62	810	1,624	3,359,186
	Cropland	31,952	3,775,380	136,868	NO	NO	NO	3,944,200
	Grassland	33,685	53	4,759,156	1,403	2,230	3,068	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	76	265,204	265,280
Total 2005		3,421,243	3,775,447	4,897,094	301,064	533,436	269,896	13,198,180

		2006						Total 1987
from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land		
1987	Forestland	3,355,451	14	1,072	75	868	1,705	3,359,186
	Cropland	33,248	3,760,078	150,874	NO	NO	NO	3,944,200
	Grassland	36,422	55	4,755,828	1,410	2,494	3,386	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	76	265,204	265,280
Total 2006		3,425,121	3,760,147	4,907,774	301,085	533,758	270,295	13,198,180

		2007						Total 1988
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1988	Forestland	3,354,967	14	1,074	79	950	2,103	3,359,186
	Cropland	33,248	3,702,382	208,570	NO	NO	NO	3,944,200
	Grassland	40,785	62	4,751,088	1,414	2,656	3,589	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	79	265,201	265,280
Total 2007		3,429,000	3,702,458	4,960,732	301,093	534,005	270,893	13,198,180

		2008						Total 1989
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1989	Forestland	3,354,809	14	1,077	79	1,025	2,183	3,359,186
	Cropland	33,248	3,693,733	217,219	NO	NO	NO	3,944,200
	Grassland	44,822	62	4,746,609	1,414	2,780	3,907	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	81	265,199	265,280
Total 2008		3,432,878	3,693,810	4,964,904	301,093	534,205	271,289	13,198,180

		2009						Total 1990
from/to	Forestland	Cropland	Grassland	Wetlands	Settlements	Other land		
1990	Forestland	3,354,729	14	1,116	79	1,038	2,210	3,359,186
	Cropland	33,248	3,685,271	225,681	NO	NO	NO	3,944,200
	Grassland	48,780	65	4,742,438	1,414	2,902	3,995	4,799,594
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,320	NO	530,320
	Other land	NO	NO	NO	NO	81	265,199	265,280
Total 2009		3,436,757	3,685,350	4,969,236	301,093	534,341	271,404	13,198,180

		2010						Total 1991
from/to		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1991	Forestland	3,358,686	15	1,120	79	1,034	2,131	3,363,065
	Cropland	33,248	3,670,840	240,112	NO	NO	NO	3,944,200
	Grassland	48,701	76	4,738,186	1,414	2,703	3,842	4,794,923
	Wetlands	NO	NO	NO	299,600	NO	NO	299,600
	Settlements	NO	NO	NO	NO	530,775	NO	530,775
	Other land	NO	NO	NO	NO	81	265,537	265,538
Total 1991		3,440,635	3,670,930	4,979,419	301,093	534,593	271,511	13,618,180

	from/to	2012						Total 2011
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2011	Forestland	3,443,938	0	2	6	115	453	3,444,514
	Cropland	0	3,559,999	6,301	NO	NO	NO	3,566,300
	Grassland	4,455	1	5,075,233	1	295	49	5,080,033
	Wetlands	NO	NO	NO	301,093	NO	NO	301,093
	Settlements	NO	NO	NO	NO	534,683	NO	534,683
2012	Other land	NO	NO	NO	NO	0	271,558	271,558
	Total 2012	3,448,393	3,560,000	5,081,536	301,099	535,093	272,060	13,198,180
2013	Forestland	3,448,356	0	0	0	20	17	3,448,393
	Cropland	0	3,519,260	40,740	NO	NO	NO	3,560,000
	Grassland	3,915	17	5,077,533	0	59	11	5,081,536
	Wetlands	NO	NO	NO	301,099	NO	NO	301,099
	Settlements	NO	NO	NO	NO	535,093	NO	535,093
2014	Other land	NO	NO	NO	NO	0	272,060	272,060
	Total 2013	3,452,271	3,519,277	5,118,273	301,099	535,172	272,087	13,198,180
2015	Forestland	3,452,240	0	0	0	3	28	3,452,271
	Cropland	0	3,467,421	51,856	NO	NO	NO	3,519,277
	Grassland	3,910	28	5,114,282	0	15	38	5,118,273
	Wetlands	NO	NO	NO	301,099	NO	NO	301,099
	Settlements	NO	NO	NO	NO	535,172	NO	535,172
2016	Other land	NO	NO	NO	NO	0	272,087	272,087
	Total 2014	3,456,150	3,467,449	5,166,139	301,099	535,190	272,153	13,198,180
2017	Forestland	3,370,758	12	353	83	1,131	2,364	3,374,700
	Cropland	33,248	3,519,175	367,077	NO	NO	NO	3,919,500
	Grassland	48,265	91	4,750,843	1,383	2,859	3,408	4,806,849
	Wetlands	NO	NO	NO	299,634	NO	NO	299,634
	Settlements	NO	NO	NO	NO	531,104	NO	531,104
2018	Other land	NO	NO	NO	NO	77	266,316	266,393
	Total 2013	3,452,271	3,519,277	5,118,273	301,099	535,172	272,087	13,198,180
2019	Forestland	3,374,689	11	349	82	1,115	2,333	3,378,579
	Cropland	30,848	3,467,321	414,431	NO	NO	NO	3,912,600
	Grassland	50,613	117	4,751,359	1,382	2,791	3,285	4,809,545
	Wetlands	NO	NO	NO	299,636	NO	NO	299,636
	Settlements	NO	NO	NO	NO	531,209	NO	531,209
2020	Other land	NO	NO	NO	NO	76	266,535	266,611
	Total 2014	3,456,150	3,467,449	5,166,139	301,099	535,190	272,153	13,198,180

6.3 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The various forms of land uses in 2014 are presented in **Figure 6.2**.

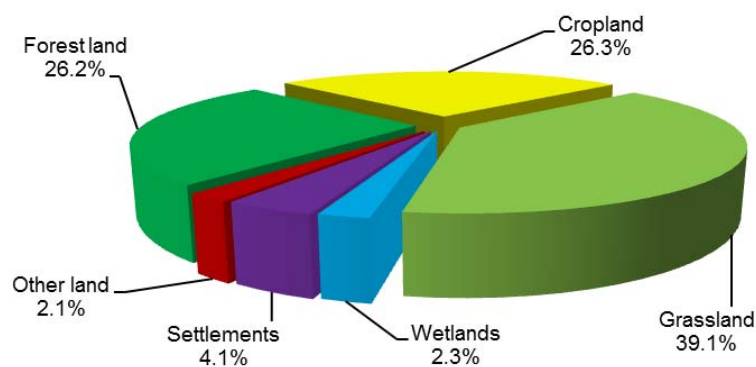


Figure 6.2 Distribution of the area of Greece in 2014 by land-use category

The information used for the representation of land areas was the following:

- the first National Forest Inventory (1st NFI) prepared by the General Secretariat of Forests and Natural Environment (GSFNE, 1992, 1994),
- the afforestation registry and statistics of the Ministry of Environment and Energy,

- the "Agricultural Statistics of Greece" of the Hellenic Statistical Authority (EL.STAT., annual census),
 - the "Distribution of the Country's Area by Basic Categories of Land Use" of the Hellenic Statistical Authority (EL.STAT., decennial survey),
 - the "Land Use Change Database" of the Ministry of Environment and Energy, which comprises annual acts of land use change since 1990,
- the "Forest Management Plans Database", of the Ministry of Environment and Energy.

In the following **Table 6.6** all the above mentioned data sources are classified, while their content and the land use category for which these data have been used are presented.

Table 6.6 *The classification of the data sources and how they are used for the representation of land areas*

Data source	Content	Land use category
The first National Forest Inventory (1st NFI) prepared by the General Secretariat of Forests and Natural Environment	Forest land area, Grassland area	Forest land, Grassland
The afforestation registry and statistics of the Ministry of Environment and Energy	Afforested/reforested area	Land converted to Forest land
The "Agricultural Statistics of Greece" of the Hellenic Statistical Authority	Cropland area, Cropland converted to Grassland area	Cropland, Cropland converted to Grassland
The "Distribution of the Country's Area by Basic Categories of Land Use" of the Hellenic Statistical Authority	Area per land use category	Forest land, Cropland, Grassland, Wetlands, Settlements, Other land
The "Forest Management Plans Database", of the Ministry of Environment and Energy	Managed forest land area	Forest land remaining forest land
The "Land Use Change Database" of the Ministry of Environment and Energy, which comprise acts of land use change since 1990	Area of land use categories converted to other land uses	Forest land/Grassland converted to other land uses, Other land converted to Settlements

More information on the use of these datasets and the land-use definitions used in the classification of areas is given under the corresponding category in the following chapters.

As mentioned already, in the current submission Greece performed a complete reconstruction of the land use, and land-use change matrices for the whole period 1990-2014, following also ERT's recommendation.

For that purpose, all the available data from the data sources listed previously have been used.

It should be noted that the total country area amounts to 13.198,18 kha in the current inventory, increased by 2.44 kha in comparison to previous inventories (13.195,74 ha).

For the development of the land use, land-use change matrices the results of the two "Distribution of the Country's Area by Basic Categories of Land Use" projects of the Hellenic Statistical Authority have been used. Both of the projects constitute complete, in terms of land use coverage, cadastre surveys providing the necessary information on the distribution of land areas per each land use category. The 1st survey provides for the country land use area distribution for the year 1990, while the second one provides data for the year 2000.

In this context, the total country area has been chosen as the one estimated in the latter survey. For the purposes of the land use, land-use change matrices development, the area difference of the total country area between the two surveys has been classified under Grassland category in 1990. The forest land area between the two years where the survey conducted was estimated using linear interpolation, while for the period after 2000 using linear extrapolation. For the cropland area, annual estimates provided by the Hellenic Statistical Authority have been used.

6.4 Forest land (CRF Source Category 4A)

6.4.1 Category description

Carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter and soil organic matter) and emissions of non-CO₂ gases from Forest Land remaining Forest Land and Land converted to Forest Land have been assessed and reported under this category.

Carbon stocks increased during the period 1990 – 2014 due to biomass increment in Forest Land remaining Forest Land and in Land converted to Forest Land (afforestation of croplands). Non-CO₂ greenhouse gases released to the atmosphere during biomass burning. Estimates of emissions / removals in this category are presented in *Table 6.7*.

The sink capacity of Forest Land has increased from approximately 1.09 Mt CO₂ eq in 1990 to approximately 2.27 Mt CO₂ eq in 2014. This rising trend is attributed mainly to the reduction in fellings and the afforestation programmes started in 1994.

Table 6.7 *Net GHG emissions / removals (in kt) from Forest Land by subcategory and gas for the period 1990 – 2014*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest land remaining forest land											
CO ₂	-1139.19	-1272.89	-1560.71	-1616.19	-1340.96	-1557.59	-1597.33	-1249.49	-1207.80	-1490.03	-1068.82
CH ₄	1.86	0.71	2.05	2.14	1.87	1.22	0.51	1.48	4.63	0.29	5.71
N ₂ O	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.04
Land converted to forest land											
CO ₂	NE,NO	NE,NO	NE,NO	NE,NO	-9.83	-25.34	-32.53	-53.67	-60.72	-91.65	-64.69
CH ₄	NO	NO	NO	NO	0.00	0.00	0.00	0.01	0.02	0.00	0.04
N ₂ O	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO₂ eq)	-1089	-1254	-1505	-1558	-1300	-1550	-1616	-1263	-1143	-1574	-978

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Forest land remaining forest land														
CO ₂	-1719.97	-1765.46	-1777.42	-1767.62	-2104.21	-2092.26	-1550.93	-2045.36	-2037.13	-2094.40	2118.55	-2069.76	-2131.53	2142.98
CH ₄	0.60	0.06	0.09	0.23	0.19	0.57	7.51	1.17	1.28	0.54	0.23	0.86	0.07	0.04
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Land converted to forest land														
CO ₂	-79.51	-116.49	-103.80	-104.69	-129.19	-131.10	-2.89	-100.50	-123.42	-138.37	-126.41	-114.01	-136.23	-123.87
CH ₄	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.01	0.01	0.01	0.00	0.01	0.00	0.00
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO₂ eq)	-1783	-1880	-1879	-1866	-2228	-2208	-1349	-2114	-2126	-2218	-2239	-2160	-2266	-2266

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

6.4.2 Methodology

The definition of forest land used in this 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.

Carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass and soil organic carbon are estimated and reported only for managed forests. Hence, this inventory estimates carbon stock changes and emissions of non-CO₂ gases from forests that have been managed with a forest management plan. The area of the managed forests is 1.236.887 ha, which corresponds to approximately 35.8% of the total forest land. The same definition of forest land is used in the Kyoto Protocol inventory, in order to maintain coherence and congruence between the two inventories.

6.4.2.1 Forest land remaining forest land

The section "Forest land remaining Forest land (FF)" describes the estimation of changes in carbon stock in the five carbon pools, as well as emissions of non-CO₂ gases from these pools, in forest lands which have been forest lands for at least the past 20 years. The results of estimations are reported in the appropriate subdivision of the land use category (i.e. managed forest land). The summary equation, which estimates the annual emissions or removals from FF with respect to changes in carbon pools, is given in the following equation:

$$\Delta C_{FF} = (\Delta C_{FFLB} + \Delta C_{FFDOM} + \Delta C_{FFSoils})$$

where, ΔC_{FF} is the annual change in carbon stocks from forest land remaining forest land, t C yr⁻¹, ΔC_{FFLB} is the annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, t C yr⁻¹, ΔC_{FFDOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land, t C yr⁻¹ and $\Delta C_{FFSoils}$ is the annual change in carbon stocks in soils in forest land remaining forest land, t C yr⁻¹.

Change in carbon stocks in living biomass

The methodology applied is consistent with the carbon stock change method described in the 2006 GL AFOLU (equation 2.8). According to this method, estimations of carbon stock changes are based on the difference in biomass stocks in a forest area at two points in time. The annual change

in the carbon stocks in a forest area is the difference between the carbon stocks at time t_2 and time t_1 , divided by the number of years between the inventories:

$$\Delta C_{FFLB} = (C_{t_2} - C_{t_1}) / (t_2 - t_1)$$

where, ΔC_{FFLB} is the annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, $t \text{ C yr}^{-1}$, C_{t_2} is the total carbon in biomass calculated at time t_2 , $t \text{ C}$, C_{t_1} is the total carbon in biomass calculated at time t_1 , $t \text{ C}$.

The total carbon in biomass is calculated according to the equation:

$$C_{t_i} = [V_{t_i} \cdot D \cdot BEF] \cdot (1+R) \cdot CF$$

Where, C_{t_i} is the total carbon in biomass calculated at time t_i ($t \text{ C}$), V_{t_i} is the merchantable volume at time t_i ($\text{m}^3 \text{ ha}^{-1}$), D is the basic wood density of merchantable volume ($t \text{ dry matter m}^{-3}$), BEF is the biomass expansion factor for conversion of merchantable volume to aboveground tree volume (dimensionless), R is the root-shoot ratio (dimensionless), and, CF is the carbon fraction of dry matter ($t \text{ C (t d.m.)}^{-1}$).

CO_2 emissions and removals from managed forests are calculated according to the equation above, comparing the carbon stocks in forest biomass that is estimated by the successive forest management plans (FMP). Annual change in carbon stocks in every studied forest during the period of two inventories is estimated by linear interpolation, while for the period before the first and after the last inventory is estimated by linear extrapolation. For these estimations 1,276 forest management plans (FMP) have been considered.

The merchantable volume, V , and the area covered by each forest are obtained from the FMPs. Appropriate IPCC default factors for root-shoot ratio R were selected for each forest species. For the conversion of dry matter to carbon the IPCC default factor ($CF = 0.47$) was used throughout the inventory.

For the conversion of merchantable volume to aboveground tree biomass it is suggested by the 2006 GL AFOLU the use of Biomass Expansion Factors. Since, national expansion factors have not been developed in Greece, factors developed for Mediterranean species under similar climatic and ecological conditions, in the frame of the Ecological and Forest Inventory of Catalonia, were used instead. In this inventory, biomass expansion factors BEF (for the conversion of merchantable volume to aboveground tree volume) and the wood density D (for the conversion of tree volume to tree biomass) are combined in one factor $BEFD$ that directly converts the merchantable volume to aboveground tree biomass.

Table 6.8 *Biomass expansion factors BEFD used for biomass estimation*

Conifers	BEFD
Abies sp.	0.61
Pinus halepensis	0.74

Pinus pinea	0.73
Pinus brutia	0.73
Pinus nigra – Other conifers	0.64
Pinus sylvestris	0.62
Picea abies	0.44
Cupressus sp.	0.55
Broadleaves	BEFD
Fagus sp.	0.81
Deciduous oaks– Other broadleaves	0.89
Quercus ilex – Evergreen oaks	1.28
Castanea sativa	0.75
Betula pendula	0.73
Alnus sp. – Populus sp.	0.62
Ulmus sp. – Platanus sp.	0.90
Fraxinus sp.	0.83

Source: Centro de Investigacion Ecologica y Aplicaciones Forestales (CREAF)

Following previous ERT's recommendation, Greece decided to proceed with a verification of the estimates of carbon stock changes in living biomass resulted from the use of the carbon stock change method as described previously. The Carbon Budget Model⁴ (CBM) was used for that purpose and the whole work has been carried out in the framework of the technical assistance on Land Use, Land Use Change and Forestry reporting and accounting provided by the Joint Research Centre, European Commission, in the context of task 2b of the Administrative Arrangement No 071201/2011/611111/CLIMA.A2 (Analysis of and proposals for enhancing, monitoring, reporting and verification of land use, land use change and forestry in the EU-LULUCF MRV).

The CBM model is an inventory-based, yield-data driven model that simulates the stand-and landscape-level C dynamics of above- and belowground biomass, and dead organic matter (DOM) including soil (Kurz et al., 2009). It is compliant with the carbon estimation methods outlined in the guidelines of the Intergovernmental Panel on Climate Change. The model uses much of the same information that is required for forest management planning activities (e.g., forest inventory, growth and yield curves, natural and human-induced disturbance information, forest management schedule, and land-use change information), supplemented with information from national ecological parameter databases (Operational-Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)/User's Guide).

In order the model to run, the necessary input data provided by Greece were used, which comprised the forest area under management, volume and increment data, a reference year, forest fire area

⁴ <http://www.nrcan.gc.ca/forests/climate-change/13107>

data, and harvest amount data. In particular, the volume and increment data were derived from the same forest management plans used in the carbon stock change method.

The results of this analysis are presented in *Figure 6.3* below.

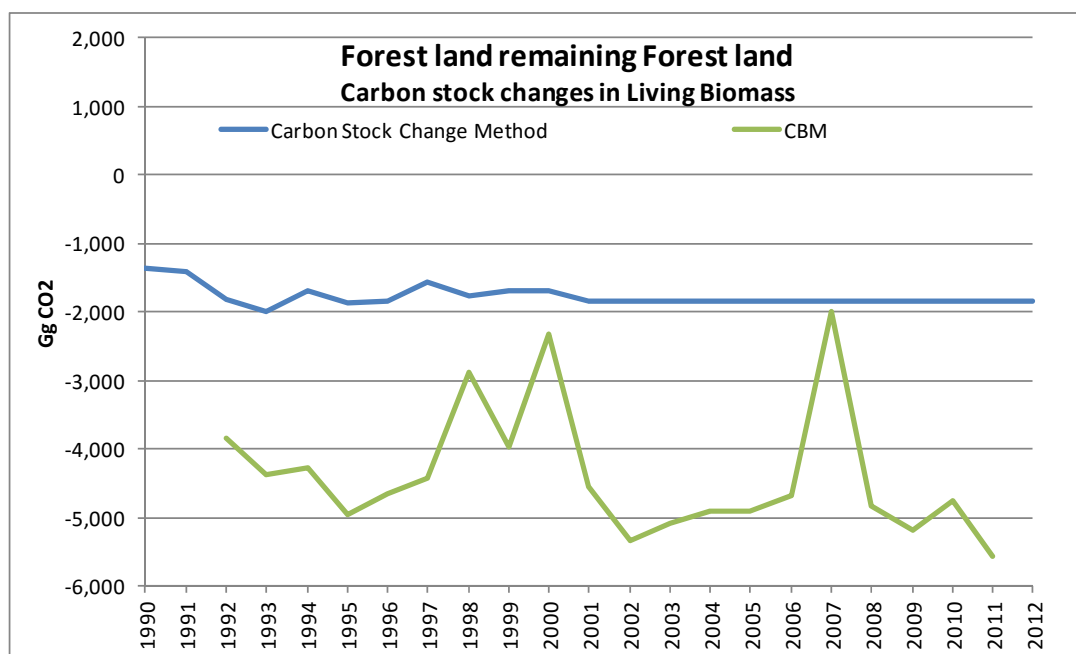


Figure 6.3 *Comparison of the carbon stock changes in Living biomass in Forest land remaining Forest land, with the application of Carbon Stock Change Method and the CBM⁵*

As depicted in the figure above, the trend of the carbon stock changes in living biomass is almost the same between the two methods, during the period 1990 - 2012. Nevertheless, there is a difference in the sink magnitude with the carbon stock change method appearing to be the most conservative one. In addition, some remarkable peaks in the CBM results as illustrated in the graph need a closer attention. These values refer to the years 1998, 2000, 2007 and are mainly attributed to the effects of forest fires. Those three years considered to be exceptional ones in the history of modern Greece, in terms of forest area burnt. On the other hand, the implication of the use of the carbon stock change method, is the "smoothing" of the net emissions/removals of CO₂ in Forest land remaining Forest land category, since these emissions are not depicted in the year an event (i.e. forest fire) occur, but they are distributed over the period as determined by the two points in time the carbon stocks are measured.

⁵ The analysis was made during the Inventory submission for 2014.

Change in carbon stocks in dead organic matter

Changes in carbon stocks in two types of dead organic matter pools have to be considered: a) dead wood and b) litter. The IPCC Guidelines do not require estimation or reporting on dead wood or litter, on the assumption that the time average value of these pools will remain constant, with inputs to dead matter pools balanced by outputs. This Tier1 approach was followed for dead organic matter carbon stocks in all forest land, and is considered as true-to-life since these lands do not experience significant changes in forest types or management regimes. Prescribed fires and post logging burning of harvest residues are not practiced in Greece. More detailed evidence transparently substantiating the assertion above is provided in par. 9.3.1.2.

Change in carbon stocks in soils

Two types of forest soil organic pools are considered under this category: a) the organic fraction of mineral forest soils, and b) organic soils. CO₂ emissions / removals from soils are associated with changes in the amount of organic carbon stored in soils. These changes are a function of the balance between inputs to soil of photosynthetically fixed carbon and losses of soil carbon via decomposition. In general, changes in forest type, management intensity and disturbance regime alter the carbon dynamics of forest soils. Under Tier 1, it is assumed that when forest remains forest the carbon stock in soil organic matter of mineral soils does not change, regardless of changes in forest management, forest types, and disturbance regimes, i.e. the carbon stock in mineral soil remains constant so long as the land remains forest. In Greece, forest type and management activities, such as silvicultural system, rotation length, harvest practices, site preparation activities do not change significantly over time, and therefore Tier 1 assumption can be used without introducing significant error in the calculations. More detailed evidence transparently substantiating the assertion above is provided in par. 9.3.1.2.

Changes in carbon stocks of organic soils are associated with drainage and management perturbations of these soils. In Greece, areas of organic soils covered by forest are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered.

Wildfires - Non CO₂ greenhouse gas emissions

The carbon stock change method used to estimate emissions and removals from managed forests – and forests under art. 3.4 activity Forest Management – encompasses the loss of carbon in areas affected by wildfires. For this reason no extra emissions of CO₂ from biomass as a result of wildfires are reported. The implication of the use of this method on the inventory is the normalisation of the net emissions/ removals of CO₂ from the LULUCF sector, since these emissions are not reported at the year of disturbance – that resulted the high annual fluctuation of

emissions – rather than they are distributed over the period between the successive management plans.

However, the biomass burnt annually in managed forests had to be estimated, in order to estimate and report the non-CO₂ GHG emissions. According to IPCC Guidelines, CH₄ and CO emissions from wildfires were estimated as ratios to carbon released during burning ($L_{\text{disturbance}}$), and N₂O and NO_x emissions as ratios to total nitrogen released. Nitrogen content was calculated based on the nitrogen-carbon ratio (N/C was taken as 0.01).

$$\text{CH}_4 \text{ emissions} = L_{\text{disturbance}} \cdot 0.012 \cdot 16/12$$

$$\text{CO emissions} = L_{\text{disturbance}} \cdot 0.06 \cdot 28/12$$

$$\text{N}_2\text{O emissions} = L_{\text{disturbance}} \cdot (\text{N/C ratio}) \cdot 0.007 \cdot 44/28$$

$$\text{NO}_x \text{ emissions} = L_{\text{disturbance}} \cdot (\text{N/C ratio}) \cdot 0.121 \cdot 46/14$$

The IPCC default values for trace gas emission ratios were used, whereas the factors 16/12, 28/12, 44/28 and 46/14 were used to convert emissions to full molecular weights.

The annual carbon loss in living biomass from wildfires was estimated according to equation 2.14:

$$L_{\text{disturbance}} = \sum_i A_{\text{disturbance}_i} \cdot Bw_i \cdot (1 - fBL_i) \cdot CF \cdot (1+R) \cdot fd$$

where, $L_{\text{disturbance}}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere (t C yr⁻¹), $A_{\text{disturbance}_i}$ is the forest areas affected by wildfires, by forest type ($i = 21$) (ha yr⁻¹), Bw_i is the average biomass stock of forest areas, by forest type (t d.m. ha⁻¹), fBL_i is the fraction of biomass transferred to dead organic matter, by forest type and CF is the carbon fraction of dry matter (t C (t d.m.)⁻¹), R is the ratio of below-ground biomass to above-ground biomass (t d.m. bg biomass (t d.m. ag biomass)⁻¹), fd is the fraction of biomass lost in disturbance.

It was assumed a complete destruction of forest biomass in area affected, i.e. there was not any biomass left alive in the area. Data on area affected by wildfires were obtained from the statistics of the Ministry of Environment and Energy, and the Fire Service disaggregated by two general categories; forests and grasslands. A flammability indicator for 21 forest types was developed, based on national statistics of areas burnt stratified by forest type during the period 1990 – 1996, in order to draw disaggregated activity data. Since data on burnt area of managed forests are not available, a weighted average is used, based on the total area burnt in each prefecture and the percentage of forests managed in this area. The fraction of biomass transferred to dead organic matter varies with the vegetation type (diameter of fuel). Two general values were selected from Table 2.6 of 2006 GL AFOLU; $fBL = 0.55$ for forests and $fBL = 0.28$ for scrublands.

The average biomass stock of each forest type was calculated from the average volume of growing stock given in the 1st NFI and the average biomass stock in the understorey vegetation, with the following equation:

$$B_w = V \cdot BCEFs$$

$$B_{w_{\text{understorey}}}$$

where, V is the average volume of growing stock, overbark ($\text{m}^3 \text{ ha}^{-1}$), $BCEFs$ is the biomass conversion and expansion factor for converting volumes of growing stock to total aboveground biomass, $B_{w_{\text{understorey}}}$ is the average biomass stock of understorey vegetation (t d.m. ha^{-1}).

The average biomass stock of understorey vegetation was acquired from a study reviewing relevant articles and the data of the 1st NFI (Kokkinidis, 1989). Appropriate IPCC default factors for biomass conversion and expansion factors, and the ratio of below-ground biomass to above-ground biomass were selected from Table 4.5, and Table 4.4 of the 2006 GL AFOLU, respectively. Finally, due to the methodology applied for estimating greenhouse gas emission from biomass burning in Cropland converted to Forest land, the respective proportion of emissions was subtracted from that reported under Forest land remaining Forest land category.

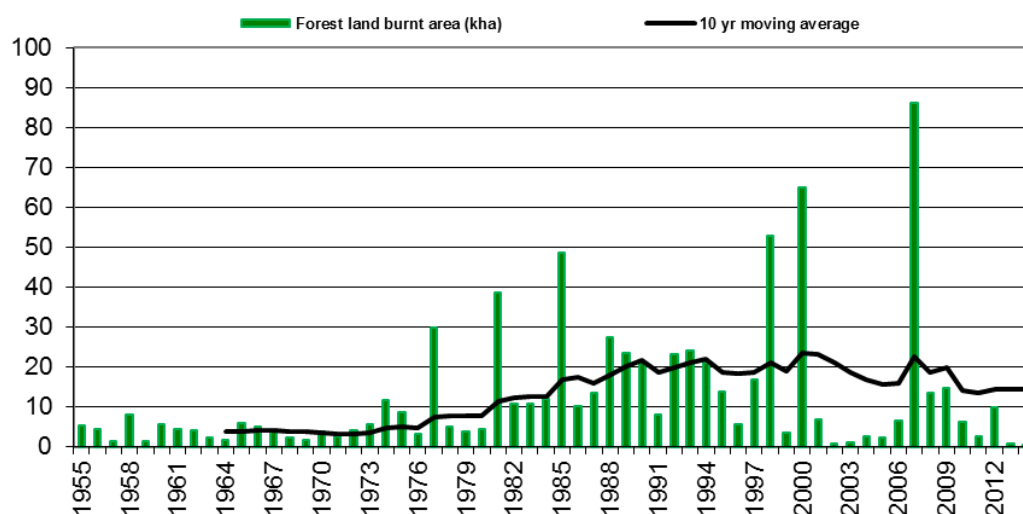


Figure 6.4 Areas of Forest Land burnt since 1955

As it has already been mentioned one of the improvements performed in the current inventory is the estimation and reporting for the first time of CO_2 and non- CO_2 greenhouse gas emissions resulted from dead organic matter pool (dead wood and litter) subject to wildfires. For those estimations, the same methodology described above has been followed, along with litter and dead wood stock values prior to wildfire presented in *Table 6.12*, and *Table 6.13*. In the case of dead organic matter subject to wildfires it was assumed a complete oxidation (the factor (fBLi) was taken equal to "0")

N₂O and NO_x are also produced in soils as a by-product of nitrification and denitrification. Emissions are stimulated by N fertilisation of forests and drainage of wet forest soils. Such emissions have not been considered since these activities do not occur in forest lands of the country.

6.4.2.2 Land converted to Forest Land

This section describes the estimates of carbon stock changes and greenhouse gas emissions and removals from lands converted to forest land during the last 20 years. Managed land is converted to forest land by afforestation, either by natural or artificial regeneration. In this inventory changes in carbon stocks in croplands converted to forest land since 1994, under the EEC Regulations 2080/92 and 1257/99, have been estimated. Grassland areas converted to forestland constitute a natural forest expansion and therefore there are no associated emissions by sources and removals by sinks, since that kind of conversion is not direct human induced, but rather occur under natural drivers. Following ERT's recommendation, Greece reports in the current submission on the area of grassland converted to forest land for the first time, according to the methodology described in section 6.3. The estimation of carbon change was based on the summary equation.

$$\Delta C_{LF} = (\Delta C_{LFLB} + \Delta C_{LFDOM} + \Delta C_{LFSoils})$$

where, ΔC_{LF} is the annual change in carbon stocks in land converted to forest land, t C yr⁻¹, ΔC_{LFLB} is the annual change in carbon stocks in living biomass (includes above and belowground biomass) in land converted to forest land, t C yr⁻¹, ΔC_{LFDOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter) in land converted to forest land, t C yr⁻¹ and $\Delta C_{LFSoils}$ is the annual change in carbon stocks in soils in land converted to forest land, t C yr⁻¹.

Change in carbon stocks in living biomass

As already mentioned, in that section only changes in carbon stocks in croplands converted to forest land have been estimated and reported. These lands have been converted to forest land by planting in the context of the EEC Regulations. The carbon stock change in living biomass has been calculated taking into account the increase and the decrease of carbon stocks related to the areas converted to forest land, following the equation below:

$$\Delta C_{LFLB} = (\Delta C_{LFGROWTH} - \Delta C_{LFLOSS})$$

where, ΔC_{LFLB} is the annual change in carbon stocks in living biomass, t C yr⁻¹, $\Delta C_{LFGROWTH}$ is the annual increase in carbon stocks in living biomass due to biomass growth in land converted to forest land, t C yr⁻¹, and ΔC_{LFLOSS} is the annual decrease in carbon stocks due to biomass loss in land converted to forest land, t C yr⁻¹.

In the absence of country specific data with regard to annual losses in carbon stocks in living biomass in those areas and based on the work done in the context of the EU "Project on Assistance to MS with KP Reporting", it was decided emission factors from a neighbouring country to be used instead. In particular, an average value each year for the period 1990 - 2014 from the most updated implied emission factors (IEFs) of four Italian regions, namely Abruzzo, Molise, Basilicata and Puglia, was applied. Those specific four regions were selected based on the most similar climatic and ecological conditions to Greece.

For the estimation of the annual increase in carbon stocks in living biomass, an average IEF was used for the above-ground and below-ground biomass separately, each year. Similarly, decreases in carbon stocks in living biomass were estimated applying an average IEF from the four Italian regions and the above-ground and below-ground biomass were treated separately each year, according to the equation below:

$$\Delta C_{\text{LFGROWTH/LOSS}} = (\text{IEF}_{\text{AGavg}} + \text{IEF}_{\text{BGavg}}) \cdot A$$

where, $\Delta C_{\text{LFGROWTH/LOSS}}$ is the annual increase/decrease in carbon stocks in living biomass, t C yr^{-1} , $\text{IEF}_{\text{AGavg}}$ is the average IEF each year for increase/decrease in above-ground biomass from the four Italian regions, t C ha^{-1} , $\text{IEF}_{\text{BGavg}}$ is the average IEF each year for increase/decrease in below-ground biomass from the four Italian regions, t C ha^{-1} , and A is the area converted to forest land, ha. Data on area afforested were obtained from the statistics of the Ministry of Environment and Energy. In **Table 6.9** the IEFs used for the estimation of carbon stock changes in living biomass in land converted to forest land are presented.

Table 6.9 *Average IEFs from four Italian regions (Abruzzo, Molise, Basilicata, Puglia) that were used for the estimation of carbon stock changes in living biomass in land converted to forest land*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
IEF for increase in living biomass (Gg kha^{-1})											
Above-ground	1.98	1.98	1.98	1.98	1.98	1.98	1.99	1.99	1.99	1.99	1.99
Below-ground	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38
IEF for decrease in living biomass (Gg kha^{-1})											
Above-ground	1.05	0.97	1.02	1.22	1.02	0.93	1.11	1.13	1.11	0.96	1.30
Below-ground	0.21	0.19	0.20	0.24	0.20	0.18	0.22	0.22	0.22	0.18	0.26

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
IEF for increase in living biomass (Gg kha^{-1})														
Above-ground	1.99	1.99	1.99	1.99	2.00	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Below-ground	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
IEF for decrease in living biomass (Gg kha^{-1})														
Above-ground	1.22	0.97	1.13	1.18	1.07	1.08	1.93	1.29	1.13	1.03	1.12	1.20	1.05	1.06
Below-ground	0.24	0.19	0.22	0.23	0.21	0.21	0.37	0.25	0.22	0.20	0.22	0.23	0.20	0.21

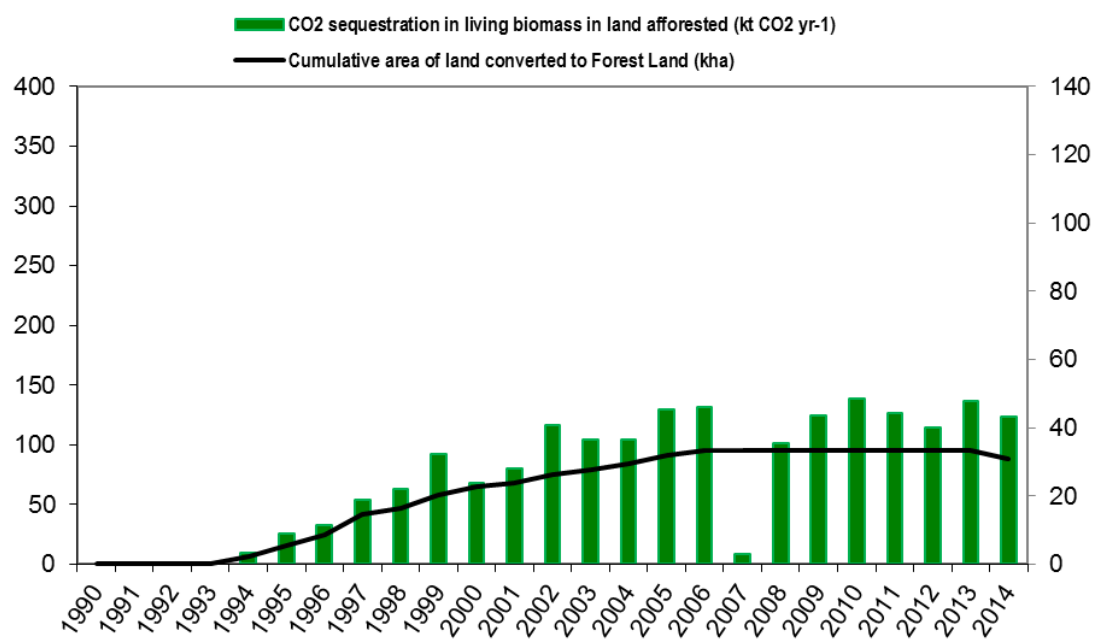


Figure 6.5 Carbon sequestration in living biomass and area of land converted to Forest land during 1990 - 2014

Change in carbon stocks in dead organic matter

For the dead wood and litter pools the tier 1 approach was followed according to which the assumption made is that these pools increase linearly from zero since the previous land use category is a non-forest category, and thus not any change in carbon stocks in dead organic matter has been reported.

Change in carbon stocks in soils

Soil carbon is generally found to accumulate following afforestation on agricultural areas (Guo, 2002). The changes in soil carbon stocks in these lands were estimated according to Tier 1 as:

$$\Delta C_{LF\text{Soils}} = \Delta C_{LF\text{Mineral}} = \left[\sum_i (\text{SOC}_{\text{Ref}} - \text{SOC}_{\text{Cropland}_i}) \cdot A_{\text{aff}_i} \right] / T_{\text{aff}}$$

$$\text{SOC}_{\text{Cropland}} = \text{SOC}_{\text{Ref}} \cdot F_{\text{LU}} \cdot F_{\text{MG}} \cdot F_{\text{I}}$$

where, $\Delta C_{LF\text{Mineral}}$ is the annual change in carbon stocks in mineral soils for inventory year, t C yr^{-1} , SOC_{Ref} is the carbon stock, under native, unmanaged forest on a given soil, t C ha^{-1} , $\text{SOC}_{\text{Cropland}_i}$ is the soil organic carbon stock on previous cropland use, by crop type, t C yr^{-1} , F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime, F_{I} is the stock change factor for input of organic matter, A_{aff_i} is the area of the cropland afforested, by crop type, ha and T_{aff} is the duration of the transition from $\text{SOC}_{\text{Cropland}}$ to SOC_{Ref} , yr. However, carbon stock changes in mineral soils have not been reported on the basis of data and documentation demonstrating that this pool is not a source. More details are given in section 9.3.1.2.

Wildfires - Non CO₂ greenhouse gas emissions

In this section the method used to estimate GHG emissions from biomass burnt annually in land converted to forest land is presented. The method applied to estimate carbon stock changes in living biomass in land converted to forest land encompasses the loss of carbon due to wildfires. For that reason no extra emissions of CO₂ from wildfires are reported.

For the estimation of non-CO₂ GHG emissions the same method as for Forest land remaining Forest land category was followed.

According to IPCC Guidelines, CH₄ and CO emissions from wildfires were estimated as ratios to carbon released during burning ($L_{\text{disturbance}}$), and N₂O and NO_x emissions as ratios to total nitrogen released. Nitrogen content was calculated based on the nitrogen-carbon ratio (N/C was taken as 0.01, IPCC Guidelines).

$$\text{CH}_4 \text{ emissions} = L_{\text{disturbance}} \cdot 0.012 \cdot 16/12$$

$$\text{CO emissions} = L_{\text{disturbance}} \cdot 0.06 \cdot 28/12$$

$$\text{N}_2\text{O emissions} = L_{\text{disturbance}} \cdot (\text{N/C ratio}) \cdot 0.007 \cdot 44/28$$

$$\text{NO}_x \text{ emissions} = L_{\text{disturbance}} \cdot (\text{N/C ratio}) \cdot 0.121 \cdot 46/14$$

The IPCC default values for trace gas emission ratios were used, whereas the factors 16/12, 28/12, 44/28 and 46/14 were used to convert emissions to full molecular weights.

The annual carbon loss in living biomass from wildfires was estimated as:

$$L_{\text{disturbance}} = \sum_i A_{\text{disturbance}_i} \cdot Bw_i \cdot (1 - fBL_i) \cdot CF \cdot (1+R) \cdot fd$$

where, $L_{\text{disturbance}}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere (t C yr⁻¹), $A_{\text{disturbance}_i}$ is the forest areas affected by wildfires, by forest type ($i = 21$) (ha yr⁻¹), Bw_i is the average biomass stock of forest areas, by forest type (t d.m. ha⁻¹), fBL_i is the fraction of biomass transferred to dead organic matter, by forest type and CF is the carbon fraction of dry matter (t C (t d.m.)⁻¹), R is the ratio of below-ground biomass to above-ground biomass (t d.m. bg biomass (t d.m. ag biomass)⁻¹), fd is the fraction of biomass lost in disturbance.

It was assumed a complete destruction of forest biomass in area affected, i.e. there was not any biomass left alive in the area. The fraction of biomass transferred to dead organic matter varies with the vegetation type (diameter of fuel). Two general values were selected from Table 2.6 of 2006 GL AFOLU; $fBL = 0.55$ for forests and $fBL = 0.28$ for scrublands.

The average biomass stock of each forest type was calculated from the average volume of growing stock given in the 1st NFI and the average biomass stock in the understorey vegetation, with the following equation:

$$Bw = V \cdot BCEFs$$

$$Bw_{\text{understorey}}$$

where, V is the average volume of growing stock, overbark (m³ ha⁻¹), BCEFs is the biomass conversion and expansion factor for converting volumes of growing stock to total aboveground biomass, $Bw_{\text{understorey}}$ is the average biomass stock of understorey vegetation (t d.m. ha⁻¹).

The average biomass stock of understorey vegetation was acquired from a study reviewing relevant articles and the data of the 1st NFI (Kokkinidis, 1989). Appropriate IPCC default factors for biomass conversion and expansion factors, and the ratio of below-ground biomass to above-ground biomass were selected from Table 4.5, and Table 4.4 of the 2006 GL AFOLU, respectively.

Since data on burnt area of croplands that were afforested were not available, wildfire emissions were apportioned between forest land remaining forest land and cropland converted to forest land each year, based on the area of forest land covered by each activity. Data on total forest area affected by wildfires were obtained from the statistics of the Ministry of Environment and Energy, and the Fire Service.

6.5 Cropland (CRF Source Category 4B)

6.5.1 Category description

Carbon stock changes in Cropland remaining Cropland and in Land converted to Cropland are estimated and reported in this category. Carbon stock changes in living biomass and soil in Cropland remaining Cropland were caused by changes in management practices and crop type. Emissions of CH₄ and N₂O from these lands were estimated as part of *Agriculture*. The net CO₂ emissions / removals from each subcategory are presented in *Table 6.10*.

Table 6.10 *Net CO₂ emissions / removals (kt CO₂) from Cropland by subcategory for the period 1990 – 2014*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cropland remaining Cropland	-908	-951	-852	-1007	-931	-1012	-655	-739	-813	-994	-680
Biomass	-1153	-1196	-1097	-1252	-1176	-1256	-900	-983	-1057	-1238	-925
Dead Organic matter	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Soils	244	244	244	244	244	244	244	244	244	244	244
Land converted to Cropland	0.07	0.20	0.18	0.40	0.15	0.27	0.27	0.13	0.19	0.27	0.19
Biomass	0.06	0.16	0.12	0.30	0.05	0.14	0.12	0.02	0.05	0.10	0.05
Dead Organic matter	NO	0.01	0.02	0.03	0.01	0.03	0.04	NO	0.02	0.05	NO
Soils	0.01	0.02	0.04	0.07	0.08	0.09	0.10	0.11	0.11	0.12	0.12
Cropland	-908	-951	-852	-1007	-931	-1011	-655	-738	-812	-994	-680

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cropland remaining Cropland	-433	-685	-368	-562	-449	-500	327	-551	-431	-256	-449	-447	-311	-317
Biomass	-677	-930	-612	-806	-693	-744	83	-796	-675	-501	-693	-691	-556	-562
Dead Organic matter	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Soils	244	244	244	244	244	244	244	244	244	244	244	244	244	244
Land converted to Cropland	0.24	0.28	0.33	0.38	0.20	0.24	0.35	0.23	0.28	0.56	0.36	0.30	0.36	0.65
Biomass	0.05	0.09	0.13	0.19	0.00	0.04	0.13	0.01	0.05	0.29	0.06	0.02	0.06	0.28
Dead Organic matter	0.04	0.04	0.04	NO	NO	NO	NO	NO	NO	0.01	NO	NO	NO	NO
Soils	0.13	0.14	0.15	0.18	0.18	0.18	0.20	0.20	0.21	0.24	0.27	0.26	0.27	0.34
Cropland	-432	-685	-367	-561	-448	-500	328	-551	-431	-256	-449	-447	-311	-317

According to the Agricultural Statistics of the Hellenic Statistical Authority of Greece, during the last 40 years tree crops have almost doubled in area, mainly against cereal crops. This considerable change in crops cultivated has resulted in the creation of a sink in the increasing biomass stocks where carbon is accumulating. The magnitude of this sink is about 0.3-1.0 Mt CO₂ eq yr⁻¹ during the period 1990 – 2014 (with the exception of the year 2007 in which the category acts as a source). Carbon stock changes in mineral soils are the result of changes in practices or management through time. Hence, since there weren't different set of data demonstrating subsequent changes in management during the period under investigation, carbon stock changes have been estimated to be

zero. Cultivation of organic soils resulted in net emissions of 244 kt CO₂ yr⁻¹ during the same period.

6.5.2 Methodology

Cropland includes all annual and perennial crops as well as temporary fallow land.

6.5.2.1 Cropland remaining cropland

The Paragraph "Cropland Remaining Cropland (CC)" describes the estimation of changes in carbon stock in living biomass and soil pools in croplands which have been croplands for at least the past 20 years. The following summary equation was used:

$$\Delta C_{CC} = \Delta C_{CCLB} + \Delta C_{CCDOM} + \Delta C_{CCSoils}$$

where, ΔC_{CC} is the annual change in carbon stocks in cropland remaining cropland, t C yr⁻¹, ΔC_{CCLB} is the annual change in carbon stocks in living biomass in cropland remaining cropland, t C yr⁻¹, ΔC_{CCDOM} is the annual change in carbon stocks in dead organic matter in cropland remaining cropland, t C yr⁻¹ and $\Delta C_{CCSoils}$ is the annual change in carbon stocks in soils in cropland remaining cropland, t C yr⁻¹.

Change in carbon stocks in living biomass

A Tier 2 methodology was used to estimate carbon stock changes in living biomass, with country-specific values for areas and carbon accumulation and loss rates. For annual crops, increase in biomass stocks in a single year was assumed equal to biomass losses from harvest and mortality in that same year - thus there was no net accumulation of biomass carbon stocks. Perennial woody crops (e.g. tree crops) accumulate biomass for a finite period until they are removed through harvest or reach a steady state where there is no net accumulation of carbon in biomass because growth rates have slowed and incremental gains from growth are offset by losses from natural mortality or pruning. After this period, perennial woody crops are replaced by new ones and carbon stored in biomass is released to the atmosphere through burning (on-site or off-site) or decomposition. These crops constitute therefore a significant carbon pool, but when management practices or crop type do not change, it is assumed that removals from biomass increment are balanced by emissions from harvest, and thus in a long term, they are neither a sink nor a source of carbon.

Changes in carbon stocks in living biomass were only estimated when new plantations of such perennial woody crops, i.e. tree crops and vineyards for the case of Greece, were established or eradicated (changed to a different crop type).

$$\Delta C_{CCLB} = \Delta C_{CCG} - \Delta C_{CCL}$$

where, ΔC_{CCLB} is the annual change in carbon stocks in living biomass in cropland remaining cropland and changes crop type, t C yr⁻¹, ΔC_{CCG} is the annual increase in carbon stocks due to biomass growth in new plantations, t C yr⁻¹ and ΔC_{CCCL} is the annual decrease in carbon stocks due to biomass loss in eradicated crops, t C yr⁻¹.

It was assumed that these plantations accumulate biomass linearly until they reach maturity, assumed to be at half the replacement cycle (**Figure 6.6**). During maturity biomass increases are offset by losses from pruning - in order the tree to be retained to the desired form - and natural mortality, and hence changes in living biomass are assumed to be zero. The annual growth rate (G_w), during the growth period, is derived thus by dividing biomass stock at maturity (B_M) by the time from crop establishment to maturity reach ($\lambda/2$). The annual increase in carbon stocks due to biomass growth in new plantations was calculated as:

$$\Delta C_{CCG} = \sum_i \sum_{j=k-(\lambda_i/2)-1}^k A_{planted_{ij}} \cdot G_{w_i} \cdot CF, \quad G_{w,i} = B_{M,i} / (\lambda_i / 2)$$

where, $A_{planted_{ij}}$ is the area where new plantations were established, by crop type ($i = 17$), ha yr⁻¹, G_{w_i} is the growth rate in new plantations, by crop type, t d.m. ha⁻¹ yr⁻¹, CF is the carbon fraction of dry matter, t C (t d.m.)⁻¹, k is the inventory year, B_{M_i} is the average biomass stock at maturity, by crop type, d.m. ha⁻¹ and λ_i is the average replacement cycle, by crop type, yr.

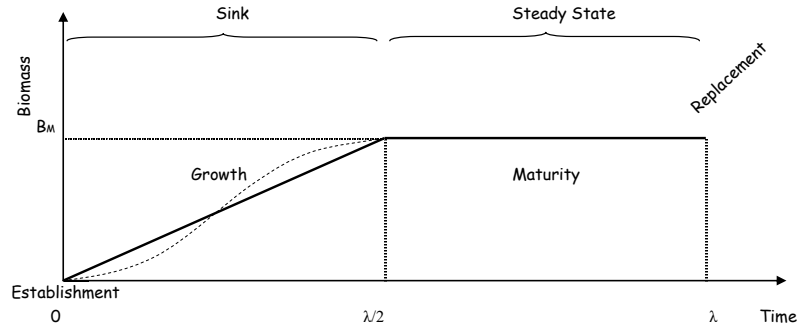


Figure 6.6 Assumed biomass accumulation in new plantations

The default annual loss rate is equal to biomass stocks at replacement (B_M), which are assumed to be removed entirely in the year of removal. The annual decrease in carbon stocks due to biomass loss from eradication (ΔC_{CCCL}) was estimate as:

$$\Delta C_{CCCL} = \sum_i A_{eradicated_i} \cdot B_{M_i}$$

where, $A_{eradicated_i}$ is the area of crop eradicated, by crop type ($i = 17$), ha yr⁻¹ and B_{M_i} is the average biomass stock at maturity / replacement, by crop type, t d.m. ha⁻¹.

Data on areas planted and eradicated were obtained from the "Agricultural Statistics of Greece" of the Hellenic Statistical Authority, disaggregated by 17 crop types (16 tree crops and vineyards). Data on the factors B_M and λ for these crops were obtained from the Ministry of Rural Development and Food (Ministry of Agriculture, 1981) and expert judgment and are presented in **Table 6.11**.

Change in carbon stocks in soils

A Tier 1 methodology was used for the estimation of carbon stock changes in soil, with country specific data for areas and IPCC default coefficients. The annual change in carbon stocks in soils in cropland remaining cropland ($\Delta C_{CCSoils}$, t C yr⁻¹) was estimated as the difference between the annual emissions from cultivated organic soils ($\Delta C_{CCOrganic}$, t C yr⁻¹) and the annual change in organic carbon stocks in mineral soils ($\Delta C_{CCMineral}$, t C yr⁻¹).

$$\Delta C_{CCSoils} = \Delta C_{CCMineral} - \Delta C_{CCOrganic}$$

According to the 2006 GL AFOLU, changes in dead organic matter have not been estimated since it is assumed that the dead wood and litter stocks either are not present or are at equilibrium. Liming of soils is applied to some extent in croplands, mainly in the west of the country, that face more soil acidification problems. However, oxide (CaO) and hydroxide (Ca(OH)₂) of lime are used for this purpose - rather than carbonate containing lime - that do not result in emissions of CO₂ when applied to soil. These materials are proved to be more efficient, since limestone (CaCO₃) has large diameter that result in small / slow dissolubility under the Greek dry conditions. CO₂ is produced in the production of lime and hydrated lime, but these emissions are estimated and reported under the Industrial Processes Sector.

Table 6.11 *Average biomass stock at maturity and replacement cycle for the different crop types*

Crop Type	B_M (tonnes d.m. ha ⁻¹)	λ (yr)
Vineyards	12	26
Citrus trees (orange, lemon, mandarin, bitter orange, citron, bergamot trees)	54	30
Apple trees	54	26
Pear trees	48	26
Peach trees	48	26
Apricot trees	60	30
Cherry trees	60	40
Sour cherry trees	54	30
Fig trees for fresh figs	42	30
Fig trees for dried figs	42	30
Almond trees	60	40

Walnut trees	60	50
Chestnut trees	90	50
Carob trees	54	50
Hazelnut trees	54	50
Pistachio trees	42	30
Olive trees ⁶	71	50

Mineral soils

The estimation method for mineral soils is based on changes in soil C stocks over a finite period following changes in management that impact soil C, and consequently changes in concentration of soil carbon is only driven by the change in practices or management, as shown in the equation 2.25 of the 2006 GL AFOLU:

$$\Delta C_{CCMineral} = [\sum_i (SOC_0 \cdot A)_i - \sum_i (SOC_{(0-T)} \cdot A)_i] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, SOC_0 is the soil organic carbon stock in the inventory year, $t\ C\ ha^{-1}$, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, $t\ C\ ha^{-1}$, T is the inventory time period, yr, A is the land area of each parcel, ha, i represents the set of cropland types or crop type categories, SOC_{REF} is the reference soil organic carbon stock, $t\ C\ ha^{-1}$, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

Because there weren't different set of data of the relative stock change factors (F_{LU} , F_{MG} , F_I) demonstrating subsequent changes in management for the inventory period 1990 – 2014, carbon stock changes in mineral soils have been reported to be equal to zero.

Organic Soils

Unlike the situation of mineral soils, where carbon fluxes are driven by changes in soil carbon stocks followed by changes in management, emissions from organic soils were estimated as net annual flux caused by cultivation and continuous exhaustion of organic matter. The annual loss of carbon from organic soils was estimated using a Tier1 method based on the equation 2.26 of the 2006 GL AFOLU.

$$\Delta C_{CCOrganic} = A_{Organic} \cdot EF$$

⁶ Olive groves constitute the majority of new plantations (approximately 90%) during 1990-2014. They are not subject of regular replacement since they retain their productivity for many decades, but a replacement cycle was assigned for inventory estimation purposes.

where, $\Delta C_{CCOrganic}$ represents CO_2 emissions from cultivated organic soils in cropland remaining cropland, $t\ C\ yr^{-1}$, $A_{Organic}$ is the land area of cultivated organic soils, ha and EF is the emission factor for cultivated organic soils, $t\ C\ ha^{-1}yr^{-1}$.

All cultivated organic soils are found under warm temperate climate, hence one climate type was considered when choosing the emission factor ($EF = 10\ t\ C\ ha^{-1}yr^{-1}$, Table 5.6, 2006 GL AFOLU). Area of cultivated organic soils was obtained from a study of the Soil Science Institute of Athens (SSIA, 2001).

6.5.2.2 Land converted to Cropland

Changes in biomass, dead organic matter, and soil carbon stocks associated with Forest land and Grassland conversion to Cropland are addressed in this category, as well as the increase in N_2O emissions arising from the conversion of land to cropland. The carbon emissions and removals in land use conversion to cropland result from the removal of existing and replacement with different vegetation. 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. These data were provided by the local Forest Service for each land unit converted.

Change in carbon stocks in living biomass

The methodology used to estimate C stock changes in biomass in forest land and grassland converted to cropland follows the 2006 GL AFOLU approach as proposed by equations 2.15 and 2.16, where the carbon stock change is equal to the carbon stock change due to removal of biomass from the initial land use (i.e. carbon in biomass immediately after conversion minus the carbon in biomass prior to conversion), plus carbon stocks from biomass growth following conversion.

$$\Delta C_{LCLB} = A_{Conversion} \cdot (L_{Conversion} + \Delta C_{Growth})$$

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

where, ΔC_{LCLB} is the annual change in carbon stocks in living biomass in land converted to cropland, $t\ C\ yr^{-1}$, $A_{Conversion}$ is the annual area of land converted to cropland from some initial use, $ha\ yr^{-1}$, $L_{Conversion}$ is the carbon stock change per area for that type of conversion when land is converted to cropland, $t\ C\ ha^{-1}$, ΔC_{Growth} is the carbon stocks from one year of growth of cropland vegetation after conversion, $t\ C\ ha^{-1}$, C_{After} is the carbon stocks in biomass immediately after conversion to cropland, $t\ C\ ha^{-1}$, C_{Before} is the carbon stocks in biomass immediately before conversion to cropland, $t\ C\ ha^{-1}$. The average carbon stocks in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock Bw of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground

biomass stocks were approximated using the root-shoot ratio. As a result of conversion, it is assumed that the dominant vegetation is removed entirely, thus $C_{\text{After}} = 0$.

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to cropland, the methodology applied is consistent with the 2006 GL AFOLU, according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{\text{DOM}} = \Delta C_{\text{DW}} + \Delta C_{\text{LT}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1} , ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1} , ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1} .

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{\text{DOM}} = (C_n - C_o) \cdot A_{\text{on}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1} , C_o is the dead wood/litter stock under the old land use category, t C ha^{-1} , C_n is the dead wood/litter stock under the new land use category, t C ha^{-1} , A_{on} is the area converted from forest land to cropland, ha.

It is assumed that all carbon contained in dead wood and litter is removed during conversion and that there is no dead wood or litter that remains or accumulates in land converted to cropland. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece, were used. Under the BioSoil project, 4 Level II plots from representative forest ecosystems in Greece have been surveyed in 2007. The results of the measurements and analyses performed were obtained from the MEEN and are presented in **Table 6.12**.

Table 6.12 *Average litter carbon stocks of the four Level II plots in Greece, under the Biosoil project*

Soil Layer	Plot 1 Maquis (t C ha ⁻¹)	Plot 2 Oak (t C ha ⁻¹)	Plot 3 Beech (t C ha ⁻¹)	Plot 4 Fir (t C ha ⁻¹)
L	7.10	5.01	5.17	4.96

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion, dead wood coefficients from Italy were applied. Those coefficients were estimated on the basis of data collected in the framework of the Italian forest inventory⁷ per Italian region and per inventory typology. A selection of the coefficients estimated for the Italian regions, for the different inventory typologies, was carried out, in order to detect only those that are more suitable to Greek climatic conditions and vegetation types, respectively. The coefficients used to estimate the carbon stock changes in the deadwood pool are reported in the **Table 6.13**.

Table 6.13 *Dead mass in the different Italian regions per inventory typology*

Dead mass dry matter (Mg ha ⁻¹)	Lazio	Molise	Campania	Puglia	Basilicata	Calabria	Sicilia
silver fir	0.000	1.550	0.000	0.000	6.840	1.430	0.000
mountain pines	1.180	0.585	1.375	0.825	0.755	2.065	0.845
mediterranean pines	3.410	0.000	0.720	0.910	0.850	4.260	0.550
other conifers	9.140	0.000	0.810	2.850	5.560	6.420	4.060
european beech	1.680	2.330	1.240	2.600	1.100	2.350	0.940
other oaks	0.750	2.350	0.940	0.890	0.300	1.050	1.400
other broadleaves	1.200	2.270	1.020	1.210	0.410	1.080	1.940
sweet chestnut	7.980	8.960	4.010	1.030	5.470	7.800	7.620
hornbeams	1.700	2.560	1.020	0.870	2.110	0.210	1.490
evergreen oaks	1.410	0.000	1.880	0.300	0.350	1.040	0.930
other broadleaves coppices	1.820	0.000	1.070	0.600	0.000	0.000	0.110
riparian forest	3.240	4.420	4.250	0.000	0.920	2.580	3.200
shrublands	0.210	0.000	0.000	0.940	0.410	1.260	1.530

Each prefecture in Greece was assigned to one of the Italian regions described above based on its regional climatic and vegetation cover characteristics, using expert judgment.

For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

⁷ http://www.sian.it/inventarioforestale/jsp/home_en.jsp; Further information related to the methodology applied to deduce the deadwood coefficients may be found in the paper *L. Di Cosmo et al., 2013*.

DOM in grasslands is assumed to be zero and, thus, no carbon stock changes in DOM have been estimated.

Change in carbon stocks in soils

A Tier 1 methodology was used for the estimation of carbon stock changes in soils in forest land and grassland converted to cropland, with country specific data and IPCC default coefficients. The annual change in carbon stocks in soils in land converted to cropland ($\Delta C_{LC\text{Soils}}$, t C yr⁻¹) was estimated as the difference between the annual emissions from cultivated organic soils converted to cropland ($\Delta C_{LC\text{Organic}}$, t C yr⁻¹) and the annual change in organic carbon stocks in mineral soils in land converted to cropland ($\Delta C_{LC\text{Mineral}}$, t C yr⁻¹).

$$\Delta C_{LC\text{Soils}} = \Delta C_{LC\text{Mineral}} - \Delta C_{LC\text{Organic}}$$

In Greece, areas of organic soils covered by forest are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered.

Mineral soils

The Tier 1 method applied for the estimation of carbon stock changes in mineral soils in forest land and grassland converted to cropland is based on the 2006 GL AFOLU using the equation 2.25:

$$\Delta C_{LC\text{Mineral}} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LC\text{Mineral}}$ is the annual change in carbon stocks in mineral soils, t C yr⁻¹, SOC_0 is the soil organic carbon stock in the inventory year, t C ha⁻¹, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha⁻¹, T is the inventory time period, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stock, t C ha⁻¹, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The 20 years inventory period was used (T = 20). The initial (pre-conversion) soil C stocks were determined assuming that the F_{LU} , F_{MG} , F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks. The current soil C stocks (SOC_0) on land converted to cropland were estimated from the same reference soil C stocks together with representative stock change factors. According to the climatic classification (by Thornwaite) of Greece, about 80% of croplands are found on dry warm temperate climate and the rest 20% on moist warm temperate (Carras, 1973). Moreover, since land area data disaggregated by climatic

type were not available, representative weighted average land use factor, management factor and input factor from Table 5.5 of the 2006 GL AFOLU were used, namely $F_{LU} = 0.78$, $F_{MG} = 1.03$, $F_I = 1.00$. For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece. The Ministry of Agriculture coordinated the project which lasted for approximately 20 years (1979-1998), and 2,260 plots has been surveyed (the L layer was not sampled). The results are available in four different vegetation zones in Greece, and are presented in **Table 6.14**, along with the representative plant species. In the cases where grassland converted to croplands the $SOC_{REF} = 72.3 \text{ t C ha}^{-1}$ value was used.

Table 6.14 *Average carbon stocks in forest soils per vegetation zone in Greece*

	Mediterranean zone (0 – 500 m)	Sub-Mediterranean zone (500 – 1000 m)	Mountainous zone (1000 – 1700 m)	Pseudoalpine zone (1700 – 2500 m)
Plant species	Evergreen broadleaf & Mediterranean Pine	Deciduous oak	Fir, Pine, Beech	Herbaceous vegetation
Average forest soil carbon stocks (t C ha ⁻¹)	72.3	80.3	116.0	111.0

N₂O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils

In this section the method used to estimate the increase in N₂O emissions arising from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils is presented. N₂O emissions increase can be expected following the conversion of forest land and grassland to cropland. This is a consequence of the enhanced mineralisation (conversion to inorganic form) of soil organic matter (SOM) that normally takes place as a result of that conversion.

The method used is consistent with the 2006 GL AFOLU following equations 11.1 and 11.8 from chapter 11, vol. 4.:

$$\text{Total N}_2\text{O-N}_{\text{conv}} = \sum_i \text{N}_2\text{O-N}_{\text{conv},i}$$

where, Total N₂O-N_{conv} are the total annual emissions of N₂O from mineral soils in land converted to cropland, kg N₂O-N yr⁻¹ and N₂O-N_{conv,i} are the N₂O emissions from land conversion type *i*, kg

$\text{N}_2\text{O-N yr}^{-1}$. As shown in the equation, the total emissions of N_2O are equivalent to the sum of all N_2O emissions from land use conversions.

The equation used to estimate N_2O emissions as a result of the disturbance associated with land use conversion of forest land and grassland to cropland is:

$$\text{N}_2\text{O-N}_{\text{conv}} = \text{N}_2\text{O}_{\text{net-min-N}}$$

$$\text{N}_2\text{O}_{\text{net-min-N}} = \text{EF}_1 \bullet \text{N}_{\text{net-min}}$$

where $\text{N}_2\text{O-N}_{\text{conv}}$ are the emissions as a result of the disturbance associated with land use conversion of forest land and grassland to cropland, $\text{kg N}_2\text{O-N yr}^{-1}$, $\text{N}_2\text{O}_{\text{net-min-N}}$ are the additional emissions arising from the land use change, $\text{kg N}_2\text{O-N yr}^{-1}$, $\text{N}_{\text{net-min}}$ is the N released annually by net soil organic matter mineralisation as a result of the disturbance, kg N yr^{-1} , and EF_1 is the IPCC default emission factor for N_2O emissions from N inputs, $\text{kg N}_2\text{O-N/kg N}$.

The N released by net mineralisation, $\text{N}_{\text{net-min}}$ can be calculated following the calculation of the soil C mineralisation over the same period (20 years). The default method assumes a constant C:N ratio in the soil organic matter over the period, thus:

$$\text{N}_{\text{net-min}} = \Delta\text{C}_{\text{LCMineral}} \bullet 1 / \text{C:N}$$

where $\text{N}_{\text{net-min}}$ is the annual N released by net soil organic matter mineralisation as a result of the disturbance, kg N yr^{-1} , $\Delta\text{C}_{\text{LCMineral}}$ are values obtained from the equation applied for mineral soils to areas of land converted to cropland, kg C yr^{-1} , C:N is the ration by mass of C to N in the soil organic matter (SOM), kg C (kg N)^{-1} . The default IPCC values for the EF_1 (Table 11.1) and the C:N ratio were used, namely $0.01 \text{ kg N}_2\text{O-N/kg N}$ and 15, respectively.

6.6 Grassland (CRF Source Category 4C)

6.6.1 Category description

Grassland includes rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed it without human intervention. Pastures that have been fertilised or sown are considered as cropland.

Under this category, CO₂ emissions from Grassland remaining Grassland and from Land converted to Grassland are reported, as well as non-CO₂ emissions from wildfires (*Table 6.15*).

Table 6.15 Emissions / removals of greenhouse gases (in kt) from Grassland for the period 1990 – 2014

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Grassland											
CO ₂	0.22	0.20	5.74	53.00	-51.93	-58.20	-68.48	-74.07	-86.57	-141.34	-167.53
CH ₄	0.63	0.53	1.61	1.13	1.18	0.50	0.54	0.81	1.59	0.18	2.48
N ₂ O	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02
Total (kt CO₂ eq)	17.21	14.59	49.31	83.54	-20.10	-44.71	-53.96	-52.22	-43.63	-136.49	-100.35

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Grassland														
CO ₂	-171.21	-199.33	-178.22	-259.27	-236.89	-325.98	-282.90	-523.27	-543.10	-556.98	-430.47	-874.96	-776.25	-850.53
CH ₄	0.50	0.09	0.13	0.31	0.16	0.25	5.14	0.54	0.54	0.10	0.48	0.87	0.57	0.33
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Total (kt CO₂ eq)	-157.69	-196.80	-174.83	-250.86	-232.57	-319.13	-143.93	-508.63	-528.53	-554.22	-417.62	-851.37	-760.75	-841.53

6.6.2 Methodology

6.6.2.1 Grassland remaining Grassland

The living biomass pool in grassland includes above and belowground carbon stocks in woody and herbaceous vegetation. Grasslands in Greece are extensively managed without significant management improvements (e.g. species changes, irrigation, fertilisation) and management practices applied are generally static. Hence, the Tier 1 assumption that is no change in biomass stocks was followed for the majority of these lands, except some cases where vegetation clearing took place and woody vegetation was substituted by annual vegetation. In these lands, CO₂ emissions result from the removal of existing and replacement with different vegetation. The amount of C stock change in living biomass was estimated by multiplying the area of intervention by the difference in carbon stocks between biomass in the land prior to intervention (C_{Before}) and

after the intervention (C_{After}). The equation used to estimate annual changes in carbon stocks in living biomass is:

$$\Delta C_{\text{GGLB}} = A \bullet (C_{\text{After}} - C_{\text{Before}})$$

where, ΔC_{GGLB} is the annual change in carbon stocks in living biomass, t C yr^{-1} , A is the area of intervention, ha yr^{-1} , C_{After} is the carbon stocks in living biomass immediately after intervention, t C ha^{-1} , C_{Before} is the carbon stocks in living biomass immediately before intervention, t C ha^{-1} . Actual areas of intervention have been provided by the local Forest Service disaggregated by vegetation type.

The methods used to estimate emissions from wildfires in grasslands are those described in Forest land section, with the difference that all carbon in the aboveground biomass is assumed to be released to the atmosphere upon disturbance (no transfer to dead organic pool is considered, $f_{\text{BL}} = 0$). However, CO_2 released is assumed to be removed by photosynthesis of vegetation regrowing during the subsequent year and therefore only emissions of non- CO_2 gases are reported. For these estimations two grassland types were considered; one with herbaceous vegetation and average biomass stock of $2.2 \text{ t d.m. ha}^{-1}$ and one with woody vegetation (shrubland) and average biomass stock of 8 t dm. ha^{-1} (Kokkinidis, 1989). Data on area of grasslands burnt were obtained from the statistics of the Ministry of Environment and Energy (GDPDFNE, annual statistics).

According to the 2006 GL AFOLU, it is assumed that the dead wood and litter stocks are at equilibrium, thus no carbon stock changes for these pools have been reported. Concerning the carbon pool in mineral soils, all area was characterised as nominal managed both in the inventory year and 20 years ago, and hence according to the equation 2.25, $F_{\text{LU}} = F_{\text{MG}} = F_{\text{I}} = 1$ and $\Delta C_{\text{GGMineral}} = 0$, i.e. the annual change in carbon stocks in mineral soils was zero. Changes in carbon stocks of organic soils are associated with drainage and other management perturbations of these soils. In Greece, areas of organic soils under the grassland classification are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered. CO_2 emissions from liming of grasslands were not considered since liming is not applied on these lands. Non- CO_2 emissions from other sources (e.g. CH_4 emissions from grazing livestock on grassland) were estimated and reported in the *Agriculture* sector.

6.6.2.2 Land converted to Grassland

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.

Table 6.16 *Net CO₂ emissions / removals (kt CO₂) from Land converted to Grassland by subcategory for the period 1990 – 2014*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Land converted to Grassland	0	0	6	53	-52	-58	-69	-74	-87	-141	-168
Biomass	0.01	NO	0.04	11.61	0.08	3.95	1.50	0.02	0.05	0.16	NO
Dead Organic matter	0.01	NO	0.04	11.71	0.08	3.97	1.51	0.02	0.05	0.16	NO
Soils	0.0	0.0	-7.9	-60.7	-72.5	-79.9	-91.0	-115.0	-155.5	-175.1	-185.9

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Land converted to Grassland	-171	-200	-178	-259	-237	-326	-283	-523	-543	-557	-431	-875	-776	-851
Biomass	35.60	17.76	91.43	3.40	19.80	178.66	175.09	116.95	135.20	169.95	134.54	137.53		
Dead Organic matter	NO	0.02	0.27	0.20	NO	0.04	0.06	0.07	1.00	0.10	NO	0.05	NO	NO
Soils	-206.8	-217.3	-269.9	-284.2	-351.9	-388.5	-539.2	-561.8	-583.7	-621.4	-894.8	-903.4	-957.0	-1080.7

Change in carbon stocks in living biomass

Since Greek law allow the land use change of Forest land only in cases of national interest, there is only a very small area where such deforestation occur (e.g. construction of high-tension lines). The carbon emissions and removals in land use conversion to grassland result from the removal of existing and replacement with different vegetation, and from the establishment of vegetation in cropland areas when these are abandoned. The methodology used to estimate C stock changes on these lands follows the 2006 GL AFOLU equations 2.15 and 2.16, where the carbon stock change is equal to the carbon stock change due to removal of biomass from the initial land use (i.e. carbon in biomass immediately after conversion minus the carbon in biomass prior to conversion), plus carbon stocks from biomass growth following conversion. As a result of conversion, it is assumed that the dominant vegetation is removed entirely, after which the area is taken over by grassland.

$$\Delta C_{LGLB} = A_{\text{Conversion}} \cdot (L_{\text{Conversion}} + \Delta C_{\text{Growth}})$$

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

where, ΔC_{LGLB} is the annual change in carbon stocks in living biomass in land converted to grassland, t C yr⁻¹, $A_{\text{Conversion}}$ is the annual area of land converted to grassland from some initial use, ha yr⁻¹, $L_{\text{Conversion}}$ is the carbon stock change per area for that type of conversion when land is converted to grassland, t C ha⁻¹, ΔC_{Growth} is the carbon stocks from one year of growth of grassland vegetation after conversion, t C ha⁻¹, C_{After} is the carbon stocks in biomass immediately after conversion to grassland, t C ha⁻¹, C_{Before} is the carbon stocks in biomass immediately before conversion to grassland, t C ha⁻¹.

For the area of forest land converted to grassland, direct estimates of spatially disaggregated areas converted annually for each initial forest type and each final grassland type, were used. These data were provided by the local Forest Service for each land unit converted.

The average carbon stock in biomass immediately before conversion C_{Before} was obtained from the average biomass stock B_w of each forest type, as calculated in the category Forest land remaining Forest land. Carbon stocks in biomass immediately after conversion are assumed to be zero ($C_{\text{After}} = 0$). For changes in biomass carbon stocks for grassland established following land use conversion ΔC_{Growth} are accounted for in the year of the conversion. For these estimations two grassland types were considered; one with herbaceous vegetation and average biomass stock of 2.2 t d.m. ha⁻¹ and one with woody vegetation (shrubland) and average aboveground biomass stock of 8 t dm . ha⁻¹ (Kokkinidis, 1989). Belowground biomass stocks were approximated using the default root-shoot ratio.

Croplands that have been abandoned and taken over by grassland were also considered in this section. When such conversions occurred in Greece it has been assumed, using expert judgment, that these lands were mostly annual crops. Carbon stocks in biomass immediately after conversion assumed to be zero ($C_{\text{After}} = 0$), while for the carbon stocks before conversion the default value for annual crops ($C_{\text{Before}} = 5 \text{ t C ha}^{-1}$) from table 5.9 of the 2006 GL AFOLU was used. Finally, for the carbon stocks from one year of growth of grassland vegetation after conversion, a weighted average value from Table 6.4 of the 2006 GL AFOLU ($0.8*6.1+0.2*13.5=7.6$) was used, according to the climatic classification (by Thornwaite) of Greece.

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to grassland, the methodology applied is consistent with the 2006 GL AFOLU , according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{\text{DOM}} = \Delta C_{\text{DW}} + \Delta C_{\text{LT}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr⁻¹, ΔC_{DW} is the change in carbon stocks in dead wood, t C yr⁻¹, ΔC_{LT} is the change in carbon stocks in litter, t C yr⁻¹.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{\text{DOM}} = (C_n - C_o) \cdot A_{\text{on}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1} , C_o is the dead wood/litter stock under the old land use category, t C ha^{-1} , C_n is the dead wood/litter stock under the new land use category, t C ha^{-1} , A_{on} is the area converted from forest land to grassland, ha.

It is assumed that all carbon contained in dead wood and litter is removed during conversion and that there is no dead wood or litter that remains or accumulates in forest land converted to grassland. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece (MEEN), were used (*Table 6.12*).

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used instead (*Table 6.13*).

For the conversion of dry matter to carbon the IPCC factor ($\text{CF} = 0.47$) was used.

Change in carbon stocks in soils

A Tier1 methodology was used for the estimation of carbon stock changes in soils in forest land and cropland converted to grassland, with country specific data and IPCC default coefficients. The annual change in carbon stocks in soils in land converted to grassland ($\Delta C_{\text{LGSoils}}$, t C yr^{-1}) was estimated as the difference between the annual emissions from organic soils converted to grassland ($\Delta C_{\text{LGOrganic}}$, t C yr^{-1}) and the annual change in carbon stocks in mineral soils in land converted to grassland ($\Delta C_{\text{LGMineral}}$, t C yr^{-1}).

$$\Delta C_{\text{LGSoils}} = \Delta C_{\text{LGMineral}} - \Delta C_{\text{LGOrganic}}$$

Neither forestland nor cropland on organic soils have been converted to grassland, and therefore emissions from organic soils have not been considered.

Mineral soils

For the Tier 1 method the equation 2.25 of the 2006 GL AFOLU, was used:

$$\Delta C_{\text{LGMineral}} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LGMineral}$ is the annual change in carbon stocks in mineral soils, $t\ C\ yr^{-1}$, SOC_0 is the soil organic carbon stock in the inventory year, $t\ C\ ha^{-1}$, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, $t\ C\ ha^{-1}$, T is the inventory time period, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stock, $t\ C\ ha^{-1}$, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The IPCC default inventory time period was used ($T = 20$). In the case of forest land conversion to grassland the initial (pre-conversion) soil C stocks were determined assuming that the F_{LU} , F_{MG} , F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks. The current soil C stocks (SOC_0) on land converted to grassland were estimated from the same reference soil C stocks together with the stock change factors that apply to severely degraded grassland (i.e. $F_{LU} = 1.0$, $F_{MG} = 0.7$, $F_I = 1.0$, Table 6.2 2006 GL AFOLU). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (**Table 6.14**).

In the case of cropland conversion to grassland the initial (pre-conversion) soil C stocks were determined using the same stock change factors as in section 6.5.2.2, namely $F_{LU} = 0.78$, $F_{MG} = 1.03$, $F_I = 1.00$. The current soil C stock SOC_0 was assumed equal to the reference (SOC_{REF}) soil C stocks, using the $72.3\ t\ C\ ha^{-1}$ value from **Table 6.14**, applicable to Evergreen broadleaf & Mediterranean Pine.

6.7 Wetlands (CRF Source Category 4D)

Wetlands include land that is covered or saturated by water for all or the greatest part of the year (e.g. lakes, reservoirs, marshes), as well as river bed (including torrent beds) and that does not fall into the forest land, cropland, grassland or settlements categories. In this category, carbon stock changes, as well as N₂O and CH₄ emissions associated with organic soils managed for peat extraction and flooded lands in the category Land converted to Wetlands have to be reported. The first activity is not considered since it does not occur in the country. Flooded lands are defined as water bodies regulated by human activities for energy production, irrigation, recreation, etc., and where substantial changes in water area due to water level regulation occur.

Table 6.17 Emissions / removals of greenhouse gases (in kt) from Wetlands for the period 1990 – 2014

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Wetlands											
CO ₂	NE,NO	NE,NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO ₂ eq)	NE,NO	NE,NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Wetlands														
CO ₂	0.74	2.37	1.37	26.30	3.10	4.23	3.58	2.82	2.82	2.61	2.59	2.85	2.52	0.09
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO ₂ eq)	0.74	2.37	1.37	26.30	3.10	4.23	3.58	2.82	2.82	2.61	2.59	2.85	2.52	0.09

NO: Not Occurring, NE: Not Estimated

Change in carbon stocks in living biomass

Carbon stock changes in lands converted to flooded lands are caused by decomposition of living biomass in these areas. The difference between initial and final living biomass carbon pools is used to calculate change in carbon stocks due to land use conversion. The equation used to estimate annual changes in carbon stocks in living biomass in land converted to wetlands is:

$$\Delta C_{LWLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{LWLB} is the annual change in carbon stocks in living biomass in land converted to wetlands, t C yr⁻¹, A is the area of land converted annually to wetland from some initial use, hayr⁻¹,

C_{After} is the carbon stocks in living biomass immediately after conversion to wetlands, t C ha^{-1} ,
 C_{Before} is the carbon stocks in living biomass immediately before conversion to wetlands, t C ha^{-1} .

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_w of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio. It is assumed that the carbon stock prior to the conversion is lost in the first year following conversion ($C_{\text{After}} = 0$).

Actual areas converted annually have been used for each unit of land converted to Wetlands. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type.

Change in carbon stocks in dead organic matter – soil organic matter

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. The methodology applied follows the Tier 1 approach of the GPG LULUCF (Appendix 3a.3), according to which CO_2 emission from flooded lands occur via the molecular diffusion across the air-water interface after flooding has occurred. This is a simplified approach to estimating emissions using default emission data, and area data converted annually provided by the local Forest Service, based on the equation:

$$\text{CO}_2 \text{ emissions}_{\text{SWW flood}} = P \cdot E(\text{CO}_2)_{\text{diff}} \cdot A_{\text{flood, total surface}}$$

where, $\text{CO}_2 \text{ emissions}_{\text{SWW flood}}$ is the total CO_2 emissions from flooded lands, $\text{Gg CO}_2 \text{ yr}^{-1}$, P is the period, days, $E(\text{CO}_2)_{\text{diff}}$ is the averaged daily diffusive emissions, $\text{Gg CO}_2 \text{ ha}^{-1} \text{ day}^{-1}$, $A_{\text{flood, total surface}}$ is the total flooded surface area, including flooded land, flooded lake and flooded river surface area, ha.

The method described in the previous section for the estimation of carbon stock changes in aboveground living biomass due to land conversion to flooded land assumes that all aboveground biomass is converted into CO_2 in the first year following the conversion. According to the GPG LULUCF, in actuality, the part of the above ground biomass that is left on site before flooding will decompose more slowly, while decay of soil carbon will also contribute to the emissions. These CO_2 emissions were estimated using the equation above, during the ice-free and ice-cover periods, encompassing both emissions from dead organic and soil organic matter.

The 365 days period, and the CO_2 emission factors via the diffusion pathway for the ice-free period for the entire year were used (Tier 1). Given the high uncertainty of the estimations of that method, and the considerable range of values between the diffusion emission factors provided by the GPG

LULUCF for the temperate climate zone (-3.1 and $13.2 \text{ kg CO}_2 \text{ ha}^{-1} \text{ day}^{-1}$, table 3A.3.5), the respective factors provided by the 2006 GL AFOLU (table 2A.2, Appendix 2) were chosen instead, and more specifically a weighted average value for the whole of the country ($E(\text{CO}_2)_{\text{diff}} = 80\% \cdot 5.2 + 20\% \cdot 8.1 = 5.78 \text{ kg CO}_2 \text{ ha}^{-1} \text{ day}^{-1}$).

The default assumption that the CO₂ emissions are limited to 10 years after the flooding took place, was made.

Table 6.18 *Net CO₂ emissions / removals (kt CO₂ eq.) from Land converted to Wetlands by subcategory for the period 1990 – 2014*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Land converted to Wetlands	NO	NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51
Biomass	NO	NO	0.0	0.6	0.2	0.0	0.1	0.4	1.8	NO	2.0
Dead Organic matter	NO	NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
Soils	NO	NO	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.5

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Land converted to Wetlands	0.74	2.37	1.37	26.30	3.10	4.23	3.58	2.82	2.82	2.61	2.59	2.85	2.52	0.09
Biomass	0.2	1.8	0.8	23.3	0.1	1.2	0.6	NO	NO	NO	NO	0.3	NO	NO
Dead Organic matter	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
Soils	0.6	0.6	0.6	3.0	3.0	3.0	3.0	2.8	2.8	2.6	2.6	2.6	2.5	0.1

NO: Not Occurring, IE: Included Elsewhere

6.8 Settlements (CRF Source Category 4E)

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in other land-use categories.

For Settlements remaining Settlements category the tier 1 approach has been followed for living biomass, dead organic matter, and soil organic matter. According to this approach, there is no change in carbon stocks in living biomass pool, with the growth balancing losses. Similarly, dead wood and litter stocks are in equilibrium. Finally, it is assumed that inputs equal outputs so that no carbon stock changes occur in soils in settlements remaining settlements.

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 the remaining of this chapter.

Table 6.19 *Emissions / removals of greenhouse gases (in kt) from Settlements for the period 1990 – 2014*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Settlements											
CO ₂	6.08	7.80	4.79	5.22	6.01	4.03	14.44	5.72	5.39	8.52	13.21
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO₂ eq)	6.08	7.80	4.79	5.22	6.01	4.03	14.44	5.72	5.39	8.52	13.21

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Settlements														
CO ₂	8.95	10.28	24.46	15.37	21.03	17.98	18.51	16.99	14.79	13.86	12.36	24.32	13.38	11.33
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO₂ eq)	8.95	10.28	24.46	15.37	21.03	17.98	18.51	16.99	14.79	13.86	12.36	24.32	13.38	11.33

NO: Not Occurring

Change in carbon stocks in living biomass

The amount of C stock change in living biomass in land that is cleared for expanding settlements is estimated by multiplying the area converted annually to settlements by the difference in carbon stocks between biomass in the land prior to conversion (C_{Before}) and that in the settlements after conversion (C_{After}). The equation used to estimate annual changes in carbon stocks in living biomass in land converted to settlements is:

$$\Delta C_{LSLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{LSLB} is the annual change in carbon stocks in living biomass in land converted to settlement, $t\ C\ yr^{-1}$, A is the area of land converted annually to settlement from some initial use, $ha\ yr^{-1}$, C_{After} is the carbon stocks in living biomass immediately after conversion to settlement, $t\ C\ ha^{-1}$, C_{Before} is the carbon stocks in living biomass immediately before conversion to settlement, $t\ C\ ha^{-1}$.

The assumptions that have been followed are that all living biomass present before conversion to settlements is lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion (C_{After}) are equal to zero.

Three types of land use changes to settlements have been identified:

- Forest land converted to Settlements
- Grassland converted to Settlements, and
- Other land converted to Settlements

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_w of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio.

Actual areas converted annually have been used for each unit of land converted to settlements. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type.

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to settlements, the methodology applied is consistent with the 2006 GL AFOLU, according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), $t\ C\ yr^{-1}$, ΔC_{DW} is the change in carbon stocks in dead wood, $t\ C\ yr^{-1}$, ΔC_{LT} is the change in carbon stocks in litter, $t\ C\ yr^{-1}$.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{DOM} = (C_n - C_o) \cdot A_{on}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr⁻¹, C_o is the dead wood/litter stock under the old land use category, t C ha⁻¹, C_n is the dead wood/litter stock under the new land use category, t C ha⁻¹, A_{on} is the area converted from forest land to settlements, ha.

It is assumed that all carbon contained in dead wood and litter is lost during conversion and that there is to be no subsequent accumulation of new dead organic matter in the settlements after conversion. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece (MEEN), were used (*Table 6.12*).

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used instead (*Table 6.13*).

For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

Change in carbon stocks in soils

Land conversion to Settlements occurs with development and expansion of cities and towns on former Forest land, Grassland, Wetlands, and Other land. These conversions change soil C stocks due to mechanical disturbance of the soil; soil burial or collection during development; type and amount of vegetated cover; in addition to the new management regime, particularly with respect to nutrient and water applications.

The change in soil C stocks in Forest land and Grassland converted to Settlements was estimated using the equation 2.24 of the 2006 GL AFOLU with country specific data and IPCC default coefficients:

$$\Delta C_{LSOils} = \Delta C_{LSMineral} - \Delta C_{LSOrganic}$$

where, ΔC_{LSOils} is the annual change in carbon stocks in soils in forest land and grassland converted to settlements, t C yr⁻¹, $\Delta C_{LSMineral}$ is the annual change in organic carbon stocks in mineral soils, t C yr⁻¹, and $\Delta C_{LSOrganic}$ is the annual loss of carbon from drained organic soils, t C yr⁻¹ in land converted to settlements. Since the areas of organic soils covered by forest in Greece

are negligible and remain in a natural state, only emissions/removals for mineral soils have been considered.

Mineral soils

For mineral soils, the default method is based on changes in soil C stocks over a finite period of time. The change is computed based on C stock after the conversion relative to the carbon stock in a reference condition. The following assumptions were made:

- Over time, soil organic C reaches a spatially-averaged, stable value specific to the soil, climate, land-use management practices, and
- Soil organic C stock changes during the transition to a new equilibrium SOC occurs in a linear fashion.

The Tier 1 approach was followed using the equation 2.25 of the 2006 GL AFOLU:

$$\Delta C_{LSMineral} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / D, SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LSMineral}$ is the annual change in carbon stocks in mineral soils, t C yr⁻¹, SOC_0 is the soil organic carbon stock in the inventory year, t C ha⁻¹, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha⁻¹, T is the inventory time period, yr, A is the land area of each parcel, ha, D is the time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr, SOC_{REF} is the reference soil organic carbon stock, t C ha⁻¹, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The default 20 years inventory time period and time dependence of the stock change factors was used. The initial (pre-conversion) soil C stocks were determined assuming that the F_{LU} , F_{MG} , F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks when a forest land converted to settlements, while for the cases of grassland conversions to settlements the $SOC_{(0-T)}$ was taken equal to 72.3 t C ha⁻¹. The current soil C stocks (SOC_0) on land converted to settlements were estimated using the stock change factors that apply to settlement area that is paved over (i.e. product of F_{LU} , F_{MG} and F_I equal to 0.8 times the corresponding product for the previous land use). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (**Table 6.14**).

In the following **Table 6.20**, the net CO₂ emissions/removals from each subcategory are presented.

Table 6.20 *Net CO₂ emissions / removals (kt CO₂ eq.) from Land converted to Settlements by subcategory for the period 1990 – 2014*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000			
Land converted to Settlements	6.08	7.80	4.79	5.22	6.01	4.03	14.44	5.72	5.39	8.52	13.21			
Biomass	4.7	5.7	2.6	2.8	3.2	1.3	8.1	2.3	1.8	4.0	7.2			
Dead Organic matter	0.1	0.4	0.2	0.4	0.4	0.3	3.4	0.2	0.3	0.9	1.7			
Soils	1.2	1.7	1.9	2.1	2.4	2.5	3.0	3.2	3.3	3.7	4.4			
IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Land converted to Settlements	8.95	10.28	24.46	15.37	21.03	17.98	18.51	16.99	14.79	13.86	12.36	24.32	13.38	11.33
Biomass	3.3	4.2	13.5	6.0	11.5	7.5	6.8	4.7	3.7	3.5	2.2	10.4	2.0	0.5
Dead Organic matter	0.9	0.8	4.5	2.3	1.1	1.3	1.8	1.8	0.3	0.0	0.2	3.0	0.4	0.1
Soils	4.7	5.2	6.5	7.1	8.4	9.2	9.9	10.4	10.8	10.3	10.0	10.9	10.9	10.7

6.9 Other land (CRF Source Category 4F)

The category of "Other land" includes all land areas that do not fall into any of other land-use categories (e.g. rocky areas, bare soil, mine and quarry land). In accordance with the 2006 GL AFOLU, changes in carbon stocks and non-CO₂ emissions were not assessed for the category "Other Land remaining Other Land" assuming that it is typically unmanaged. However, changes in carbon stocks associated with the conversion of Forest land and Grassland to Other land (mainly mines and quarries) have been reported, since the act of conversion releases the carbon previously held on these lands.

Table 6.21 Emissions / removals of greenhouse gases (in kt) from Other land for the period 1990 – 2014

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Other land											
CO ₂	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO₂ eq)	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Other land														
CO ₂	64.23	69.89	69.09	77.69	69.91	82.51	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (kt CO₂ eq)	64.23	69.89	69.09	77.69	69.91	82.51	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47

Change in carbon stocks in living biomass

The difference between initial and final living biomass carbon pools is used to calculate change in carbon stocks due to land-use conversion. In accordance with guidance provided by 2006 GL AFOLU, the equation used to estimate annual changes in carbon stocks in living biomass in land converted to other land is:

$$\Delta C_{LOLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{LOLB} is the annual change in carbon stocks in living biomass in land converted to other land, t C yr⁻¹, A is the area of land converted annually to other land from some initial use, ha yr⁻¹, C_{After} is the carbon stocks in living biomass immediately after conversion to other land, t C ha⁻¹, C_{Before} is the carbon stocks in living biomass immediately before conversion to other land, t C ha⁻¹.

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_w of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio. It is assumed that the dominant vegetation is removed entirely, resulting in no carbon remaining in living biomass after conversion. ($C_{\text{After}} = 0$).

Actual areas converted annually have been used for each unit of land converted to "Other Land". These data were provided by the local Forest Service disaggregated by initial land use and vegetation type.

Change in carbon stocks in dead organic matter

The conversion to Other land from some initial land use may also cause changes to the carbon amount stored in dead organic matter and soils. Below the methodology applied for the estimation of emissions/removals from these carbon pools in forest land converted to other land is presented.

The assessment of carbon stock changes in dead organic matter in forest land converted to other land was made in accordance with the 2006 GL AFOLU. Two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{\text{DOM}} = \Delta C_{\text{DW}} + \Delta C_{\text{LT}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1} , ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1} , ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1} .

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{\text{DOM}} = (C_n - C_o) \cdot A_{\text{on}}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1} , C_o is the dead wood/litter stock under the old land use category, t C ha^{-1} , C_n is the dead wood/litter stock under the new land use category, t C ha^{-1} , A_{on} is the area converted from forest land to other land, ha.

It is assumed that no carbon remains in dead organic matter after conversion to Other land, and that all carbon stocks are assumed to be emitted in the year of conversion, thus there is no accumulation

of DOM stocks (Tier 1). Consequently, dead wood and litter stocks following conversion are assumed to be equal to zero.

The litter stocks prior to conversion were calculated with the use of the data collected within the European project BioSoil in Greece (*Table 6.12*). For the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used (*Table 6.13*). For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

Change in carbon stocks in mineral soils

In accordance with the 2006 GL AFOLU, the change in carbon stocks in mineral soils in forest land and grassland converted to other land were estimated and reported. The estimation method for mineral soil is based on change in soil carbon stocks over a finite period following change in management that impacts soil carbon stocks, based on the equation 2.25:

$$\Delta C_{LOMineral} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T, \quad SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LOMineral}$ is the annual change in carbon stocks in mineral soils in land converted to Other land, t C yr⁻¹, SOC_0 is the soil organic carbon stock in the inventory year, t C ha⁻¹, $SOC_{(0-T)}$ is the soil organic carbon stocks T years prior to the inventory year, t C ha⁻¹, T is the time period for the conversion, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stocks, t C ha⁻¹, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The IPCC default time period for the conversion was used (T = 20). The initial (pre-conversion) soil C stocks were determined assuming that the F_{LU} , F_{MG} , F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks when a forest land converted to other land, while for cases of grassland conversions to other land the $SOC_{(0-T)}$ was taken equal to 72.3 t C ha⁻¹. The soil C stocks after conversion (SOC_0) were assumed to be zero for Other land (Tier 1). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (*Table 6.14*).

For the area of land converted to other land, direct annually estimates of spatially disaggregated areas were used. These data were provided by the local Forest Service for each land unit converted. In *Table 6.22*, the net CO₂ emissions/removals from each subcategory are presented.

Table 6.22 *Net CO₂ emissions / removals (kt CO₂ eq.) from Land converted to Other land by subcategory for the period 1990 – 2014*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Land converted to Other land	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15
Biomass	13.35	4.90	13.65	6.55	6.64	5.83	11.24	10.88	8.39	8.79	12.59
Dead Organic matter	2.3	0.8	4.4	1.9	1.7	1.8	3.4	2.8	1.7	1.8	2.4
Soils	4.9	7.3	12.7	15.6	18.5	20.6	25.4	31.9	36.7	41.5	44.9

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Land converted to Other land	64.23	69.89	69.09	77.69	69.91	82.51	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47
Biomass	11.00	13.12	8.66	10.90	3.82	10.57	20.87	13.80	3.30	3.43	2.63	36.65		
Dead Organic matter	4.6	3.1	2.0	3.9	1.0	2.0	8.9	1.9	0.6	0.7	1.0	10.2	0.3	0.6
Soils	49.3	54.5	58.9	63.5	65.2	70.6	79.0	84.4	86.0	82.6	80.9	83.5	81.1	79.1

6.10 Harvested wood products (HWP) (CRF Source Category 4G)

Annual carbon stock changes and CO₂ emissions and removals from the Harvested Wood Products pool are reported in this category. The methodology applied is consistent with Decision 2/CMP.7, and the guidance provided by 2006 GL AFOLU (chapter 12, vol. 4), and 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement).

More specifically, the production approach has been followed for the estimation of emissions/removals associated with carbon stock changes from HWP originating from the country's forest, using the tier 2 (First Order Decay) approach. The same methodology has been followed for estimating and reporting annual changes from that pool both under the UNFCCC and KP.

Three harvested wood products categories have been addressed, namely sawnwood, wood-based panels, and paper and paperboard. The necessary activity data for all three categories have been obtained from FAO statistics database. In particular data for production, import and export from 1961 onwards.

Carbon stocks and annual carbon stock changes have been estimated using the equation 2.8.5 of the KP Supplement:

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

$$\Delta C(i) = C(i+1) - C(i)$$

where, i is the year, $C(i)$ is the carbon stock in the particular HWP category at the beginning of year i , $Gg\ C$, k is a decay constant of FOD for each HWP category (HWP_j) given in units yr^{-1} ($k = \ln(2)/HL$, where HL is half-life of the HWP pool in years, $Inflow(i)$ is the inflow to the particular HWP category (HWP_j) during year i , $Gg\ C\ yr^{-1}$, and $\Delta C(i)$ is the carbon stock change of the HWP category during year i , $Gg\ C\ yr^{-1}$.

The change in carbon stocks was estimated separately for each product category. For the estimation of the annual fraction of the feedstock coming from domestic harvest for categories sawnwood and wood-based panels equation 2.8.1 of the KP Supplement has been used, and equation 2.8.2 for the estimation of annual fraction of domestically produced wood pulp as feedstock for paper and paperboard production:

$$F_{IRW}(i) = (IRW_P(i) - IRW_{EX}(i)) / (IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i))$$

$$F_{PULP}(i) = (PULP_P(i) - PULP_{EX}(i)) / (PULP_P(i) + PULP_{IM}(i) - PULP_{EX}(i))$$

Where, $f_{IRW}(i)$ is the share of industrial roundwood for the domestic production of HWP originating from domestic forests in year i , $IRW_P(i)$ is the production of industrial roundwood in year i , Gg C yr⁻¹, $IRW_{IM}(i)$ is the import of industrial roundwood in year i , Gg C yr⁻¹ and $IRW_{EX}(i)$ is the export of industrial roundwood in year i , Gg C yr⁻¹, $f_{PULP}(i)$ is the share of domestically produced pulp for the domestic production of paper and paperboard in year i , $PULP_P(i)$ is the production of wood pulp in year i , Gg C yr⁻¹, $PULP_{IM}(i)$ is the import of wood pulp in year i , Gg C yr⁻¹ and $PULP_{EX}(i)$ is the export of wood pulp in year i , Gg C yr⁻¹.

It is assumed that the HWP pool is in steady state at the initial time t_0 , when the activity data start. For each HWP category the carbon stock in this steady state has been estimated using the following equation:

$$C(t_0) = \text{Inflow}_{\text{average}} / k$$

with,

$$\text{Inflow}_{\text{average}} = \left(\sum_{i=t_0}^{t_4} \text{Inflow}(i) \right) / 5$$

For the estimation of annual HWP amounts produced from domestic harvest the equation 2.8.4 was used:

$$\text{HWP}_j(i) = \text{HWP}_P(i) \bullet f_{DP}(i)$$

where, $f_{DP}(i) = f_{IRW}(i)$ for HWP categories sawnwood and wood-based panels, and $(f_{IRW}(i) \bullet f_{PULP}(i))$ for HWP category paper and paperboard, with $f_{IRW}(i) = 0$ if $f_{IRW}(i) < 0$ and $f_{PULP}(i) = 0$ if $f_{PULP}(i) < 0$, $f_{DP}(i)$ is the share of domestic feedstock for the production of the particular HWP category originating from domestic forests in year i , $\text{HWP}_j(i)$ are the amounts produced from domestic harvest associated with activity j in year i , in m³ yr⁻¹ or Mt yr⁻¹ and $\text{HWP}_P(i)$ is the production of the particular HWP commodities in year i , in m³ yr⁻¹ or Mt yr⁻¹.

For the estimation of emission factors for each HWP category the default half-lives values from table 2.8.2 of the KP Supplement, namely 2 years for paper, 25 years for wood panels, and 35 years for sawnwood have been applied, while default values presented in table 2.8.1 (KP Supplement) have been used as conversion factors for the default HWP categories.

Figure 6.7 presents the HWP in use for the whole period 1961-2014, while in **Figure 6.8** the annual change in stocks for the period 1990-2014 per each category is presented.

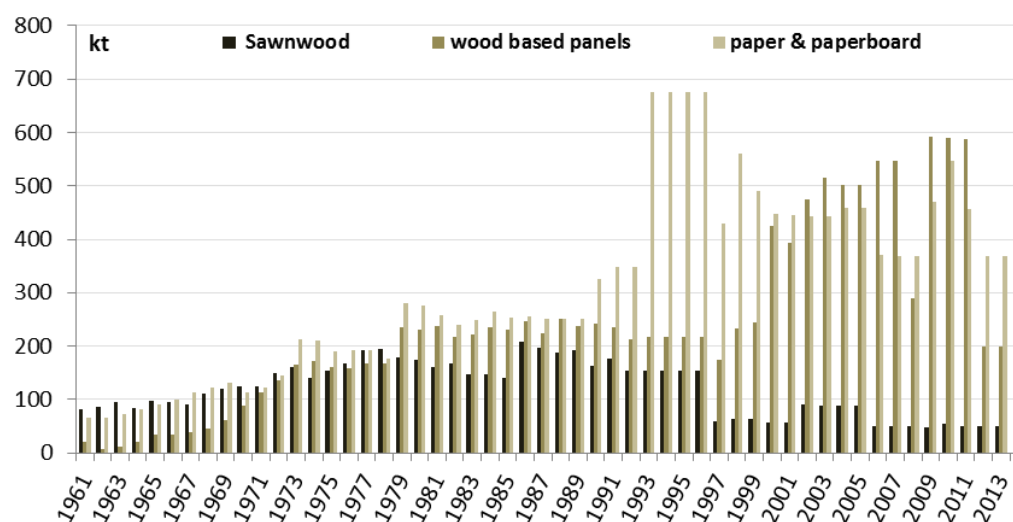


Figure 6.7 *Harvested wood products in use*

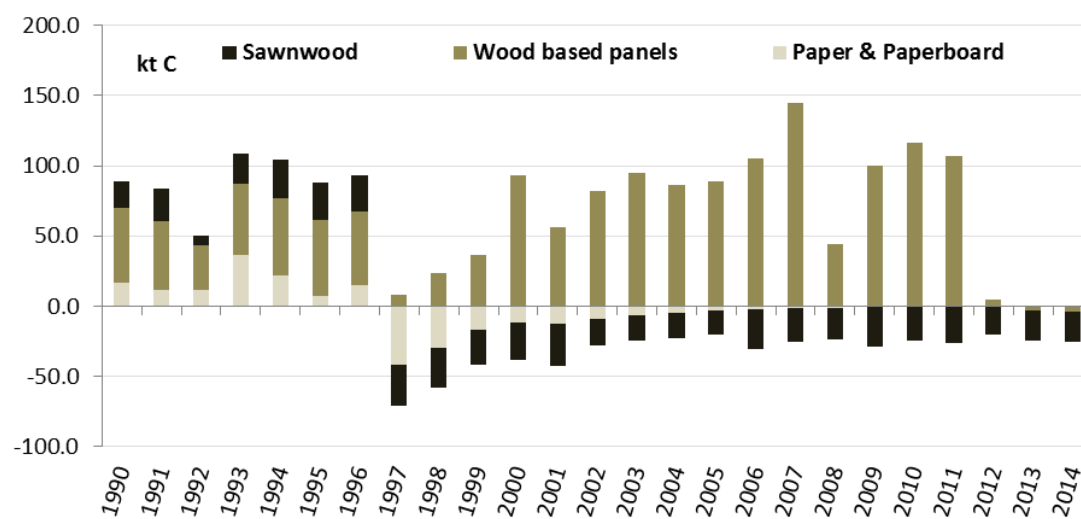


Figure 6.8 *Annual change in carbon stocks (kt)*

7. Waste (CRF sector 5)

7.1 Overview

In this chapter the emissions of greenhouse gases from the sector *Waste* are presented and the relative methodologies of emissions calculation per source are described.

According to the IPCC Directives, the following source categories are included in this sector:

- ↳ Solid waste disposal on land
- ↳ Wastewater handling
- ↳ Waste incineration
- ↳ Biological treatment

The remainder of this chapter is organized as follows, Paragraph 7.1 continues with the presentation of emissions trends from the waste sector, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for the waste sector. Then (Paragraphs 7.2 – 7.4) detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source of emissions is presented.

7.1.1 Emissions trends

In 2014 GHG emissions from *Waste* decreased by 21.8% compared to 1990 levels (**Figure 7.1**), while the average annual rate of decrease of emissions for the period 1990 – 2014 is estimated at 0.91%.

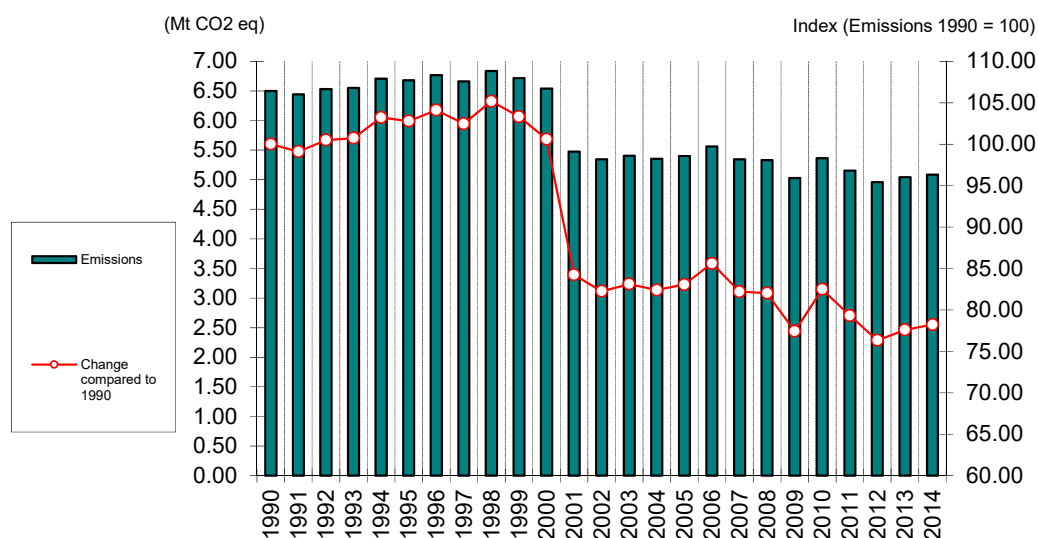


Figure 7.1 Total GHG emissions (in kt CO₂ eq) from Waste for the period 1990 – 2014

The sector *Waste* is responsible for carbon dioxide, methane and nitrous oxide emissions. GHG emissions from *Waste* per gas are presented in *Table 7.1*.

Table 7.1 *GHG emissions (in kt CO₂ eq) from Waste per gas for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
CH ₄	6219.9	6158.3	6244.6	6259.0	6414.7	6383.2	6468.4	6355.7	6529.7	6397.7	6217.6
N ₂ O	279.4	283.2	287.2	288.5	294.3	297.1	298.3	303.9	307.3	318.0	321.8
Total	6499.5	6441.8	6532.0	6547.7	6709.2	6680.5	6766.9	6659.8	6837.2	6715.9	6539.6
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO ₂	0.22	0.48	0.85	1.05	1.93	2.41	3.13	3.68	3.60	3.14	2.99
CH ₄	5159.1	5033.2	5081.0	5036.3	5074.9	5229.3	5002.4	5001.3	4703.3	5022.9	4814.9
N ₂ O	316.3	312.7	320.8	318.7	321.8	333.0	337.2	326.8	324.7	334.8	338.4
Total	5475.7	5346.4	5402.7	5356.0	5398.6	5564.7	5342.8	5331.7	5031.6	5360.9	5156.3
Year	2012	2013	2014								
CO ₂	3.23	3.12	3.11								
CH ₄	4617.4	4697.8	4740.0								
N ₂ O	341.0	341.6	341.6								
Total	4962.1	5007.2	5084.8								

Methane represents the major greenhouse gas from *Waste*, with a contribution which, however, decreased from 93.0% in 1990 to 95.7% in 2014. Overall, CH₄ emissions in 2014 decreased by 23.8% compared to 1990 levels, with an average annual rate of -1.0%.

Greenhouse gases emissions from solid waste disposal on land present an increasing trend, with some fluctuations due to variations on the CH₄ recovered each year, while, on the contrary, emissions from wastewater handling are gradually decreasing. The decrease is mostly noticeable since 1999 because of the constant increase of wastewater volume treated under aerobic conditions, while since 2002 the rate of increase is slowing down.

As a result, the major source category from *Waste* (*Figure 7.2*) since 1999 is solid waste disposal on land. On the contrary, GHG emissions from wastewater handling present a declining trend. Emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2014; though the contribution of this source to total GHG emissions of the sector is negligible.

7.1.2 Methodology

The calculation of GHG emissions from *Waste* is based on the methodologies and emission factors suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

- ↳ Data on quantities of waste generated and sent to managed or unmanaged landfills is provided by the Waste management sector of the Ministry of Environment, Energy and Climate Change (MEECC) and the ELSTAT.
- ↳ Data on population used in the calculations are provided by the ELSTAT.
- ↳ The main sources of information for the necessary data and parameters are the Ministry of Environment, Energy and Climate Change (MEECC), the Association of Communities and Municipalities in the Attica Region (ACMAR), the Athens Water Supply and Sewerage Company (EYDAP) as well as various research studies and international databases.

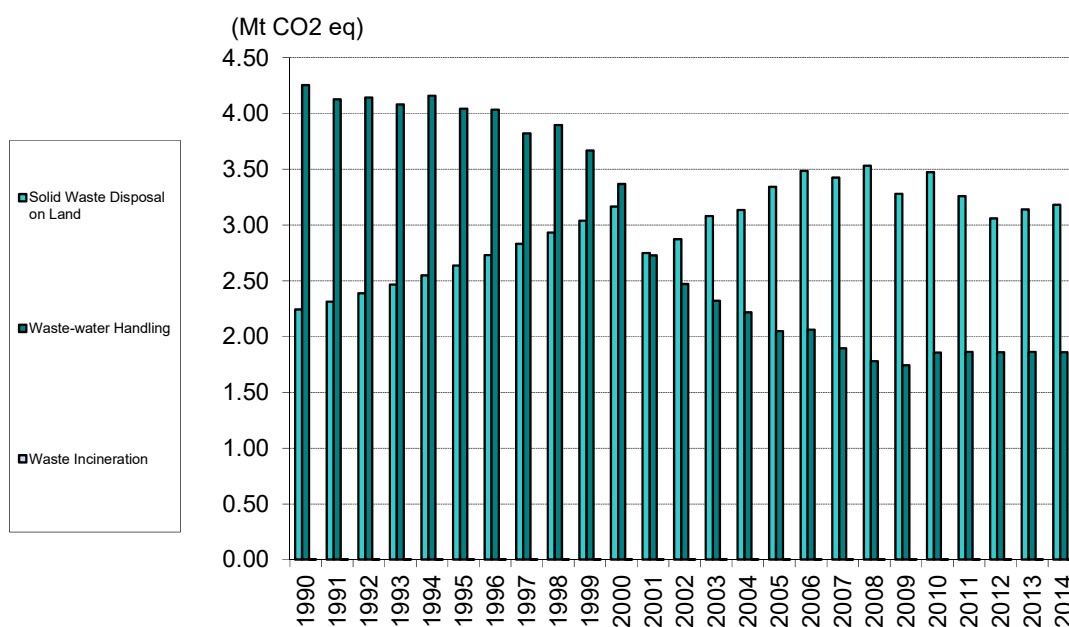


Figure 7.2 Greenhouse gases emissions (in kt CO₂ eq) from Waste per source category for the period 1990 – 2014

The methodology applied for the calculation of emissions per source category is briefly presented in *Table 7.2*, while a detailed description is given in Paragraphs 7.2 – 7.4.

Key categories

The following key categories are included in the sector *Waste* (**Table 7.3** - see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations).

Table 7.2 *Methodology for the estimation of emissions from waste*

	CO ₂		CH ₄		N ₂ O	
	Methodology	Emission Factor	Methodology	Emission Factor	Methodology	Emission Factor
Solid waste disposal on land			T2	D, CS		
Wastewater handling			D, CS	D, CS	D, CR	D, CS
Waste Incineration	D	D, CS	D	D	D	D
Biological treatment			D	D	D	D

T2: Tier 2 IPCC methodology

D: Default IPCC methodology / emission factor

CS: Country Specific

Table 7.3 *Key categories from the Waste sector*

Source category	Gas	Level assessment	Trend assessment
Solid waste disposal on land	CH ₄	☒	☒
Wastewater handling	CH ₄	☒	☒

7.1.3 Completeness

Table 7.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the waste sector.

Table 7.4 *Completeness of the GHG inventory for the waste sector*

	CO ₂	CH ₄	N ₂ O
A. Solid waste disposal on land			
1. Managed waste disposal on land	NO	☒	
2. Unmanaged waste disposal on land	NO	☒	
3. Disposal of sewage sludge	NO	☒	
4. Industrial solid waste (Managed SWDS)	NO	☒	
5. Industrial solid waste (Unmanaged SWDS)	NO	☒	
6. Construction and demolition waste (Managed SWDS)	NO	☒	
7. Construction and demolition waste (Unmanaged SWDS)	NO	☒	
B. Wastewater treatment			
1. Industrial wastewater		☒	☒
2. Domestic and commercial wastewater		☒	☒
C Waste incineration			

1. Biogenic	NA	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2. Hospital waste	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
3. Other	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
D. Other			
1 Composting	NO	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

NO: Not Occurring, NA: Not Applicable

7.2 Solid waste disposal on land (CRF Source Category 5A)

7.2.1 Description

Solid waste disposal on land is responsible for methane emissions. Methane is emitted during the anaerobic decomposition of organic waste disposed of in various solid waste disposal sites (SWDS). The main characteristic of this process is that organic waste decomposes at a diminishing rate over time and takes many years to decompose completely. Moreover, other factors such as the type of waste disposed, the characteristics of the disposal sites and the climate conditions, affect the decomposition rate.

Carbon dioxide emissions occur during the flaring of biogas released from the decomposition of waste. However, these emissions should not be included in the total GHG emissions of the sector as they are of biogenic origin. Recovery and flaring of biogas constitute a waste management practice in the major managed SWDS of Greece since 1992. The amounts of biogas flared were estimated taking into account detailed data for biogas recovery in the largest SWDSs of the country from the national energy balance.

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. Methane emissions for all the sub-categories were calculated using the First Order Decay (FOD) method (Tier 2)

The application of the FOD method requires historical data of several decades related to the waste generated, their composition over the years, the waste management practices applied and the specific conditions at the sites (e.g. organic matter, humidity, temperature). In Greece, there is a lack of an integrated national system for the collection of these data, especially for historical data, while additional difficulties are created by the existence of a significant number of unmanaged waste disposal sites still operating. Therefore, the application of the FOD method was based on assumptions and estimations of certain parameters that were impossible to be calculated analytically for each waste disposal site.

For the municipal solid waste, for the period 2001-2014 the official data provided by the MEECC was used. Concerning the data for the period 1960-2000 total quantities of generated waste were estimated according to studies by the Waste management sector of the MEECC. As far as the annual sludge generated in the wastewater treatment facilities and the amounts landfilled in the SWDS, data derive from the Waste management sector of the MEECC, EYDAP and ACMAR. Finally, for the estimation of emissions from industrial solid waste and from construction and demolition solid waste, data from ELSTA were acquired.

CH₄ emissions from solid waste disposal on land in 2014 accounted for 62.6% of total GHG emissions from Waste and for 3.14% of total national emissions (without LULUCF). The average

annual rate of increase of emissions from solid waste disposal on land, for the period 1990 – 2014 is estimated at 2.0%. CH₄ emissions from managed and unmanaged solid waste disposal sites are presented in **Table 7.5**.

Table 7.5 *CH₄ emissions (in kt) from managed and unmanaged solid waste disposal*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Managed SWDS	2.44	4.84	7.24	9.64	12.17	14.74	17.33	20.02	22.87	25.90	29.62
Unmanaged SWDS	73.97	73.39	73.05	72.92	72.87	72.95	73.16	73.40	73.63	73.76	73.88
Sludge treatment	0.44	0.85	1.24	1.61	1.96	2.37	2.76	3.22	3.64	4.04	4.49
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Managed SWDS	11.80	15.45	22.14	23.33	30.38	34.70	32.40	36.85	27.85	37.99	31.89
Unmanaged SWDS	73.77	73.73	73.84	73.33	72.62	71.86	70.30	68.51	65.60	62.97	60.39
Sludge treatment	4.92	5.43	5.93	6.44	7.26	8.09	8.39	8.64	9.26	9.49	9.62
Year	2012	2013	2014								
Managed SWDS	26.39	31.98	36.09								
Unmanaged SWDS	57.96	55.65	53.45								
Sludge treatment	9.74	9.85	9.95								

7.2.2 Methodology

The estimation of methane emissions from solid waste disposal on land is based on the application of the FOD method. The method was applied separately for the managed and unmanaged waste disposal, taking account of the different conditions in those sites and the detailed information available regarding the opening and closure years of the operation of the managed sites. Calculations were based on the following main assumptions:

↳ Unmanaged wastes are considered to be landfilled in sites of similar characteristics concerning their composition and management (depth of sites), while the starting year of disposal and degradation of total unmanaged waste is assumed to be 1960.

↳ Managed SWDS started operating in 1990, according to the decision of 1986, Joint Ministerial Decision 4951 / 1424/1986, which was prepared for the implementation of the

provisions of the European Directive 75/442/EU. The operation of the managed SWDS was reinforced in 1997 through the release of Joint Ministerial Decision 114218/1997 in which official provisions concerning the administrative procedures for the operation of the sites were issued.

↪ Industrial waste and construction and demolition solid waste is deposited in the same landfills as MSW and similar method was used for the estimation of its emissions.

The equations used for the estimation of CH₄ emissions are the following:

$$\text{CH}_4 \text{ generated at year } t: P_t = \sum_{x=x_0}^t (A \cdot k \cdot MSW_T(x) \cdot MSW_F(x) \cdot Lo(x)) \cdot e^{-k \cdot (t-x)}$$

$$\text{CH}_4 \text{ emissions at year } t: E_t = (P_t - R_t) \cdot (1 - OX)$$

$$Lo(x) = MCF \cdot DOC \cdot DOC_F \cdot F \cdot \frac{16}{12}$$

Where, P_t is methane generation in the year t , E_t is methane emissions in the year t , A is the normalization factor which corrects the summation, k is the methane generation rate constant, MSW_T is the total municipal solid waste (MSW) generated, MSW_F is the fraction of MSW disposed at solid waste disposal sites, $Lo(x)$ is the methane generation potential, R is the recovered CH₄, OX is the oxidation factor, MCF is the methane correction factor, DOC is the degradable organic carbon, DOC_F is the fraction DOC dissimilated and F the fraction by volume of CH₄ in landfill gas.

Methane emissions from sewage sludge are also calculated separately using the FOD method, considering the specific characteristics related to the DOC , DOC_F and k parameters. The sludge content of the municipal waste disposed in the SWDS is not included in the waste composition used for the calculations of methane from municipal solid waste disposal on land.

The basic steps followed for the calculation of methane emissions are presented hereafter.

Generated quantities of municipal solid waste

At national level, there is a lack of confirmed official time-series of data regarding the composition and quantity of municipal solid waste (MSW) generated. Only a limited number of recent measurements on solid waste composition exist, while the acquisition of data from disposal sites on *weighted* solid waste quantities is extremely difficult. Furthermore, prefectural authorities often face problems in hiring adequate and skilled personnel, a fact which results to significant shortages concerning maintenance and processing of related databases. Additional difficulties arise from the fact that for the majority of the previous years, a large number of unmanaged SWDS existed.

According to the Ministry of Environment, Energy and Climate Change (MEECC), 2182 unmanaged SWDS were still operating in 2000 (MEECC 2001). Following the National and Regional Planning of Solid Waste Management (compiled in the end of 2003), the process of closure and rehabilitation of unmanaged sites is already in progress and is expected to be completed in the following years, along with the construction of managed SWDS, following to the standards set by the EU directives, in order to cover the needs of the country. Nowadays, there is a small number of unmanaged WDS which is planned to be eliminated until the end of 2014.

Estimates on solid waste quantities generated are included in various reports from research programmes and studies, but refer to specific points in time rather than to a whole period, while different assumptions have been applied in each case for the estimation of quantities generated. Therefore, data for some years are either missing or are unreliable. The quantities of municipal solid wastes for the period 1960-2000 was estimated on the basis of population figures and coherent assumptions regarding generation rates per capita and day, in order to derive complete time series for waste quantities generated. For the rest of the period 2001-2014 more accurate data for the quantities of municipal solid wastes was used as they were provided by the waste management sector of the Ministry of Environment, Energy and Climate Change (MEECC).

In **Table 7.6** the estimated data on population served for the whole period 1960-2014 is presented.

Table 7.6 *Total population served (in thousands)*

Year	Permanent population	Tourists (in equivalent permanent)	Total population served
1960	8350.54	79.73	8430.27
1965	8540.59	81.75	8622.34
1970	8730.63	83.83	8814.46
1975	9157.35	85.96	9243.31
1980	9643.24	88.14	9731.38
1985	9948.21	97.24	10045.45
1990	10156.90	99.45	10256.35
1991	10256.29	83.62	10339.91
1992	10369.87	101.09	10470.96
1993	10465.53	101.67	10567.19
1994	10553.04	113.49	10666.53
1995	10634.39	106.22	10740.61
1996	10709.17	97.25	10806.43
1997	10776.50	108.80	10885.30
1998	10834.88	115.53	10950.41
1999	10882.58	124.61	11007.19
2000	10917.48	127.18	11044.66
2001	10949.96	119.05	11069.01
2002	10987.54	110.55	11098.09
2003	11019.04	110.71	11129.74

2004	11050.62	111.97	11162.60
2005	11103.92	111.60	11215.53
2006	11148.46	117.96	11266.42
2007	11192.85	131.73	11324.58
2008	11237.07	131.44	11368.50
2009	11282.75	127.88	11410.63
2010	11305.12	134.21	11439.33
2011	11309.89	149.36	11459.25
2012	11290067	150.75	11440.82
2013	11303634	161.49	11465.27
2014	11296109	169.76	11465.87

For the estimation of the quantities of municipal solid wastes the method was used in previous submission were based on the assumption that MSW generation rates was in the order of 0.8 – 1.1 kg/ capita and day, depending on the type of region (rural, semi-urban, urban, large urban regions) in 1997. According to the Ministry of Environment, Energy and Climate Change (MEECC) the MSW generation rate was assumed to change annually by 0.028 kg/ capita and day, while a higher figure (annual increase by 0.035 kg/capita and day) was assumed for the regions of Athens, Central Macedonia, Crete and the islands of South Aegean. A higher figure for MSW generation rate (2.1 kg/ capita and day) was considered for foreign visitors. For the period 1960 – 1990 the rates of annual per capita waste increase are lower (0.8% - 1.5% depending on the region). The average values of daily waste generation rates estimated, are presented In **Table 7.7**.

Table 7.7 *Waste generation rates (kg/cap/day) of permanent population and tourists*

Year	Permanent population	Tourists	Total population
1960	0.566	1.400	0.573
1965	0.611	1.530	0.620
1970	0.656	1.659	0.666
1975	0.697	1.789	0.707
1980	0.735	1.919	0.746
1985	0.772	2.048	0.785
1990	0.809	2.100	0.821
1991	0.816	2.100	0.827
1992	0.844	2.100	0.856
1993	0.872	2.100	0.884
1994	0.901	2.100	0.913
1995	0.929	2.100	0.940
1996	0.957	2.100	0.967

1997	0.985	2.100	0.996
1998	1.017	2.100	1.029
1999	1.050	2.100	1.062
2000	1.082	2.100	1.094
2001	1.118	2.100	1.128
2002	1.136	2.100	1.145
2003	1.150	2.100	1.159
2004	1.164	2.100	1.174
2005	1.176	2.100	1.186
2006	1.189	2.100	1.198
2007	1.200	2.100	1.210
2008	1.213	2.100	1.224
2009	1.228	2.100	1.237
2010	1.403	2.100	1.411
2011	1.325	2.100	1.335
2012	1.276	2.100	1.287
2013	1.207	2.100	1.219
2014	1.193	2.100	1.207

On the basis of the above, the following MSW quantities for the years 1990 – 2014 were estimated (**Table 7.8**). For the period 2001-2014, confirmed data were obtained from the Waste management sector of the Ministry of Environment, Energy and Climate Change (MEECC) as it is mentioned above. These data is presented in **Table 7.8**.

Table 7.8 *Quantities of MSW generated by year (in Mt)*

Year	1960	1965	1970	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Generated MSW	1.765	1.951	2.142	2.384	2.651	2.877	3.075	3.119	3.273	3.41	3.556	3.686	3.815	3.958	4.112
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Generated MSW	4.266	4.411	4.559	4.640	4.710	4.781	4.854	4.927	5.002	5.077	5.154	5.892	5.586	5.376	5.102
Year	2014														
Generated MSW	5.051														

Composition of generated municipal solid waste

As mentioned before, accurate data on the composition of municipal solid waste generated at national level are not available, as a comprehensive analysis at national scale covering a complete

time period (so as to take into account seasonal variations because of tourist activity) has not been accomplished yet. However, measurements in some regions have been carried out, although they refer to different time periods (e.g. ULAPA 1996, MEECC 1999). Recent estimates of the composition of MSW at national level exist only for 1997 (MEECC 1998), while a more recent analysis obtained by ACMAR at the Attica region during 2007.

As far as the evolution of the waste composition is concerned, the following assumptions were considered (MEECC 2001a) for the period 1990-2014:

↳ The share of putrescibles is assumed to decrease by 0.3% annually, while metals and glass are assumed to decrease annually by 0.1% and 0.02% respectively.

↳ The share of paper and plastics is assumed to increase by 0.2% annually.

↳ The share of garden (yard) waste, park waste and other non-food organic putrescibles, wood and textiles is assumed to be constant.

For the period 1960 – 1990 an annual increase (backwards) of 0.2% was assumed for putrescibles, metals and glass are also assumed to increase (backwards) by 0.1% and 0.02% respectively, while paper and plastics are assumed to decrease annually (backwards) by 0.1% and 0.2% respectively.

The estimated composition of generated MSW on an annual basis is presented in **Table 7.9**.

Table 7.9 *Estimated composition (%) of MSW generated for the period 1990 - 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food	49.10	48.80	48.50	48.20	47.90	47.60	47.30	47.00	46.70	46.40	46.10
Non-Food	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Textiles	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Wood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Paper	18.60	18.80	19.00	19.20	19.40	19.60	19.80	20.00	20.20	20.40	20.60
Plastics	7.10	7.30	7.50	7.70	7.90	8.10	8.30	8.50	8.70	8.90	9.10
Metals	5.20	5.10	5.00	4.90	4.80	4.70	4.60	4.50	4.40	4.30	4.20
Glass	4.64	4.62	4.60	4.58	4.56	4.54	4.52	4.50	4.48	4.46	4.44
Rest	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Soils	6.61	6.63	6.65	6.67	6.69	6.71	6.73	6.75	6.77	6.79	6.81
Other											
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Food	45.80	45.50	45.20	44.90	44.60	44.30	44.00	43.70	43.40	43.10	42.80
Non Food	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Textiles	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Wood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Paper	20.80	21.00	21.20	21.40	21.60	21.80	22.00	22.20	22.40	22.60	22.80
Plastics	9.30	9.50	9.70	9.90	10.10	10.30	10.50	10.70	10.90	11.10	11.30
Metals	4.10	4.00	3.90	3.80	3.70	3.60	3.50	3.40	3.30	3.20	3.10

Glass		4.42	4.40	4.38	4.36	4.34	4.32	4.30	4.28	4.26	4.24	4.22
Rest	Soils	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Other	6.83	6.85	6.87	6.89	6.91	6.93	6.95	6.97	6.99	7.01	7.03
Year		2012	2013	2014								
Food		42.50	42.20	41.90								
Non Food		1.50	1.50	1.50								
Textiles		3.25	3.25	3.25								
Wood		1.00	1.00	1.00								
Paper		23.00	23.20	23.40								
Plastics		11.50	11.70	11.90								
Metals		3.00	2.90	2.80								
Glass		4.20	4.18	4.16								
Rest	Soils	3.00	3.00	3.00								
	Other	7.05	7.07	7.09								

Quantities and composition of MSW at disposal sites

In order to estimate the quantities of MSW that end up at disposal sites (managed or unmanaged), data on the recycling of paper, aluminium, metals, plastics and glass in different regions were collected. Recycled quantities estimated, include also the part of putrescibles used for compost production. The estimated composition of the disposed municipal solid wastes in the two categories of SWDS (managed and unmanaged) is presented in *Table 7.10*.

Table 7.10 *Estimated composition (%) of MSW disposed for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food	54.22	53.80	53.28	52.76	52.24	51.76	51.29	50.48	50.05	49.61	49.19
Non-Food	1.66	1.65	1.65	1.64	1.64	1.63	1.63	1.64	1.63	1.63	1.65
Textiles	3.59	3.58	3.57	3.56	3.54	3.53	3.52	3.55	3.54	3.53	3.52
Wood	1.10	1.10	1.10	1.09	1.09	1.09	1.08	1.09	1.09	1.09	1.08
Paper	11.56	11.89	12.47	12.97	13.46	13.89	14.31	14.87	15.29	15.71	16.09
Plastics	7.84	8.04	8.24	8.42	8.61	8.80	9.00	9.12	9.28	9.45	9.63
Metals	5.74	5.62	5.39	5.24	5.10	4.98	4.85	4.78	4.65	4.52	4.39
Glass	3.69	3.68	3.71	3.73	3.75	3.76	3.76	3.81	3.82	3.83	3.83
Rest	Soils	3.31	3.31	3.30	3.28	3.27	3.26	3.25	3.28	3.27	3.25
	Other	7.30	7.31	7.31	7.30	7.30	7.30	7.37	7.38	7.38	7.38
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Food	50.23	49.87	49.19	49.90	50.05	48.93	52.83	50.93	52.85	49.36	48.61

Non Food	1.65	1.64	1.63	1.67	1.70	1.72	1.88	1.82	1.85	1.81	1.83
Textiles	3.56	3.56	3.54	3.62	3.67	3.73	4.06	3.95	4.01	3.93	3.96
Wood	0.86	0.86	0.86	0.88	0.90	0.91	1.00	0.98	0.99	1.00	1.00
Paper	14.88	15.17	16.00	15.36	15.33	16.16	5.71	9.04	6.74	10.72	11.03
Plastics	10.01	10.21	10.35	10.67	10.96	11.30	13.13	13.00	13.44	13.41	13.79
Metals	4.25	4.12	3.97	3.77	3.57	3.45	4.36	4.12	4.05	3.85	3.77
Glass	3.79	3.76	3.73	3.14	2.62	2.40	4.58	4.07	3.75	3.83	3.78
Rest Soils	3.29	3.29	3.26	3.34	3.39	3.44	3.75	3.64	3.70	3.62	3.66
Other	7.49	7.51	7.48	7.66	7.81	7.95	8.69	8.47	8.62	8.47	8.58
Year	2012	2013	2014								
Food	46.28	46.16	45.85								
Non Food	1.79	1.81	1.81								
Textiles	3.88	3.92	3.93								
Wood	0.97	0.97	0.97								
Paper	14.20	13.87	14.00								
Plastics	13.72	14.10	14.37								
Metals	3.56	3.48	3.47								
Glass	3.61	3.55	3.52								
Rest Soils	3.58	3.62	3.62								
Other	8.41	8.52	8.56								

For each managed SWDS of those sites, the start year of operation was taken into account, together with data and estimations on the quantities and composition of MSW generated in the areas served by those sites, as well as data on the quantities of recycled materials.

The remaining part of MSW (after the subtraction of the corresponding quantities of the recycled materials in the remaining regions) is disposed at unmanaged disposal sites (*Table 7.11*).

Table 7.11 *Estimated quantities of MSW and sludge disposed (in kt) and Degradable Organic Carbon (DOC) per category (in kt)*

Year	Managed SWDS	DOC – managed SWDS	Unmanaged SWDS	DOC – unmanaged SWDS	Sludge (dry)	DOC - sludge
1960			1764.55	272.93		
1965			1900.67	282.70		
1970			2073.38	306.04		
1975			2290.65	334.87		
1980			2522.02	363.87		
1985			2726.94	392.06		

1990	1160.08	160.31	1624.67	224.52	43.40	17.36
1991	1198.41	166.44	1630.78	226.49	43.40	17.36
1992	1246.11	174.92	1733.21	243.29	43.40	17.36
1993	1295.02	183.30	1820.73	257.71	43.40	17.36
1994	1406.12	200.64	1854.26	264.59	43.40	17.36
1995	1477.90	212.31	1911.78	274.64	51.62	20.65
1996	1544.44	223.33	1973.34	285.36	51.62	20.65
1997	1639.62	238.94	1983.06	288.99	61.00	24.40
1998	1799.82	264.08	896.79	131.58	59.32	23.73
1999	2005.12	296.17	1921.72	283.86	60.14	24.05
2000	2160.65	321.05	1909.25	283.69	66.34	26.53
2001	2336.78	338.13	1820.22	263.38	67.76	27.10
2002	2379.56	345.80	1853.55	269.36	77.65	31.06
2003	2423.82	357.68	1904.43	281.04	79.76	31.90
2004	2705.28	395.98	1592.98	233.17	83.37	33.35
2005	2824.04	413.96	1470.51	215.55	116.77	46.71
2006	2875.51	426.68	1419.55	210.64	123.20	49.28
2007	2805.07	318.00	1194.25	135.39	73.95	29.58
2008	3227.59	433.63	952.81	128.01	71.63	28.65
2009	3939.36	505.83	241.55	31.02	109.21	43.69
2010	4563.64	632.99	314.00	43.55	74.87	29.95
2011	4312.79	599.49	265.67	36.93	65.35	26.14
2012	4241.83	626.45	265.00	39.14	64.86	25.94
2013	3967.87	563.11	265.00	37.61	64.86	29.19
2014	3916.85	556.12	265.00	37.63	64.86	29.19

The amount of dry sewage sludge disposed in the managed site of Athens is also presented in Table 8.11. The degradable organic carbon and the fraction of DOC dissimilated are both estimated at 40%. The fraction of methane in the landfill gas released from sludge is 60%.

Biogas flaring

According to data from the MEECC, recovery and flaring of biogas constitute management practices in the 4 major managed SWDS of Greece (in the cities of Athens, Patra, Thessalonika and Larissa). For two of these sites, Athens and Thessalonika, biogas is used for energy generation. For the other two sites, Patra and Larissa, flaring of biogas constitutes management practice for environmental protection and not for energy recovery. From the National Energy balance, data are collected in Energy units, so for the transformation to methane mass recovered the proposed value of Net calorific value (50.4 TJ/Gg) by the IPCC 2006, CHAPTER 1 INTRODUCTION of Energy

Chapter, Page 1.19, is used. In **Table 7.12**, quantities of waste disposed in these two sites for which the CH₄ recovery is based on assumptions and the amount of methane obtained by the energy balance, are presented. For the rest of the sites that biogas is only flared, no CH₄ recovery is considered following the recommendation by the 2000 IPCC guidelines, Page 5.10. According to this recommendation ‘The default value for methane recovery is zero. This default should only be changed when references documenting the amount of methane recovery are available. Recovered gas volumes should be reported as CH₄ not as landfill gas, as landfill gas contains only a fraction of CH₄. Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with good practice. The use of undocumented estimates of landfill gas recovery potential is not appropriate, as such estimates tend to overestimate the amount of recovery.’ (Bilateral Review)

Table 7.12 *CH₄ recovery from biogas flaring in managed SWDS*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ recovery in Athens and Thessalonica (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.32	0.0
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ recovery in Athens and Thessalonica (kt)	23.77	23.61	20.04	23.06	19.64	19.23	24.58	23.51	38.43	33.63	45.99
Year	2012	2013	2014								
CH ₄ recovery in Athens and Thessalonica (kt)	57.68	56.07	55.77								

Industrial solid waste

Similarly with the municipal solid waste generated at national level, there are no available data for the industrial solid waste generated and disposed in sites for the whole of period of 1960 to 2014. Emissions from this source are estimated using the industrial waste amounts disposed in land provided by ELSTAT. These amounts are collected by the experts of ELSTAT based on individual researches (e.g. questionnaires sent to industries, etc).

It must be noticed that these data are provided by ELSTAT only for the years 2004, 2006 and 2008. Thus, the historical data necessary for the rest of the years were estimated by using relative drivers i.e. the Greek GDP for the case of paper, wood and textiles and the Gross Production Value of livestock for the case of animal waste from food preparation and products, for the period 1960 to 2009.

According to the data provided by the ELSTAT., industrial waste, i.e. Animal waste from food preparation and products, Paper, Wood, Textiles, Mixed waste residues and Sorting waste residues are generated by the following manufacturing plants:

1. Manufacture of food products; beverages and tobacco products,
2. Manufacture of textiles, wearing apparel, leather and related products,
3. Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials,
4. Manufacture of paper and paper products; printing and reproduction of recorded media.

According to the experts of ELSTAT., the amounts of waste disposed in SWDS are those presented in **Table 7.13** for the years 2004, 2006 and 2008.

Table 7.13 *Disposed industrial waste (in tn)*

Year	Paper	Wood	Textiles	Animal waste of food preparation and products
2004	-	1433	2980	19659
2006	15114	949	4417	-
2008	27388	4115	2987	23874

Concerning the distribution of Industrial waste disposed to managed and unmanaged solid waste disposal sites, it is considered it is the same with this of the municipal solid waste taking into account that managed solid waste disposal sites started operating in Greece in 1990.

Construction and demolition solid waste

Similarly with the MSW and the industrial solid waste generated at national level, there are no available data for the construction and demolition solid waste generated and disposed in sites for the whole of period of 1960 to 2014.

Figures for construction and demolition solid waste are provided by ELSTAT for the years 2006, 2008 and 2010, **Table 7.14**, considering that they consist of wood, plastic and class. Thus, similar with industrial solid waste, the historical data necessary for the rest of the years were estimated by using relative drivers. Actually, the gross domestic product (GDP) was used as a key driver up to

1995, while for the remaining years of the time series the gross value added (GVA) was used because GVA data are not available for the years prior to 1995.

Table 7.14 *Disposed construction and demolition solid waste (in kt)*

Year	Wood	Plastic	Glass
2006	662.5	421.6	120.5
2008	662.5	421.6	120.5
2010	202.1	128.6	36.8

As far as the distribution of construction and demolition solid waste disposed to managed and unmanaged solid waste disposal sites is concerned, it is considered that it is the same with the one of the municipal solid waste taking into account that managed solid waste disposal sites started operating in Greece in 1990.

Methane generation rate constant

The methane generation rate constant k is related to the time taken for the degradable organic carbon in waste to decay to half its initial mass:

$$k = \ln 2 / t_{1/2}$$

where $t_{1/2}$ is the time taken for the DOC in waste to decay to half its initial mass ("half life") of waste during degradation process.

The estimation of k is determined by the conditions in the disposal sites (e.g. moisture content, temperature, soil type) and by the composition of waste land filled. Considering the fact that climate in Greece is dry temperate (the ratio of mean annual precipitation to potential evapotranspiration (MAP/PET) is around 0.5), "half life" was estimated at 17 years for paper and textiles, 35 for wood, 12 years for food waste, 14 years for non-food waste and 9 years for sewage sludge disposed on land.

Other parameters

↳ Methane Correction Factor (MCF): 1 for managed SWDS, 0.8 for unmanaged SWDS.

- ↳ Degradable organic carbon (DOC): 0.4 for paper and textiles (default value), 0.3 for wood (default value), 0.15 for food waste (default value), 0.17 for non-food waste and 0.4 for sewage sludge.
- ↳ Fraction of DOC dissimilated (DOC_F) for solid waste. The default value of 0.6 was used as suggested in the IPCC good practice guidance.
- ↳ Fraction of DOC dissimilated (DOC_F) for sewage sludge 0.6 was used, the suggested figure by the IPCC good practice guidance.
- ↳ Fraction of methane in landfill gas (F): 50% (default value) for solid waste, 60% for sewage sludge.
- ↳ Oxidation factor (OX): 0.1 for managed SWDS, 0.0 for unmanaged SWDS (default values)

7.2.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ emissions from unmanaged SWDS and managed SWDS for MSW as % of total emissions are estimated by 1.0% and 0.4%, respectively. The combined uncertainty of CH₄ emissions from unmanaged SWDS and managed SWDS for Industrial waste as % of total emissions are estimated by 0.02% and 0.015%, respectively. The combined uncertainty of CH₄ emissions from unmanaged SWDS and managed SWDS for Construction and demolition as % of total emissions are estimated by 0.2% and 0.1%, 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 CH₄ emissions from unmanaged SWDS and managed SWDS are 72 % and 40 %, respectively, as it is estimated according to Good Practice Guidance.

The combined uncertainty of CH₄ 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 %.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.2.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the waste sector are:

1. Cross checking information regarding waste quantities, composition and sewage sludge by waste management sector of MEECC and by Association of Communities and Municipalities in the Attica Region (ACMAR).
2. Cross checking information provided by the waste management sector of Ministry of Environment, Energy and Climate Change (MEECC) and by the Ministry of Development, regarding the biogas recovered in MSW disposal sites which is used for energy generation.

3. Comparison of information regarding waste quantities, composition and sewage sludge with this for other countries.
4. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

7.2.5 Recalculations

Updated activity data are used for the CH₄ recovery from biogas flaring in managed SWDS for 2012 and 2013.

The deviation of the emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions from the sector of recalculations are presented in **Table 7.15**.

Table 7.15 *Recalculations of CH₄ emissions from solid waste disposal*

Year	1990	1991
Difference (kt CO ₂ eq)	-0.45	35.25
Impact on Emissions from Agriculture (%)	-0.01	0.76

7.2.6 Planned improvements

Further investigation regarding composition of disposed wastes is planned. The development of a central database which will include most of the above data has already been scheduled by the Ministry of Environment, Energy and Climate Change (MEECC) and is expected to provide valuable information in the near future. Furthermore, the National and Regional Planning for the Solid Waste Management is expected to provide data regarding the process of unmanaged sites rehabilitation and the construction of new managed sites.

7.3 Wastewater handling (CRF Source Category 5B)

7.3.1 Description

Domestic and industrial wastewater handling under anaerobic conditions produces CH₄. In Greece, domestic wastewater handling in aerobic treatment facilities shows a substantial increase since 1999, while in the industrial sector only a few units exist where wastewater is handled under anaerobic conditions.

N₂O emissions from industrial wastewater handling and from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) are also included in the wastewater handling source category.

Wastewater handling is a key category of CH₄ emissions, which have a substantial contribution in emissions trends (trend assessment). In **Table 7.16** CH₄ and N₂O emissions from wastewater handling for the period 1990 – 2014 are presented.

CH₄ emissions from domestic wastewater handling and industrial wastewater handling in 2014 decreased compared to 1990 levels. The reduction of emissions from domestic wastewater handling is mainly due to the increased number of wastewater handling facilities under aerobic conditions. According to estimates provided by the Ministry of Environment, Energy and Climate Change (MEECC) the penetration of such facilities increased from 32% (of total population served) in 1999 and to 91.0% in 2014. N₂O emissions from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) increased by 15.6% compared to 1990 levels. N₂O emissions from industrial wastewater handling increased by 5.6% compared to 1990 levels.

Considering the fact that there are not sufficient data regarding all the wastewater handling facilities of the country and as a result methane emissions are calculated based on the total population served. Emissions from domestic wastewater treatment and the sewage sludge removed from wastewater are not considered separately. However, as it is already mentioned in Paragraph 8.2, methane emissions from sewage sludge disposed in managed sites have been estimated. Therefore, in order to avoid double counting of emissions from sludge treatment, the organic load (in biochemical oxygen demand) of sludge that is actually disposed on land was subtracted by the organic load of wastewater treated.

Table 7.16 CH₄ and N₂O emissions (in kt) from wastewater handling

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Domestic and commercial wastewater	CH ₄	118.4	116.8	114.6	110.4	109.2	107.2	105.1	101.3	97.4	92.6	73.8

Human sewage	N ₂ O	0.919	0.933	0.945	0.950	0.968	0.977	0.980	0.992	1.000	1.038	1.048
Industrial wastewater	CH ₄	40.7	37.0	39.6	41.4	45.4	42.6	44.4	39.6	46.3	41.6	48.2
Industrial wastewater	N ₂ O	0.018	0.017	0.018	0.018	0.020	0.019	0.021	0.019	0.021	0.019	0.021
Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Domestic and commercial wastewater	CH ₄	46.3	40.7	35.0	28.9	25.2	22.7	21.1	20.8	20.3	20.8	20.9
Human sewage	N ₂ O	1.039	1.028	1.054	1.046	1.054	1.070	1.083	1.046	1.060	1.063	1.065
Industrial wastewater	CH ₄	50.1	45.7	45.0	47.1	44.0	46.7	41.6	37.6	36.5	40.6	40.7
Industrial wastewater	N ₂ O	0.022	0.021	0.021	0.022	0.021	0.022	0.022	0.020	0.018	0.019	0.019
Year		2012	2013	2014								
Domestic and commercial wastewater	CH ₄	20.8	20.9	20.9								
Human sewage	N ₂ O	1.063	1.065	1.065								
Industrial wastewater	CH ₄	40.6	40.6	40.6								
Industrial wastewater	N ₂ O	0.019	0.019	0.019								

7.3.2 Methodology

CH₄ and N₂O emissions from domestic wastewater handling and N₂O emissions from commercial wastewater handling were estimated according to the default methodologies suggested by IPCC. CH₄ emissions from commercial wastewater handling were estimated based on country specific data as well as on IPCC default values.

CH₄ emissions from domestic and commercial wastewater handling

It is estimated that about 91% of Greek population in 2014 was served by domestic wastewater treatment systems in compliance with the Directive 91/271/EEC (3rd Programming Period). These 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. This process occurs in biological gradient, consisting of bioreactors and final sedimentation tanks, which precipitated the biological sludge. The final output is the sea with an undersea pipeline system deep diffusion. As it is mentioned in Chapter 7.2.2, the final sludge is landfilled in the SWDS.

The remaining 9% of Greek population, mainly this in remote areas was not served by a wastewater treatment system and it is going to change during the 4th Programming period, thus, it is considered their wastewater discharges in sea, river etc.

Methane emissions from domestic and commercial wastewater handling are calculated using the following equations:

$$\text{CH}_4 \text{ emissions} = \text{TOW} \times \text{EF} - \text{MR}$$

$$\text{TOW} = P \times D_{\text{dom}}$$

$$\text{EF} = \text{Bo} \times \text{MCFs}$$

The parameters used are presented hereafter:

↳ **Total organic waste, *TOW***. The calculation of total organic waste is based on population data (*P*), as presented in **Table 7.6**, and the degradable organic component *D_{dom}*, that is set equal to 0.057 kg BOD/person/day (2006 IPCC, Chap. 6, page 6.14, Table 6.4, suggested figure for Greece) following also Bilateral Review with experts from Spain recommendation.

↳ **Emission factor, *EF***. The emission factor is estimated considering the maximum methane production potential *Bo* and the weighted average of the methane conversion factors (*MCFs*), for the different wastewater treatment systems used in the country. The value of 0.6 kg CH₄/kg BOD was used for the domestic wastewater handling while the value of 0.25 kg CH₄/kg COD was used for the industrial wastewater handling, as suggested by the IPCC Good Practice Guidance. The MCF indicates the extent to which the methane producing potential (Bo) is realised in each type of treatment method. The default values for these factors are 0 for aerobic conditions and 1 for anaerobic conditions (and these values were applied in the calculations).

↳ **Methane recovery *MR*** is considered to be equal to zero.

In **Table 7.17** the degradable organic waste (as kt BOD) for the period 1990 – 2014, is presented.

The calculation of BOD from sludge removed and disposed on land is based on the amounts of sludge transferred in the managed SWDS of Athens (**Table 7.11**) and the following parameters:

↳ Volume of biogas per unit of dry matter: 200 m³/ tn dry matter. The factor results from the data provided by EYDAP.

↳ Methane density: 0.7 kg CH₄/ m³

↳ Fraction of methane in sludge biogas (F): 0.6

Table 7.17 *BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2014*

Year	Wastewater	Sludge
1990	206.87	6.51
1991	208.61	6.51
1992	211.33	6.51
1993	213.34	6.51
1994	215.40	6.51
1995	216.48	6.98
1996	217.85	6.98
1997	218.23	8.24
1998	219.81	8.02
1999	220.88	8.13
2000	220.82	8.96
2001	221.13	9.16
2002	220.40	10.49
2003	220.78	10.78
2004	220.97	11.27
2005	217.55	15.78
2006	217.37	17.02
2007	217.51	18.10
2008	218.13	18.39
2009	216.92	20.47
2010	223.96	14.04
2011	226.16	12.25
2012	225.87	12.16
2013	226.37	12.16
2014	226.39	12.16

Biochemical oxygen demand (BOD) for sludge is finally subtracted from total BOD and methane emissions are calculated based on the fraction of BOD that degrades anaerobically. The relevant data are included in the reports of the Ministry of Environment, Energy and Climate Change (MEECC) on the implementation of EU Directive 91/71 regarding the collection, treatment and disposal of municipal wastewater.

N₂O emissions from domestic wastewater handling

N₂O emissions from domestic wastewater handling are estimated as the indirect nitrous oxide emissions from human consumption of food and their subsequent treatment through wastewater handling systems are estimated by the following equation:

$$\text{N}_2\text{O emissions} = \text{Protein} \times P \times \text{Frac}_{\text{NPR}} \times \text{EF (N}_2\text{O-N/N)}$$

Data on protein consumption (*Protein*) are provided by FAO. The population (*P*) used, is the one presented in **Table 7.6**, while the values of the parameters regarding the fraction of protein that is nitrogen (*Frac_{NPR}*) and the conversion of nitrogen to nitrous oxide [*EF (N₂O-N/N)*] are those suggested by the IPCC Guidelines.

In **Table 7.18** the consumption of protein (kg/person/year) for the period 1990 – 2014, is presented.

Table 7.18 *Annual protein consumption (in kg/person) for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Protein (kg/capita)	40.73	41.00	41.02	40.85	41.23	41.36	41.23	41.41	41.53	42.87	43.15
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Protein (kg/capita)	42.65	42.10	43.07	42.60	42.70	43.18	43.47	41.83	42.23	42.23	42.23
Year	2012	2013	2014								
Protein (kg/capita)	42.23	42.23	42.23								

CH₄ emissions from industrial wastewater handling

The methodology for calculating methane emissions from industrial wastewater is similar to the one used for domestic wastewater. In order to estimate the total organic waste produced through anaerobic treatment, the following basic steps were followed:

- ↳ Collection of data (from the ELSTAT) regarding industrial production of approximately 25 industrial sectors / sub-sectors for the period 1990 – 2014.
- ↳ Calculation of wastewater generated, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice Guidance in case where country specific data were not collected per industrial sector (m³ of wastewater/t product).
- ↳ Calculation of degradable organic fraction of waste, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice Guidance in case where country specific data were not collected (kg COD/m³ wastewater) for each sector / sub-sector.
- ↳ The distribution between aerobic and anaerobic treatment of industrial wastewater for each industrial sector was estimated on the basis of data derived from a project financed by the Ministry

of Environment, Energy and Climate Change (MEECC) (2001b). The maximum methane production potential factors B_0 and the methane conversion factors for aerobic and anaerobic treatment, which were used for the final estimation of methane emissions, are similar to those used for domestic wastewater handling.

Country specific data were collected, thus additional industrial sectors with 100 % aerobic treatment of their wastewater were included in the estimation. In the previous submission, in case where 100% of sector was served by aerobic treatment, it was not taken into account, considering zero emissions. The additional sectors included in the wastewater were additional subsectors of food and beverage, and the sectors of paper and pulp, organic chemicals, soap and detergents, plastic and resins, paints and Petroleum Refinery in the already existing sectors of food and beverage, and in the sugar and textiles sectors.

In **Table 7.19** the degradable organic waste generated by each sector (as COD) for the period 1990 – 2014, is presented.

Table 7.19 *Total industrial wastewater in COD (in kt) produced from each industrial sector for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food and beverage	211.21	190.81	204.60	215.21	237.96	221.69	228.86	201.32	238.64	219.43	253.30
Paper and pulp	6.30	6.01	6.01	4.50	4.10	4.49	4.16	3.58	3.98	3.92	4.40
Organic chemicals	0.50	0.44	0.53	1.28	1.22	1.28	1.32	1.36	1.00	0.60	0.57
Other	25.23	25.22	26.74	25.85	29.36	29.61	33.35	31.38	33.98	29.58	32.91
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Food and beverage	265.54	237.05	231.90	245.87	224.20	236.17	205.24	173.86	178.85	205.12	206.51
Paper and pulp	4.46	4.72	4.94	5.15	5.62	5.54	5.21	5.11	4.93	4.50	3.69
Organic chemicals	0.35	0.35	0.35	0.35	0.40	1.59	1.61	13.38	9.47	11.26	11.21
Other	33.23	33.31	35.29	34.52	36.28	38.65	40.98	37.59	30.49	27.84	28.29
Year	2012	2013	2014								
Food and beverage	205.82	206.17	205.99								
Paper and pulp	4.10	3.90	4.00								
Organic chemicals	11.24	11.22	11.23								
Other	28.07	28.18	28.12								

CH₄ emissions from sludge generated industrial wastewater handling

For the estimation of CH₄ emissions from sludge generated industrial wastewater handling is being used a methodology similar to the one used for the estimation of CH₄ emissions from industrial wastewater handling using the same country specific and default factors. Having estimated the degradable organic component from industrial wastewater handling treated anaerobically as described in the previous paragraph, the remaining part is considered as this treated aerobically.

The fraction of it removed as sludge is estimated based either on published data for some major Greek companies (see Vlyssides et al., 2004; Vlyssides et al., 2006; Vlyssides et al., 2007; Vlyssides et al., 2008) or on assumptions for the industrial sectors that there are not sufficient data. In general, it is considered the aerobically systems is composed of a primary treatment of wastewater (mainly a primary clarifier) and a secondary treatment, which is consisted of an aeration tank and a final clarifier. The fraction of total degradable organic component removed through the primary clarifier is considered equal to 30% for the industrial sectors for which there are no available data while the 50 % of the remaining is removed through the secondary clarifier.

The maximum methane production potential (Bo) is equal to 0.25 kg CH₄/kg COD, as suggested by the IPCC Good Practice Guidance while the methane recovery is considered to be equal to zero.

The degradable organic waste of industrial sludge (as COD) for the whole time series period 1990 – 2014 is presented in *Table 7.20*.

Table 7.20 *TOW (in COD kt) removed as sludge from industrial wastewater handling for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
COD (kt)	138.38	127.12	135.65	140.44	155.98	147.48	153.56	136.29	158.62	145.70	166.36
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
COD (kt)	172.94	157.04	156.18	163.40	153.41	161.73	145.87	133.31	129.46	144.32	144.41
Year	2012	2013	2014								
COD (kt)	144.37	144.39	144.38								

N₂O emissions from industrial wastewater handling

N₂O emissions from industrial wastewater have been estimated on the basis of the emission factors equal to 0.25 g N₂O/m³ of wastewater production (EMEP/CORINAIR, 2007). The waste water production is resulting from the model for the estimation of methane emissions from industrial waste water. The waste water production for the whole time series period 1990 – 2014 is presented in *Table 7.21*.

Table 7.21 *Waste water production from the industrial sector (1000000m³) for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Waste water	72.42	69.86	73.74	71.71	78.41	76.62	82.12	74.08	83.74	76.72	85.74
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Waste water	89.79	83.67	85.72	87.63	84.59	89.62	86.63	81.79	73.98	76.53	76.46
Year	2012	2013	2014								
Waste water	76.46	76.47	76.48								

7.3.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ 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 N₂O 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 results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.3.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the wastewater sector are:

1. Cross checking information regarding wastewater generated per production unit and degradable organic fraction of waste factors received by different Greek Industries.
2. Comparison of information regarding wastewater factors with this for other countries.

3. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

7.3.5 Recalculations

No recalculations were performed.

7.3.6 Planned improvements

The treatment conditions of the industrial wastewater and the distribution of different wastewater treatment systems are expected to be examined further in order to improve more the methodology for the estimation of the emissions from industrial wastewater.

7.4 Waste incineration (CRF Source Category 5C)

7.4.1 Description

Carbon dioxide, Methane and Nitrous oxide emissions from the incineration of clinical waste produced have been estimated. For the incineration of clinical waste, a central plant, the only existing in Greece, covers the total daily needs of hospitals in Athens.

Moreover, emissions from the incineration of biogenic agricultural residues produced in slaughterhouses and from the incineration of small amounts of industrial chemical waste are estimated. For these estimations, data provided by the Hellenic Statistical Authority as waste incinerated without energy recovery in Greece. These data were obtained by individual researches of ELSTAT.

7.4.2 Methodology

For the estimation of CO₂ emissions from clinical waste and from industrial chemical waste, the default method suggested by the IPCC Good Practice Guidance was used. CO₂ emissions were not estimated for the agricultural residues taking into account that these were of biogenic nature. CH₄ and N₂O emissions were estimated using default methodology and default emission factors for all categories by IPCC 2006 Guidelines.

Data related to the amount of clinical waste incinerated derive from the ACMAR, which is operating the incinerator. For the other categories, data were collected by the ELSTAT for the 2004, 2006, 2008 and 2010, while for the rest of the years similar figures were assumed.

The relevant parameters and emission factor used are the ones suggested in the IPCC Good Practice Guidance. Carbon Dioxide emissions were calculated based on the following equation:

$$\text{CO}_2 \text{ emissions} = CW \times CCW \times FCF \times EF \times 44/12$$

where, *CW* is the amount of clinical waste, *CCW* is the fraction of carbon content in the waste, 60% for clinical waste and 80% for chemical waste (Country specific), *FCF* is the fraction of fossil carbon, 40% for clinical waste and 100% for chemical waste (Country specific) and *EF* is the burn out efficiency of combustion of the incinerator (95%).

Methane and Nitrous oxide emissions were calculated based on the following equation:

$$\text{CH}_4 \text{ emissions} = CW \times EF_{\text{CH}_4} \text{ and}$$

$$\text{N}_2\text{O emissions} = CW \times EF_{\text{N}_2\text{O}}$$

while the emissions factors' values were 0.06 kg CH₄ / tn waste and 0.1 kg N₂O / tn waste for the CH₄ and for the N₂O, respectively, for all the waste incinerated, please refer to IPCC 2006 Guidelines, page 5.20 for CH₄ and page 5.22 for N₂O.

In **Table 7.22** the amount of waste incinerated and emissions released for the period 1990 – 2014 are presented.

7.4.3 Uncertainties and time-series consistency

The combined uncertainty of CO₂ emissions of waste incineration sector as % of total emissions is estimated by 0.003%. The combined uncertainty of CH₄ emissions of waste incineration sector as % of total emissions is estimated by 0.000003%. The combined uncertainty of N₂O 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.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data in line with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.4.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the waste incineration sector are:

1. Cross checking information regarding waste incinerated obtained by operating the incinerators and by the ELSTAT.
2. Comparison of information emissions factors with this for other countries.
3. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

Table 7.22 *Waste amounts (in tn) and emissions (in tn) for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Clinical waste	180	180	180	180	180	180	180	180	180	180	180
CO ₂	150	150	150	150	150	150	150	150	150	150	150
CH ₄	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
N ₂ O	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Biogenic (Agr. residues)	3935	3935	3935	3935	3935	3935	3935	3935	3935	3935	3935
CH ₄	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
N ₂ O	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394
Other (Chem. waste)	25	25	25	25	25	25	25	25	25	25	25
CO ₂	70	70	70	70	70	70	70	70	70	70	70
CH ₄	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
N ₂ O	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Clinical waste	180	492	939	1170	2231	2700	3666	4323	4222	3734	3547
CO ₂	150	411	785	978	1865	2257	3065	3614	3529	3122	2966
CH ₄	0.011	0.030	0.056	0.070	0.134	0.162	0.220	0.259	0.253	0.224	0.213
N ₂ O	0.018	0.049	0.094	0.117	0.223	0.270	0.367	0.432	0.422	0.373	0.355
Biogenic (Agr. residues)	3935	3935	3935	3935	3935	2943	2943	24599	24599	17528	17528
CH ₄	0.236	0.236	0.236	0.236	0.236	0.177	0.177	1.476	1.476	1.052	1.052
N ₂ O	0.394	0.394	0.394	0.394	0.394	0.294	0.294	2.460	2.460	1.753	1.753
Other (Chem. waste)	25	25	25	25	25	54	25	25	25	8	8
CO ₂	70	70	70	70	70	150	70	70	70	21	21
CH ₄	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.000	0.000
N ₂ O	0.003	0.003	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.001	0.001
Year	2012	2013	2014								
Clinical waste	3834	3710	3695								
CO ₂	3206	3098	3090								
CH ₄	0.230	0.220	0.222								
N ₂ O	0.383	0.370	0.370								
Biogenic (Agr. residues)	19885	18314	18576								
CH ₄	1.193	1.100	1.115								
N ₂ O	1.989	1.830	1.858								
Other (Chem. waste)	8	8	8								
CO ₂	21	21	21								
CH ₄	0.000	0.000	0.000								
N ₂ O	0.001	0.001	0.001								

7.4.5 Recalculations

No recalculations were performed.

7.5 Biological treatment (CRF Source Category 5.D)

7.5.1 Methodology

For the estimation of CH₄ and N₂O emissions from biological treatment (Composting) of solid waste Tier 1 approach was used (IPCC, 2006), due to emission factors are IPCC default values.

In **Table 7.23** the amount of waste composted and emissions released for the period 1990 – 2014 are presented.

Table 7.23 *Waste amounts (in ktn) and emissions (in ktn) for the period 1990 – 2014*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Waste amounts								31.5	31.5	31.5	31.5
CH ₄								0.13	0.13	0.13	0.13
N ₂ O								0.01	0.01	0.01	0.01
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Waste amounts	0	0	0	2.21	15.2	81.08	87.69	89.87	27.02	131,86	165,15
CH ₄	0.00	0.00	0.00	0.01	0.06	0.32	0.35	0.36	0.11	0.53	0.66
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.01	0.04	0.05
Year	2012	2013	2014								
Waste amounts	199.03	199.03	199.03								
CH ₄	0.80	0.80	0.80								
N ₂ O	0.06	0.06	0.06								

7.5.2 Recalculations

No recalculations were performed.

8. Recalculations and improvements

8.1 *Explanations and justifications for recalculations*

The recalculations made are driven by the results of the various review processes, QC checks and internal audits and the ERT reviews of the annual submissions of Greece by the nominated experts from the UNFCCC. In the previous submission, several recalculations were implemented as a result of new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. These new requirements include the use of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006).

The reasons for recalculations made, can be classified as follows:

- ***Changes or refinements in methods.*** A methodological change occurs when an inventory agency uses a different tier to estimate emissions from a source category (e.g. for key source categories) or when it moves from a tier described in the IPCC Guidelines to a national method. Methodological changes are often driven by the development of new and different data sets. A methodological refinement occurs when an inventory agency uses the same tier to estimate emissions but applies it using a different data source or a different level of aggregation.
- ***Inclusion of new sources.*** A new source is defined as a source for which estimates (all or some gases) did not exist in previous inventories either due to lack of data or because it has just been identified.
- ***Allocation.*** Changes in allocation of emissions to different sectors or sources/sub-sources.
- ***Correction of errors.*** This case concerns errors during calculating emissions (e.g. transcript errors) or while filling in the required information in the CRF tables. Inconsistencies resolving is also included in this category.
- ***Updated activity data.***

8.2 *Recalculations of GHG inventory*

8.2.1 **GHG inventory**

The justification of the recalculations made in the present submission as far as the preparation of GHG inventory is concerned has been presented in details in Chapters 3 – 7.

8.2.2 KP-LULUCF inventory

Table 8.1 *Overview of recalculations made for the preparation of KP-LULUCF inventory*

IPCC source / sink categories		Gas	Explanation
KP.A.1.	AR	CO ₂ /N ₂ O/CH ₄	Updated AD, use of new IPCC guidelines
KP.A.2	D	CO ₂ /N ₂ O	Updated AD, use of new IPCC guidelines
KP.B.1	Forest Management	CO ₂ /N ₂ O/CH ₄	Updated AD, use of new IPCC guidelines

8.3 Implications for emissions levels

8.3.1 GHG inventory

In *Table 8.2* the effect of the recalculations made on the total GHG emissions in Greece excluding LULUCF on a per gas basis is presented.

Table 8.2 *Comparison of the 2015 inventory with the present inventory (in Mt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO₂ emissions											
2015 submission	83.30	83.28	84.85	84.16	86.33	86.89	89.05	93.75	98.57	97.88	102.93
2016 submission	83.40	83.39	84.95	84.26	86.43	86.98	89.13	93.84	98.66	97.98	103.02
Change (%)	0.12	0.13	0.12	0.12	0.11	0.10	0.10	0.10	0.09	0.10	0.09
CH₄ emissions											
2015 submission	12.93	12.88	12.96	13.05	13.23	13.39	13.59	13.48	13.65	13.57	13.28
2016 submission	12.64	12.62	12.71	12.70	12.82	12.94	13.10	12.98	13.19	13.17	12.93
Change (%)	-2.19	-1.97	-1.95	-2.67	-3.08	-3.36	-3.63	-3.72	-3.31	-2.96	-2.58
N₂O emissions											
2015 submission	7.40	7.27	7.13	6.56	6.48	6.67	6.85	6.69	6.62	6.60	6.35
2016 submission	7.40	7.27	7.13	6.56	6.48	6.67	6.85	6.69	6.62	6.60	6.35
Change (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F-gases emissions											
2015 submission	1.41	1.62	1.37	2.18	2.83	4.26	4.89	5.31	5.94	6.85	5.41
2016 submission	1.38	1.59	1.34	2.15	2.79	4.22	4.88	5.30	5.93	6.83	5.39
Change (%)	-2.11	1.83	2.16	1.57	1.53	0.80	0.19	0.26	0.27	0.23	0.38
Total emissions											
2015 submission	105.04	105.06	106.31	105.96	108.87	111.21	114.37	119.22	124.78	124.90	127.96
2016 submission	104.83	104.88	106.13	105.68	108.52	110.82	113.96	118.80	124.41	124.58	127.69
Change (%)	-0.201	-0.170	-0.168	-0.266	-0.326	-0.354	-0.361	-0.357	-0.302	-0.258	-0.210
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO₂ emissions											
2015 submission	105.31	104.96	109.03	109.47	113.12	111.68	114.03	110.16	103.88	96.94	94.01
2016 submission	105.41	105.05	109.13	109.57	113.22	111.78	114.13	110.26	103.97	97.04	94.10
Change (%)	0.09	0.09	0.09	0.09	0.08	0.09	0.08	0.09	0.09	0.10	0.09
CH₄ emissions											
2015 submission	12.25	12.26	12.16	12.15	12.16	12.24	12.08	12.04	11.93	12.13	11.97
2016 submission	11.88	11.87	11.77	11.75	11.76	11.85	11.65	11.61	11.45	11.65	11.48
Change (%)	-2.97	-3.15	-3.20	-3.23	-3.27	-3.14	-3.56	-3.58	-4.04	-3.98	-4.03
N₂O emissions											
2015 submission	6.21	6.17	6.05	6.05	5.88	5.73	5.82	5.60	5.32	5.52	5.31
2016 submission	6.21	6.17	6.05	6.05	5.88	5.73	5.83	5.61	5.33	5.53	5.32
Change (%)	0.02	0.05	0.03	0.02	0.03	0.05	0.07	0.13	0.09	0.09	0.11
F-gases emissions											
2015 submission	4.87	5.18	4.83	5.02	5.18	2.82	3.36	3.84	4.06	4.52	4.77
2016 submission	4.87	5.18	4.83	5.02	5.18	2.82	3.36	3.84	4.06	4.52	4.78
Change (%)	0.00	0.00	0.00	0.01	0.00	0.01	0.01	-0.01	-0.03	-0.05	-0.08
Total emissions											
2015 submission	128.63	128.57	132.06	132.69	136.34	132.46	135.29	131.64	125.19	119.12	116.07
2016 submission	128.37	128.28	131.77	132.40	136.04	132.18	134.96	131.31	124.81	118.73	115.68
Change (%)	-0.208	-0.227	-0.221	-0.221	-0.221	-0.216	-0.244	-0.250	-0.308	-0.321	-0.331

Year	2012	2013
CO₂ emissions		
2015 submission	90.63	82.92
2016 submission	90.71	82.91
Change (%)	0.09	-0.01
CH₄ emissions		
2015 submission	11.84	11.71
2016 submission	11.35	11.26
Change (%)	-4.08	-3.82
N₂O emissions		
2015 submission	4.91	4.66
2016 submission	4.91	4.67
Change (%)	0.12	0.32
F-gases emissions		
2015 submission	5.21	5.82
2016 submission	5.21	5.83
Change (%)	-0.08	-0.10
Total emissions		
2015 submission	112.58	105.10
2016 submission	112.19	104.67
Change (%)	-0.344	-0.412

8.3.2 KP-LULUCF inventory

A KP-LULUCF inventory was not submitted in 2015.

8.4 Implications for emissions trends

8.4.1 GHG inventory

Total GHG emissions of years 1990-2013 in the current submission are slightly lower than the emissions reported in the 2015 submission. The emission trends in Greece for the period 1990 – 2013 according to the inventories submitted in 2015 & 2016 are shown in **Figure 8.1**. Emission trends for the period 1990-2013 have not been affected significantly by the recalculations because in most cases the recalculations concerned the whole period.

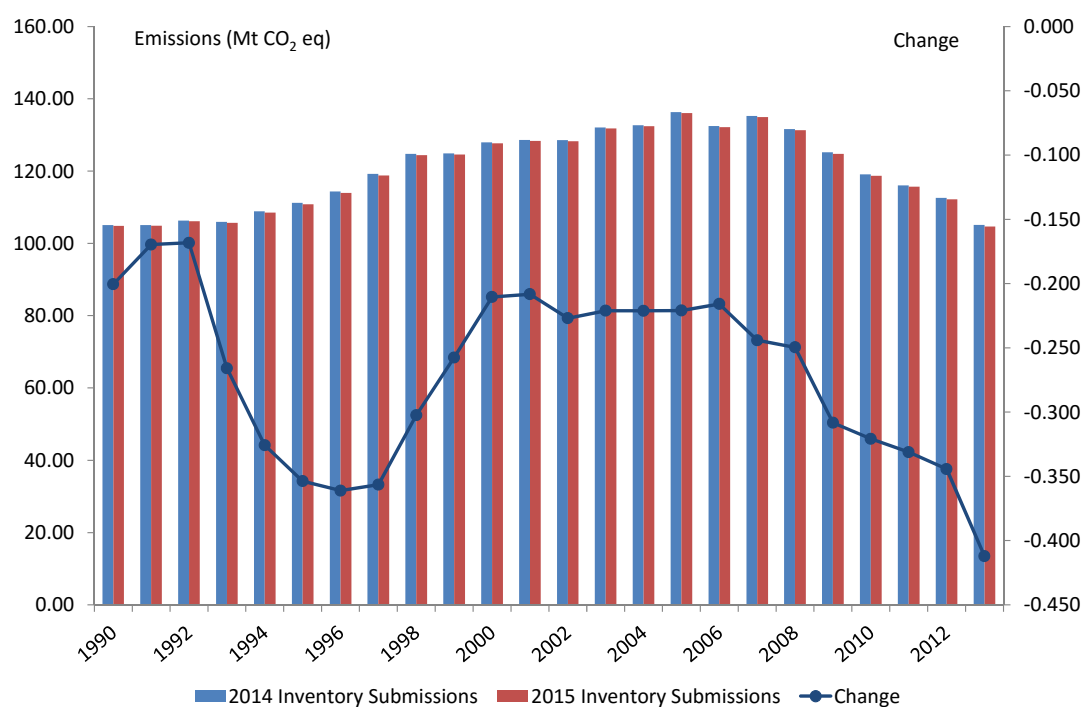


Figure 8.1 *GHG emissions trends in Greece for the period 1990 – 2013 (without LULUCF) according to the inventories submitted in 2015 & 2016*

8.5 Recalculations, including in response to the review process, and planned improvements

An inventory improvement procedure is in place, which utilizes:

- a) the recommendations from ERT reports,
- b) the findings of independent audits carried out by local experts at the end of each year,
- c) the findings of annual internal audits taken place by MEEN personnel between September and November of each year,
- d) the output of key category analysis, uncertainty analysis and QA/QC procedures,
- e) the recommendations / proposals arose in the framework of the bilateral QA exercise between the Spanish and the Greek Inventory team taking place in October of 2013.

as a basis to prioritize, plan and materialize future improvements and recalculations. As mentioned above, details on the resulted recalculations and improvements planned per source/sink category have been presented in the respective chapters (Chapters 3 – 7).

Finally, it should be mentioned that the results and the proposals that will arise from the review of the present inventory, within the technical review process defined in relevant decisions of the Conference of the Parties, will be integrated in the plan for the improvement of the GHG emissions inventory.

No major changes in methodological descriptions performed in current NIR compared to previous year NIR have implemented. Moreover, the 2015 submission was not reviewed by an ERT under UNFCCC review process.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

9. KP-LULUCF

9.1 General Information

In the framework of the Kyoto Protocol (KP) commitments, Greece reports emissions and removals from Afforestation, Reforestation and Deforestation activities under Article 3, paragraph 3, and from Forest Management activity under Article 3, paragraph 4. The estimation methodologies applied are in accordance with the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement) and relevant adopted UNFCCC Decision.

9.1.1 Definition of forest

For reporting purposes under the Kyoto Protocol Greece applies in the second commitment period the same forest definition applied during the first commitment period, in accordance with Decisions 2/CMP.6 and 2/CMP.7. Forest land is defined as land with a tree crown cover of more than 25 per cent, an area larger than 0.3 hectares and a minimum tree height of 2 metres or the potential to achieve it. The same definition of forest land is used for the UNFCCC inventory, in order to maintain coherence and congruence between the two inventories.

9.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Greece has not chosen to account for any elective activities under Article 3, paragraph 4 of the Kyoto Protocol for the second commitment period. In accordance with Decision 2/CMP.7, Forest Management activity has become a mandatory activity under Article 3.4.

9.1.3 Description of how the definitions of each activity under Article 3.3 and each mandatory and elected activity under Article 3.4 have been implemented and applied consistently over time

There is a clear correspondence between the UNFCCC categories and the Kyoto Protocol Activities. Definitions are consistent with those used in the UNFCCC inventory. Units of land subject to Article 3.3 Afforestation and Reforestation are reported jointly and are defined as units of land that did not comply with the forest definition on 1st January 1990, but do so some time thereafter. Afforestation / Reforestation category is equivalent to 4.A.2 UNFCCC category (Land converted to Forest land). Forest Management activity under Art. 3.4 is equivalent to 4.A.1.2 UNFCCC category (Forest land remaining Forest land/managed). Units of land subject to Article 3.3 Deforestation are defined as units of land that did comply with the forest definition on or after 1st January 1990 but ceased to comply later on. Deforestation encompasses the UNFCCC subcategories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 (Forest land converted to other land uses).

9.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Not applicable, as none of the elective activities under Article 3.4 has been chosen.

9.2 Land-related information

9.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit to determine the area of units of land under Article 3.3 equals the minimum area threshold for forest land, namely 0.3 ha.

9.2.2 Methodology used to develop the land transition matrix

The data sources on land areas used are the same for both the UNFCCC inventory and the Kyoto Protocol reporting, and are presented in the *Table 9.1*. Afforestation / Reforestation data are obtained from the afforestation registry of the Ministry of Environment and Energy (GDDPFAE). This registry contains afforestation activities on croplands under the EEC Regulations 2080/92 and 1257/99 since the beginning of the programmes, in 1994. Deforestation data are obtained from the Land Use Change Database developed by the Ministry of Environment and Energy. This dataset includes among others, the land use changes from forest land to grassland, wetlands, settlements and other land. Information for the units of lands under Forest Management is provided by the Forest Management Plans Database maintained by the Ministry of Environment and Energy.

The ARD and FM datasets contain direct estimates of spatially disaggregated areas converted or managed each year since 1990. These data are provided by the Forest Service (from the local to the central Forest Agency), and are consistent with the definition of forest and the activities described above.

Table 9.1 Data sources used for the Kyoto Protocol reporting

Data source	Content	Activity (AR – D – FM)
The "Forest Management Plans Database", of the Ministry of Environment and Energy	Forest Management information	3.4 FM
The afforestation registry and statistics of the Ministry of Environment and Energy	Afforestation/Reforestation information	3.3 AR
The "Land Use Change Database" of the Ministry of Environment and Energy, which comprise acts of land use change since 1990	Deforestation information	3.3 D

Table 9.2 Land transition matrices for 2013 and 2014 (areas in kha)

	2013								<i>Total beginning of year</i>
	AR	D	FM	CM	GM	RV	WDR	Other	
AR	33.25	NO							33.25
D		5.12							5.12
FM		NO	1,234.49						1,234.49
CM	NA		NA	NA	NA	NA	NA		NA
GM	NA		NA	NA	NA	NA	NA		NA
RV	NA		NA	NA	NA	NA	NA		NA
WDR	NA		NA	NA	NA	NA	NA		NA
Other	NO	0.04	NO	NO	NO	NO	NO	11,925.29	11,925.33
Total end of 2013	33.25	5.16	1,234.49	NA,NO	NA,NO	NA,NO	NA,NO	11,925.29	13,198.18

	2014								<i>Total beginning of year</i>
	AR	D	FM	CM	GM	RV	WDR	Other	
AR	33.25	NO							33.25
D		5.16							5.16
FM		NO	1,234.49						1,234.49
CM	NA		NA	NA	NA	NA	NA		NA
GM	NA		NA	NA	NA	NA	NA		NA
RV	NA		NA	NA	NA	NA	NA		NA
WDR	NA		NA	NA	NA	NA	NA		NA
Other	NO	0.03	NO	NO	NO	NO	NO	11,925.26	11,925.29
Total end of 2014	33.25	5.19	1,234.49	NA,NO	NA,NO	NA,NO	NA,NO	11,925.26	13,198.18

9.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The reporting method 1 of the KP Supplement has been used to report activities under art. 3.3 and 3.4. The geographical units that have been used for this purpose are the 51 prefectures of Greece.

Figure 9.1 presents the map and the identification codes of these geographical locations.

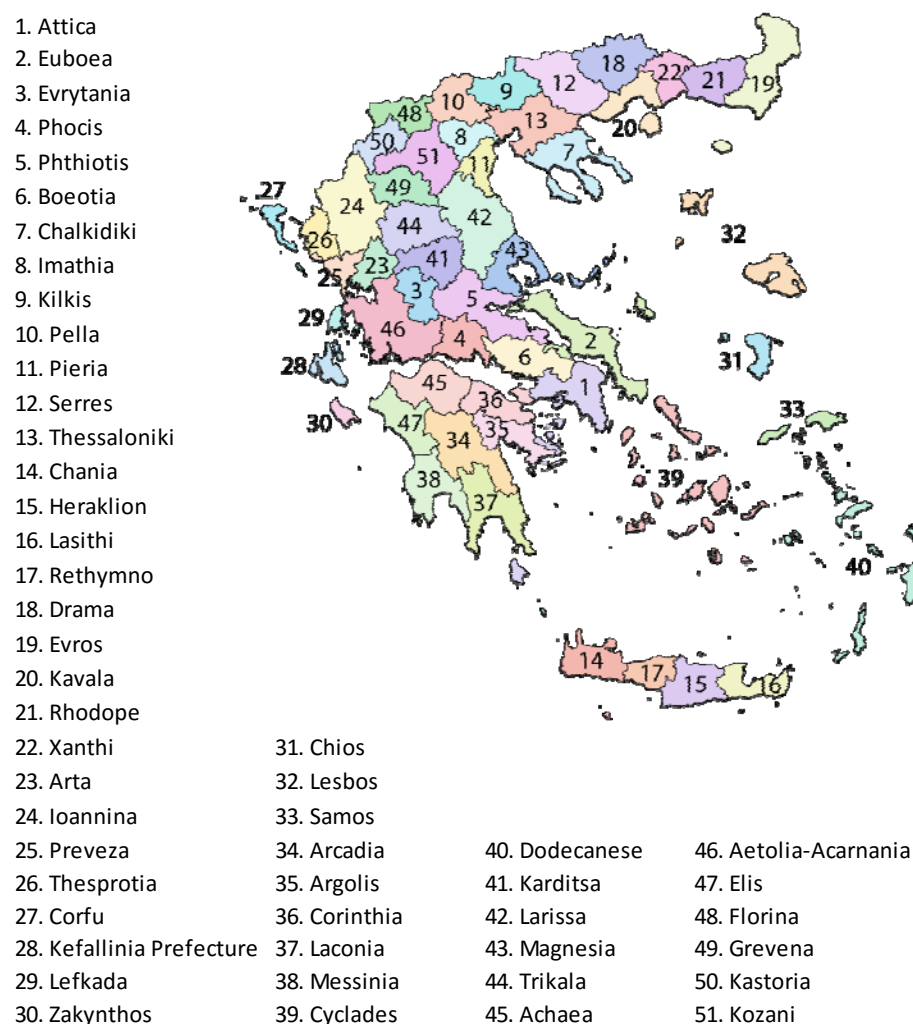


Figure 9.1 Map and identification codes for the geographical locations

9.3 Activity-specific information

9.3.1 Methods for carbon stock change and GHG emission and removal estimates

9.3.1.1 Description of the methodologies and the underlying assumptions used

Methodologies for estimating carbon stock changes and GHG emissions for Article 3.3 Afforestation/Reforestation and Deforestation and Article 3.4 Forest Management are the same as those used for the UNFCCC greenhouse gas inventory. Description of methods, assumptions, activity data and emission factors are presented in the relevant section of chapter 6.

In **Table 9.3**, the activity coverage and other information in regard to activities under Article 3.3 and Article 3.4 are presented.

Table 9.3 *NIR 1. Activity coverage*

Activity	CHANGE IN CARBON POOL REPORTED ⁽¹⁾							GREENHOUSE GAS SOURCES REPORTED ⁽²⁾										
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP ⁽⁴⁾	Fertilization ⁽⁵⁾	Drained, rewetted and other soils ⁽⁶⁾	Nitrogen mineralization in mineral soils ⁽⁸⁾	Indirect N ₂ O emissions from managed soil ⁽⁵⁾	Biomass burning ⁽⁹⁾						
					Mineral	Organic ⁽³⁾						N ₂ O	CH ₄ ⁽⁷⁾	N ₂ O	CO ₂ ⁽¹⁰⁾	CH ₄	N ₂ O	
Article 3.3 activities																		
Afforestation and reforestation	R	R	NR	NR	NR	NO	NO	NO	NO	NO	NO	NO	NO	NO	R	R	R	R
Deforestation	R	R	R	R	R	NO	NO	NO	NO	NO	NO	R	NO	NO	NO	NO	NO	NO
Article 3.4 activities																		
Forest management	R	R	NR	NR	NR	NO	R	NO	NO	NO	NO	NO	NO	NO	IE	R	R	R
Cropland management	NA	NA	NA	NA	NA	NA			NA		NA			NA	NA	NA	NA	NA
Grazing land management	NA	NA	NA	NA	NA	NA	NA		NA		NA			NA	NA	NA	NA	NA
Revegetation	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	NA
Wetland drainage and rewetting	NA	NA	NA	NA	NA		NA		NA	NA	NA			NA	NA	NA	NA	NA

⁽¹⁾ Indicate R (reported), NR (not reported), IE (included elsewhere) or NO (not occurring), for each relevant activity under Article 3.3, forest management or any elected activity under Article 3.4, or instantaneous oxidation (IO)

⁽²⁾ Indicate R (reported), NE (not estimated), IE (included elsewhere) or NO (not occurring) for greenhouse gas sources reported, for each relevant activity under Article 3.3, forest management or any elected activity under Article

⁽³⁾ Includes CO₂ emissions/removals from organic soils, including CO₂ emissions from dissolved organic carbon associated with drainage and rewetting. On-site CO₂ emissions/removals from drainage and rewetting from organic soils

⁽⁴⁾ HWP from lands reported under deforestation, which originated from the deforestation event at the time of the land-use change shall be accounted for on the basis of instantaneous oxidation (IO).

⁽⁵⁾ N₂O emissions from fertilization of afforestation/reforestation, deforestation, forest management, revegetation and wetland drainage and rewetting should be reported here when these emissions are not reported under the

⁽⁶⁾ CH₄ and N₂O emissions from drained and rewetted organic soils should be reported here, as appropriate, when emissions are not reported under the agriculture sector. For wetland drainage and rewetting only emissions from

⁽⁷⁾ CH₄ emissions from drained soils and drainage ditches should be reported here, as appropriate.

⁽⁸⁾ N₂O emissions from nitrogen mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils under afforestation/reforestation, deforestation, forest

⁽⁹⁾ Emissions from burning of organic soils should also be included here, as appropriate.

⁽¹⁰⁾ If CO₂ emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning. Parties that include CO₂ emissions from biomass burning in their carbon stock

Table NIR 1.1 Additional information

Selection of parameters for defining "Forest" under the Kyoto Protocol

Parameter	Range	Selected value
Minimum land area	0.05 - 1 ha	0.30
Minimum crown cover	10 - 30 %	25.00
Minimum height	2 - 5 m	2.00

As it has already been mentioned, there is a clear correspondence between the UNFCCC categories and the Kyoto Protocol Activities. The methods used for estimating carbon stock changes for lands subject to Article 3.3 Afforestation and Reforestation are those presented in the respective chapter for the UNFCCC category Land converted to Forest land (4.A.2 Cropland converted to Forest land). Similarly, for the estimation of carbon stock changes for land areas subject to Article 3.3

Deforestation activities, the methodologies applied are those analysed in the relevant chapters referring to Forest land conversion to the other land uses (UNFCCC subcategories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1). Forest Management (Article 3.4) encompasses forest land areas that have been managed with a forest management plan, and therefore the methodologies applied for the estimation of carbon stock changes are the same described in chapter 6.4.2.

Since there is a clear correspondence between the Kyoto Protocol activities "Afforestation / Reforestation" and "Forest Management", and the UNFCCC categories "Conversion to Forest land" and "Forest land remaining Forest land/managed", uncertainty levels of the net emissions/removals are the same for both inventories. The uncertainty of emissions from units of land under "Deforestation" is estimated to be 51%.

Table 9.4 *Uncertainty analysis of the KP-LULUCF activities*

Art. 3.3 & 3.4 Activities	Gas	Uncertainty (%)
Afforestation / Reforestation	CO ₂	113
Deforestation	CO ₂	51
Forest Management	CO ₂	33
Forest Management	CH ₄	71
Forest Management	N ₂ O	71

9.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

Areas under art. 3.3 Afforestation/Reforestation activity includes only cropland areas that have been afforested by planting in the context of EEC Regulations 2080/92 and 1257/99. Grassland areas that converted to forest land constitute a natural forest expansion and therefore there are no associated emissions by sources and removals by sinks, since that kind of conversion is not direct human induced, but rather occur under natural drivers.

According to many studies, soil organic carbon content is generally found to increase following afforestation on agricultural areas (e.g. Guo and Gifford, 2002, Post and Kwon, 2000, Vesterdal et al., 2006, Polglase et al, 2000), hence, soils in these areas are not a net source. Further, following the Tier 1 approach as stated in section 6.4.2.2, carbon stock changes in mineral soils in croplands converted to forest land were estimated, affirming the above argumentation. For the calculations the basic equation as described in section 6.4.2.2 was used, with $f_{\text{forest type}} = f_{\text{man intensity}} = f_{\text{dist regime}} = 1$, and hence the new forest SOC = SOC_{Ref}. For the SOC_{Ref} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece as presented in **Table 6.14** in section 6. The 72.3 t C ha⁻¹, and 80.3 t C ha⁻¹ values were applied for the cases where conifer, and broadleaves species were used in the afforestation project, respectively. For the SOC_{Cropland} appropriate land use factor,

management factor and input factor were used as described in section 6.5.2.2, while the IPCC default inventory time period was used ($T = 20$). The results are presented in **Figure 9.2** below.

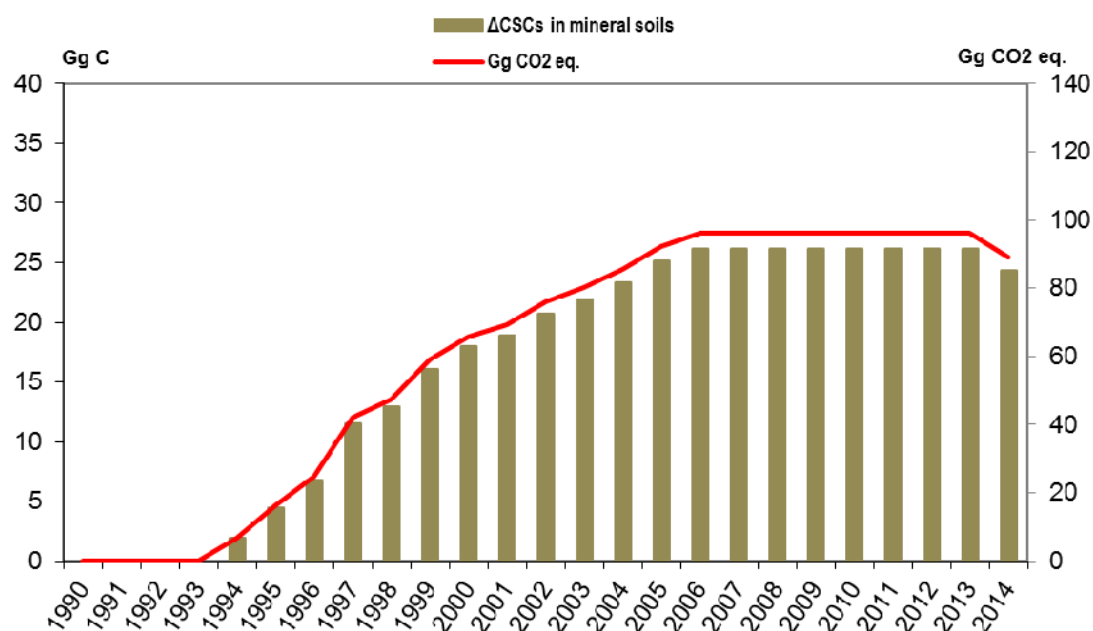


Figure 9.2 Carbon stock changes in mineral soils in the period 1990-2014

Similarly, in Croplands there is negligible, if any, amount of dead organic matter, namely the carbon stocks in that pool are almost zero. Considering that in any forest land, including plantations, the carbon stock in dead organic pool cannot be classified as negligible, any conversion from cropland to forest land, as in the case of Greece, leads to an increase in dead organic matter, and therefore the litter and the dead wood pools cannot be a source. Furthermore, in an effort to make a comparison between Greece and some neighbouring regions based on the most similar ecological conditions, the analysis depicts that in the southern regions of Italy, namely Abruzzo, Molise, Basilicata and Puglia the dead organic matter pool in areas where Afforestation/Reforestation activities occur is a net sink. In addition, according to the most recent data submitted by the EU Member States, the dead organic matter pool under art. 3.3. Afforestation/Reforestation activity was a net sink during the period 2008 - 2012. In **Figure 9.3** below, the average net carbon stock changes in dead organic matter pool under art. 3.3 Afforestation/Reforestation activity for each Member State for that period is presented.

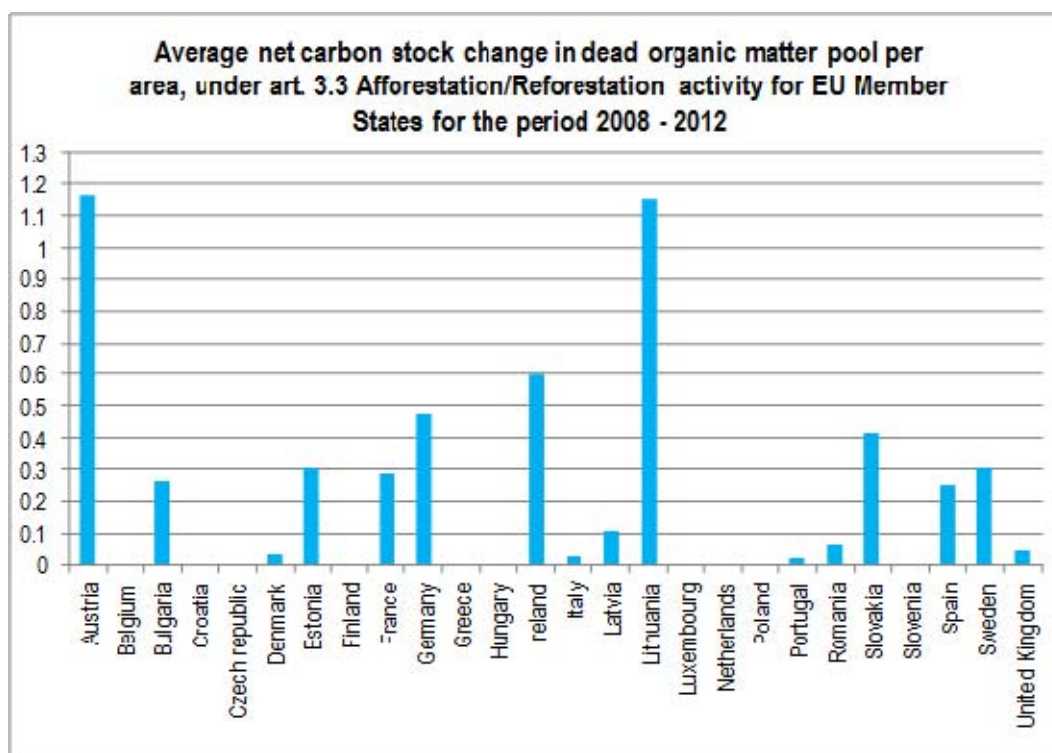


Figure 9.3 *Average net carbon stock changes in DOM pool for art. 3.3 AR activities for EU Member States for the period 2008-2012*

Furthermore, in the chart below the annual changes in carbon stock in dead wood and litter pools in lands under afforestation/reforestation activities are presented. The methodology applied is in accordance with the 2006 GL AFOLU, and the data that have been used are the litter stock values obtained from the BioSoil project (*Table 6.12*), and the dead wood values obtained from Italy (*Table 6.13*).

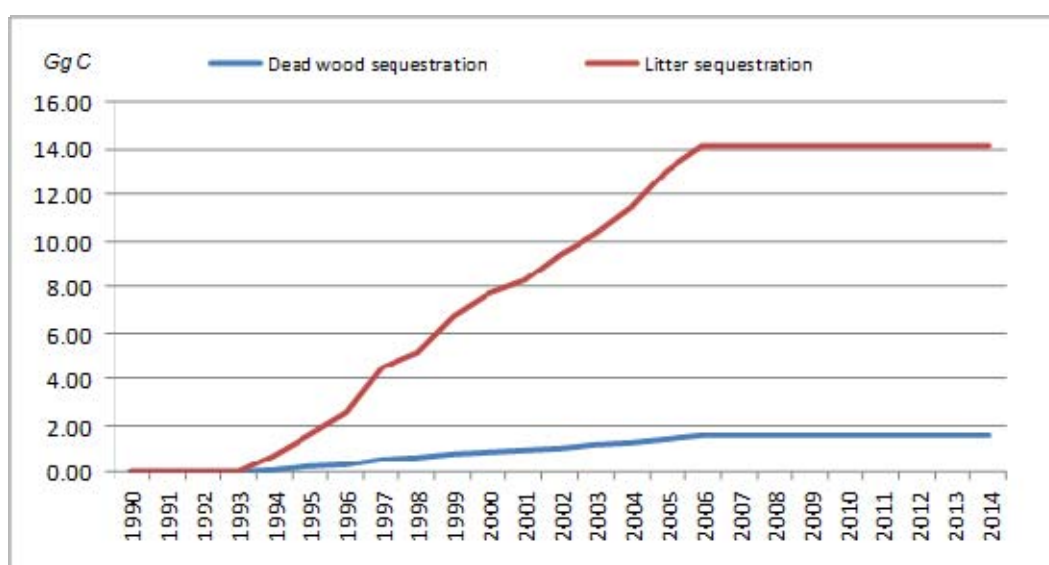


Figure 9.4 *Annual change in carbon stock in dead organic matter in lands under art. 3.3 AR activities.*

With regard to the dead organic matter and soil in areas under Forest Management, literature has shown that different forest management activities, such as rotation length, harvest practices (whole tree or sawlog; regeneration, partial cut or thinning), site preparation activities (prescribed fires, soil scarification), and fertilisation, interfere more or less strongly with dead organic matter and soil organic carbon (Harmon and Marks, 2002; Liski et al., 2001; Johnson and Curtis, 2001).

In Greece, the base for forest management was set very early with the Presidential Decree of 30.11.1928. Later the Administrative Regulation No 10223/958/1953 "Guidelines for the Implementation of Forest Management Plans in State and Private Forests", which has been revised twice (Ministerial Decisions 158072/1120/1965 and 81701/3908/1991) and the Legislative Decree No 86/1969 set very strict regulations in regard to forest management for both the public and private forests. According to that legislative framework, forest management is applied following specific rules and guidelines for practices driven by the fundamental principle and predominant goal of preserving and promoting the "sustainability" of forests in terms of their provision of products, growing stock and services. In practice this means that the harvest rate in managed forests cannot exceed their increment rate, while at the same time significant changes in forest types and management activities are prohibited. Thus, in Greece forest type and management

activities, such as silvicultural system, rotation length, harvest practices, site preparation activities do not change significantly over time. In addition, post logging burning or gathering of harvest residues, soil scarification or fertilization, the use of heavy machinery (e.g. caterpillar) which could disturb the dead organic matter pool and the soil structure are not permitted. In particular, for mineral soils, a constant or increasing carbon stock in dead organic matter determines a constant or increasing transfer of carbon stock to soil organic matter pool. All the above result to promoting the carbon accumulation in both those carbon pools in managed forests, which is even more justified by the fact that the living biomass pool in forest under management acts as a net sink, showing an increasing trend during the period 1990 - 2014. Consequently, the dead organic matter pool and mineral soils in soil organic matter pools in Greece cannot be a net source of carbon.

In addition to the above qualitative documentation, and following ERT's suggestion during the previous review process, quantitative argumentation demonstrating that the dead wood, litter and soil pools in lands under Forest Management are not a source is presented below. For that purpose, the IEFs for litter and deadwood obtained from the most recent data from the Italian national KP/LULUCF submission (2014) were used. In the chart below the carbon stock changes in dead wood and in litter in land under Forest Management are presented. IEFs from the four Italian regions, namely Abruzzo, Molise, Basilicata, and Puglia, with the most similar climatic and ecological conditions to Greece were used, and more specifically the average value for each pool every year.

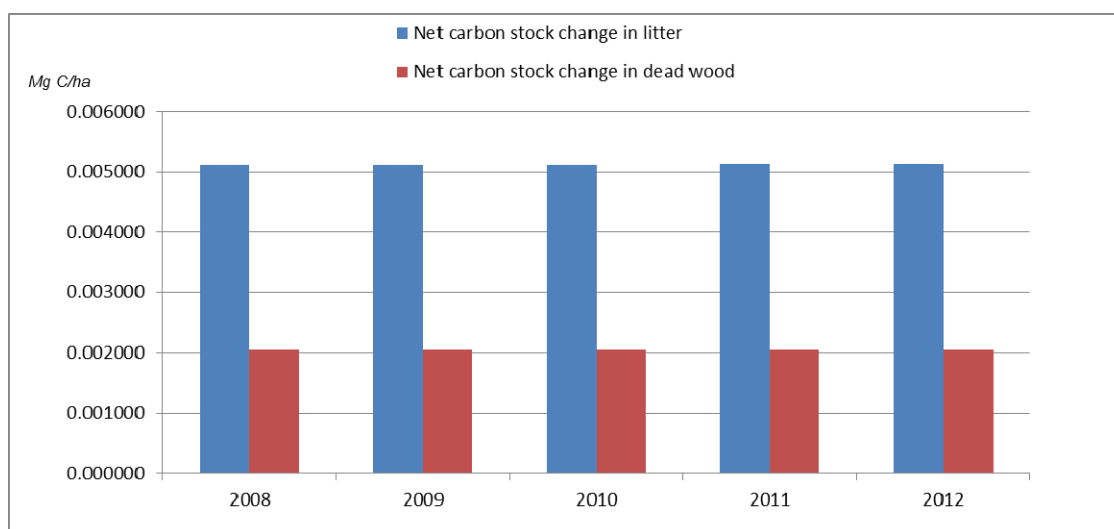


Figure 9.5 *CSCs in dead organic matter in lands under art. 3.4 FM activity.*

The diagram above depicts that the dead wood and litter pool act as a net sink, following the carbon accumulation in living biomass pool.

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9.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

Indirect or natural greenhouse-gas removals were accounted for. Concerning activities under Article 3, paragraph 3, all removals accounted for by those activities are to be considered anthropogenic since they are the result of direct human-induced activities. Further, all Art 3.3 activities have occurred after 1990, thus the dynamic effect of age is not relevant. With regard to activities under Article 3, paragraph 4, the net-net accounting approach, as well as the FMRL construction applied, completely address the issue of CO₂ removals factoring out.

9.3.1.4 Changes in data and methods since the previous submission (recalculations)

The changes in data and methods implemented in the current submission, and the subsequent recalculations are the result of the use of the new IPCC guidelines (2006 GL AFOLU, KP Supplement). In that context, updated default values, conversion and emission factors have been used.

9.3.1.5 Information on other methodological issues

Greece has elected to account for emissions and removals from activities of Article 3, paragraphs 3, and 4 at the end of the commitment period.

Verification activity of the results of the carbon stock change method used for the estimation of carbon stock changes in areas subject to art. 3.4 Forest Management

Greece has provided - following previous ERT's recommendation - a verification of the estimates of carbon stock changes in living biomass resulted from the use of the 2006 GL AFOLU carbon stock change method in areas subject to Forest Management activity. Since there is a clear correspondence between the Kyoto Protocol art. 3.4 activity "Forest Management" and 4.A.1 UNFCCC category (Forest land remaining Forest land/managed), the results of the verification activity are those reported in section 6.4.2.1.

N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

N₂O emissions associated with land-use conversion (Deforestation activities) to Cropland are reported in KP-CRF Table 4(KP-II)3. The emissions are calculated according to the methodology described in section 6.5.2.2.

9.3.1.6 The year of the onset of an activity, if after 2013

Afforestation/Reforestation and Deforestation activities under Article 3, paragraph 3, are activities occurring in land areas from 1990 onwards. With regard to Article 3.4 activities, in Forest Management, forest land areas that are managed with a forest management plan started from 1990 onwards are included.

9.4 Article 3.3

9.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Estimates of carbon stock changes and GHG emissions have been made only for afforestation activities on croplands under the EEC Regulations 2080/92 and 1257/99. Planting of these lands started in 1994. Deforestation data are obtained from the Land Use Change Database. This database contains annual statistical data on areas under land use change since 1990 collected from the local Forest Services.

9.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Extensive forest disturbances have been rare in Greece, with the exception of wildfires in some exceptional years. Further, according to the national legislative framework the forest land use after any disturbance cannot be changed. More specifically in the cases of wildfire events, the areas affected, are instantly declared to be reforested by the responsible authority which is the Forest Service, with this decision being published in the Official Government Gazette.

Harvesting, either in public or private forests, is regulated through national laws (Presidential Degree No 126/1986) and regulations, according to which, specific, and discrete procedures have to be followed only after the authorization of the Forest Service.

The Constitution of Greece of 1975 is the supreme law of Greece, which firmly established the frame and the principles upon which the national legislative framework is founded and evolving thereafter, and consequently any law, decision (ministerial, joint ministerial), degree, guideline of implementation etc., must be in line with and fulfil the principles that were set in the Constitution. The total protection of forests is addressed under the provisions of para. 1, art. 24 according to which *"Alteration of the use of forests and forested areas is prohibited, except where agricultural development or other uses imposed for the public interest prevail for the benefit of the national economy"*. Later, in para. 3, art. 117 is stated that: *"Public or private forests and forested areas which have been destroyed or are being destroyed by fire or have otherwise lost their forest cover or are losing their forest cover, shall not thereby relinquish their previous designation and shall compulsorily be proclaimed reforested, the possibility of their disposal for other uses being excluded"*.

Based on the above, the Greek forest legislative framework is very strict in the case of forest land conversion to other land uses. Deforestation activities are limited and permitted only in specific cases for the public interest and benefit (e.g. construction of roads, railways, high tension lines), following direct administrative procedures under the provision of Greek laws (Legislative Decree No 86/1969, Law No 998/1979, 1734/1987), before being authorized by the Forest Service which is the responsible authority. Any other temporarily loss of forest cover is not considered as deforestation, and is declared instantly reforested following specific administrative procedures under the provisions of Greek laws (art. 61 Legislative Decree No 86/1969, art. 37, 38, 46, 47 Law 998/1979) in order to recover in its former state.

9.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Unless there is deforestation as described above, it is assumed stock recovering for forest areas that have lost their cover through harvesting or forest disturbances. As such information on the size and location of areas that have lost forest cover is not explicitly collected on an annual basis.

9.4.4 Information on the implementation of natural disturbances provision

Greece intends to apply the provision to exclude emissions from natural disturbances for the accounting for afforestation/reforestation under Article 3, paragraph 3, of the Kyoto Protocol during the second commitment period in accordance with decision 2/CMP.7, annex, paragraph 33, and any relevant supplementary methodological guidance developed by the Intergovernmental Panel on Climate Change and adopted by the CMP and the COP. The disturbance type selected is wildfires.

The background level of emissions associated with annual natural disturbances has been estimated following an iterative process described in detail below, in accordance with footnotes 7, and 9 of annex Decision 2/CMP.7 and the guidance provided by the KP Supplement.

In particular as a first step a consistent and complete time series containing emissions from wildfires for the calibration period 1994⁸ to 2014 was set. Secondly, the estimation of the (i) arithmetic mean of the area-specific annual emissions from wildfires in AR lands followed, using all the years of the calibration period, as well as the (ii) standard deviation of the same time series. In the third step any emission(s) that were greater (outlier) than the arithmetic mean plus twice the standard deviation was/were removed from the time series. The same process from step 2 above – having excluded emissions that are greater than the arithmetic mean plus twice the standard deviation – was iterated. When no further outliers were identified, the arithmetic mean and the twice the standard deviation estimated in the last step of this process, defined the area-specific background level and the associated margin, respectively. Finally, both the area-specific background level and the margin were multiplied by the average annual area of AR estimated for the commitment period. For the projection of the area under AR for the commitment period it was assumed that the area would be stable, equal to 2014 levels.

⁸ 1994 was the first year, as this year is the first one in the time series that the activity occurs.

In the way just described for the development of the background level and the associated margin the expectation of net credits or net debits is avoided. Any emission from natural disturbances during the commitment period that is either less than or equal to the background level plus the margin is not separately excluded from accounting. During the commitment period, emissions are only excluded from accounting when the annual emissions are greater than the background level plus the margin. When this occurs, only those emissions that are greater than the background level are excluded.

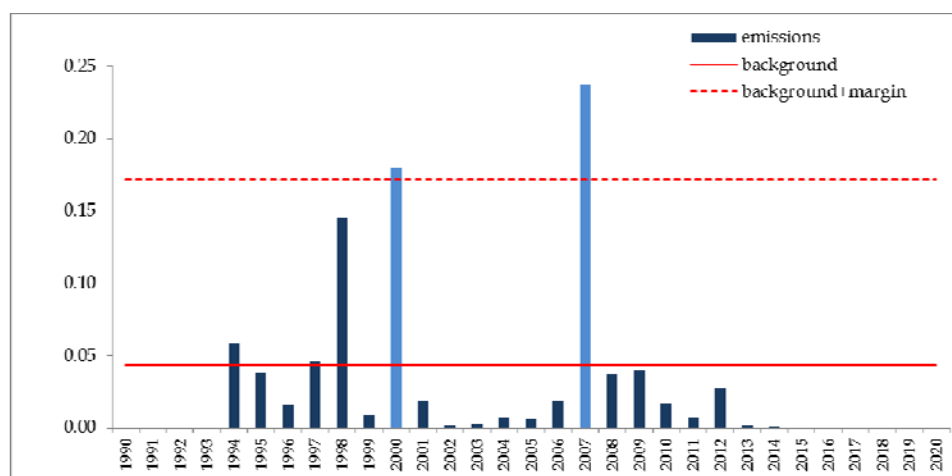
In **Table 9.5** the total and the area-specific emissions associated with disturbances for the calibration period for AR lands are presented, while **Figure 9.6** illustrates the results of the iterative process described above.

Table 9.5 *Emissions (total & area specific) from disturbances for AR*

Total and area specific emissions from disturbances for the calibration period for AR																										
Disturbance type*	Inventory year during the calibration period																									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
	Total annual emission [Gg CO ₂ eq.]																									
Wildfires					0	0	0	1	2	0	4	0	0	0	0	0	1	8	1	1	1	0	1	0	0	
Insect attacks and disease infestations																										
extreme weather events																										
geological disturbances																										
other																										
SUM					0	0	0	1	2	0	4	0	0	0	0	0	1	8	1	1	1	0	1	0	0	
For all land under AR	Total area [kha]																									
					2	6	9	15	16	20	23	24	26	28	30	32	33	33	33	33	33	33	33	33	33	
	Area-specific emissions (Emissions per unit of land area under AR, Mg CO ₂ eq. ha ⁻¹)**																									
					0.06	0.04	0.02	0.05	0.15	0.01	0.18	0.02	0.00	0.00	0.01	0.01	0.02	0.24	0.04	0.04	0.02	0.01	0.03	0.00	0.00	
* Sub-division of types can be added as needed																										
** In any year, emissions per unit of land area are calculated as the Sum divided by the total area under AR																										

* Sub-division of types can be added as needed

** In any year, emissions per unit of land area are calculated as the Sum divided by the total area under AR



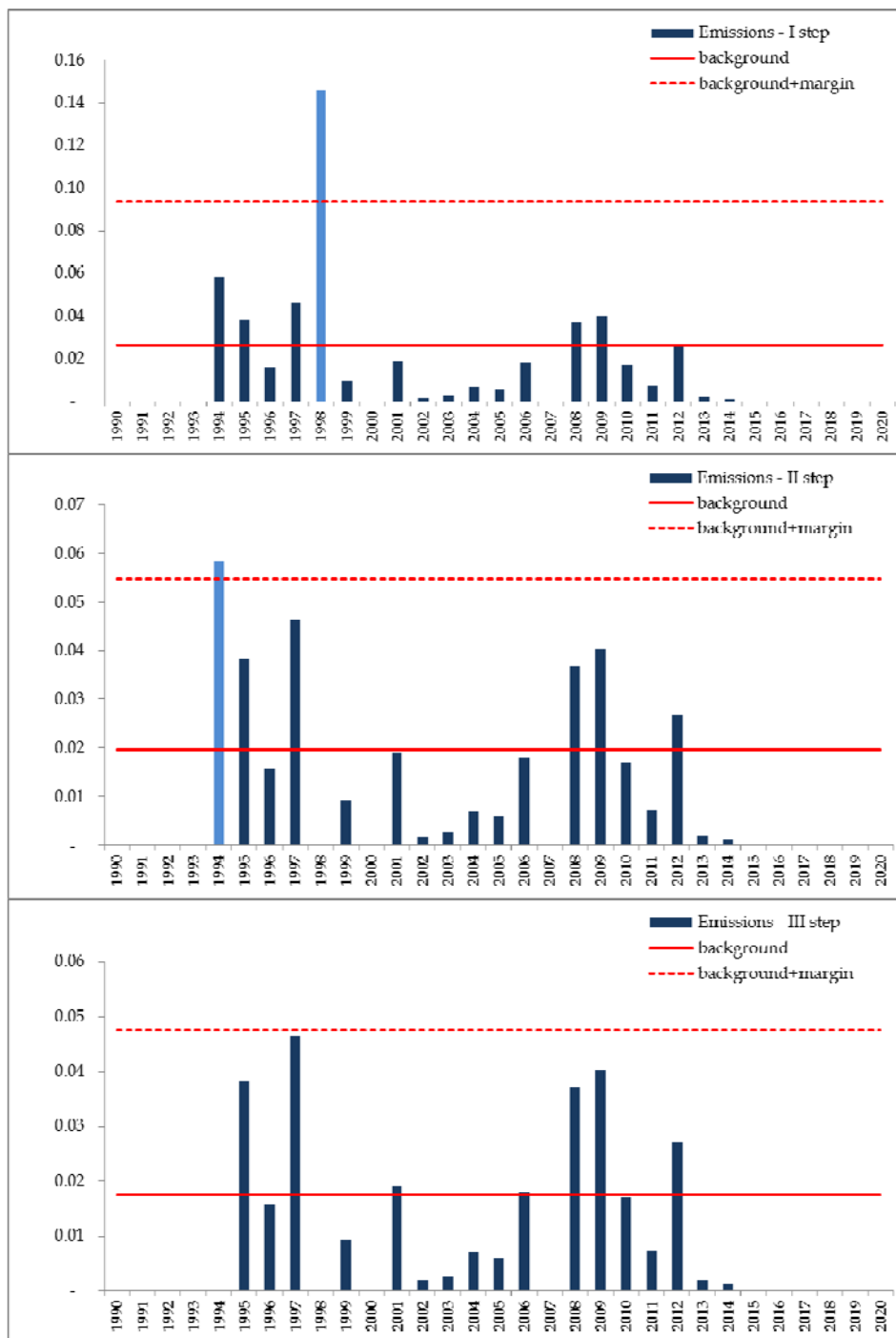


Figure 9.6 *The iterative process for defining the background level and margin*

The results of the whole process as described above are:

- i. Background level: 0.58 Gg CO₂ eq.

- ii. Margin: 1.00 Gg CO₂ eq.
- iii. Background level plus margin: 1.58 Gg CO₂ eq.
- iv. Number of excluded years: 4.
- v. Years excluded: 1994, 1998, 2000, 2007.

9.4.5 Information on Harvested Wood Products

The methodology applied for the estimation of carbon stock changes and CO₂ emissions and removals resulting from the Harvested Wood Products pool is consistent with 2006 GL AFOLU (Volume 4, chapter 12) and the KP Supplement, in accordance with Decision 2/CMP.7. HWPs from Deforestation activities are not occurring, since deforestation activities in Greece are not linked to the production of wood. As described in section 9.4.2, there is only a very small area where deforestation has occurred in Greece, because the Greek forest legislative framework is very strict in the case of forest land conversion to other land uses. Deforestation activities are limited and permitted only in specific cases for the public interest and benefit, following direct administrative procedures under the provision of Greek laws before being authorized by the Forest Service which is the responsible authority.

It is assumed that all HWPs originate from managed forests. The methodology followed for the estimation of emissions/removals resulting from the Harvested Wood Products pool under KP is the same applied for that pool under the UNFCCC, described in section 6.10.

9.5 Article 3.4

9.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

In Article 3.4 Forest Management activity, only those forests that have a forest management plan started in 1990 or later have been included. These forests cover about the 35.7% of the total forest land of Greece (high forest).

9.5.2 Information relating to Forest Management

9.5.2.1 Information on the implementation of natural disturbances provision

Greece intends to apply the provision to exclude emissions from natural disturbances for the accounting for forest management under Article 3, paragraph 4, of the Kyoto Protocol during the second commitment period in accordance with decision 2/CMP.7, annex, paragraph 33, and any relevant supplementary methodological guidance developed by the Intergovernmental Panel on Climate Change and adopted by the CMP and the COP. The disturbance type selected is wildfires.

The background level of emissions associated with annual natural disturbances has been estimated following an iterative process described in detail below, in accordance with footnotes 7, and 9 of annex Decision 2/CMP.7 and the guidance provided by the KP Supplement.

In particular as a first step a consistent and complete time series containing emissions from wildfires for the calibration period 1990 to 2014 was set. Secondly, the estimation of the (i) arithmetic mean of the annual emissions from wildfires in land areas under forest management followed, using all the years of the calibration period, as well as the (ii) standard deviation of the same time series. In the third step any emission(s) that were greater (outlier) than the arithmetic mean plus twice the standard deviation was/were removed from the time series. The same process from step 2 above – having excluded emissions that are greater than the arithmetic mean plus twice the standard deviation – was iterated. When no further outliers were identified, the arithmetic mean and the twice the standard deviation estimated in the last step of this process, defined the background level and the associated margin, respectively.

In the way just described for the development of the background level and the associated margin the expectation of net credits or net debits is avoided. Any emission from natural disturbances during the commitment period that is either less than or equal to the background level plus the margin is not separately excluded from accounting. During the commitment period, emissions are only excluded from accounting when the annual emissions are greater than the background level plus the margin. When this occurs, only those emissions that are greater than the background level are excluded.

In **Table 9.6** the total and the area-specific emissions associated with disturbances for the calibration period for land areas under forest management are presented, while **Figure 9.7** illustrates the results of the iterative process described above.

Table 9.6 Emissions (total & area specific) from disturbances for FM

Total and area specific emissions from disturbances for the calibration period for FM																									
Disturbance type*	Inventory year during the calibration period																								
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Total annual emission [Gg CO ₂ eq.]																								
Wildfires	195	74	215	224	196	129	53	155	486	31	599	63	6	9	24	20	60	789	123	134	57	24	90	7	4
Insect attacks and disease infestations																									
extreme weather events																									
geological disturbances																									
other																									
SUM	195	74	215	224	196	129	53	155	486	31	599	63	6	9	24	20	60	789	123	134	57	24	90	7	4
For all land under FM	Total area [kha]																								
	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234	1234
	Area-specific emissions (Emissions per unit of land area under AR, Mg CO ₂ eq. ha ⁻¹)**																								
	0.16	0.06	0.17	0.18	0.16	0.10	0.04	0.13	0.39	0.03	0.49	0.05	0.00	0.01	0.02	0.02	0.05	0.64	0.10	0.11	0.05	0.02	0.07	0.01	0.00

* Sub-division of types can be added as needed

** In any year, emissions per unit of land area are calculated as the Sum divided by the total area under FM

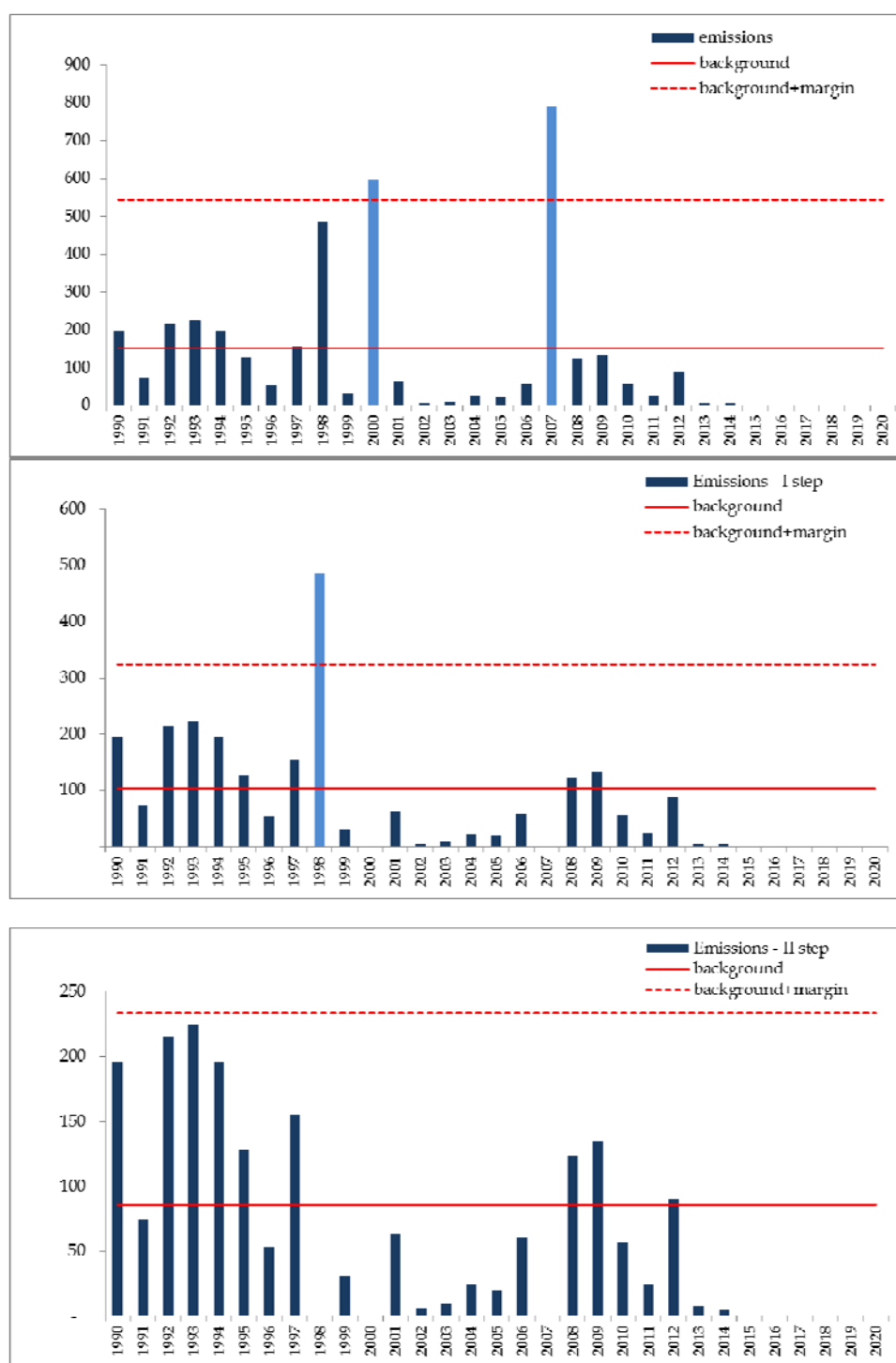


Figure 9.7 The iterative process for defining the background level and margin

The results of the whole process as described above are:

- i. Background level: 86 Gg CO₂ eq.
- ii. Margin: 147 Gg CO₂ eq.
- iii. Background level plus margin: 233 Gg CO₂ eq.
- iv. Number of excluded years: 3.
- v. Years excluded: 1998, 2000, 2007.

9.5.2.2 Forest Management Reference Level (FMRL)

The forest management reference level (FMRL) inscribed in the appendix to the annex to decision 2/CMP.7 is equal to -1.830 Mt CO₂ eq/year assuming instantaneous oxidation of HWP. The forest management reference level applying first-order decay function for HWP was not included in this appendix because as indicated in the same appendix *“In a communication to the secretariat dated 7 February 2012, Greece noted that there is no estimate for their forest management reference level value applying the first-order decay function for harvested wood products and therefore it requested the removal of the estimate reflected in the table contained in document FCCC/KP/AWG/2011/L.3/Add.2.”*

In its FMRL submission, Greece calculated a FMRL based on the projections of net emissions provided by the model G4M. During the review (technical analysis) of the FMRL, the ERT had concluded that owing to the lack of or unavailability of basic data could not accept the submitted FMRL by Greece. In response to the ERT, Greece indicated that since the G4M model could not produce credible projections for an FMRL for Greece it proposed a revised FMRL of -1.83 Mt CO₂ eq/year (which is the average removals for the period 1990–2009 including emissions from forest fires). The ERT assessed the revised FMRL using historical data on net removals for forest land remaining forest land contained in the 2011 NIR and found that the average removals for the period 1990–2009 were -1.81 Mt CO₂ eq/year. The ERT advised Greece to consider this slight discrepancy, and resubmit an FMRL that is consistent with the 2011 NIR.

Following the recommendations of the ERT that performed the technical assessment of the forest management reference level submission of Greece and pursuant to the footnote of paragraph 1(i) of Annex I of Decision 2/CMP.8, Greece is reporting in this submission a revised FMRL.

9.5.2.3 Technical Correction of FMRL

In accordance with Decision 2/CMP.7, Parties shall demonstrate methodological consistency between the reference level and reporting for forest management during the second commitment period when accounting for forest management. To that end, Parties shall make technical correction, if necessary, to ensure consistency, and shall report on how these corrections were made.

Greece, following the provisions of Decision 2/CMP.7 and the guidance provided by KP Supplement, provides a technical correction with the current submission, in order to ensure consistency between the FMRL and reporting of forest management.

For that purpose the methodological elements listed in KP Supplement were considered, namely:

- i. the method used to establish the FMRL, as reported in the FMRL submission (models or average/extrapolation of historical time series);
- ii. the historical data used to establish the FMRL, as reported in the FMRL submission (forest area, harvest, increment, age structure, forest characteristics and management, net emissions and related estimation parameters, etc.);
- iii. other methodological elements used to establish the FMRL as reported in the FMRL submission (pools and gases, the treatment of HWP, the treatment of natural disturbances, climate and other ecological parameters used by models for projecting FMRL); and
- iv. elements newly introduced or modified by Decision 2/CMP.7 as compared to the text in Decision 2/CMP.6 (the accounting HWP removed from areas under FM, the possible exclusion of emissions associated with natural disturbances).

The changes that have occurred in relation to the above mentioned list of elements, which are triggering a technical correction are:

- The update of the Forest Management Plans database. The new data incorporated in the database have resulted in the recalculation of the whole time series for the 4.A.1 “Forest land remaining Forest land/managed” category which is equivalent to the Forest Management activity.
- The area of forest land remaining forest land/managed that equals to Forest Management area has changed, amounting to 1,234.49 kha.
- In the current submission, CO₂ and non-CO₂ emissions from dead wood and litter subject to wildfires in lands under 3.4 have been reported for the first time.
- There has been a recalculation of the whole time series of emissions from wildfires.
- The period 1990-2014 has been considered for the technical correction of the FMRL, while the FMRL value inscribed in the appendix of 2/CMP.7 is based on the average of emissions/removals of the period 1990-2009.
- In the estimation of emissions/removals from Forest land remaining forest land, the updated emission and conversion factors from 2006 GL AFOLU and KP Supplement have been used. In addition, the new global warming potential values for CH₄ and N₂O from the 4th AR IPCC have been used.
- In the current submission, both a FMRL assuming instantaneous oxidation and applying the FOD function for HWP is submitted. It should be noted that a forest management

reference level applying first-order decay function for HWP was not included in the appendix of 2/CMP.7, as described in the section 11.5.2.2.

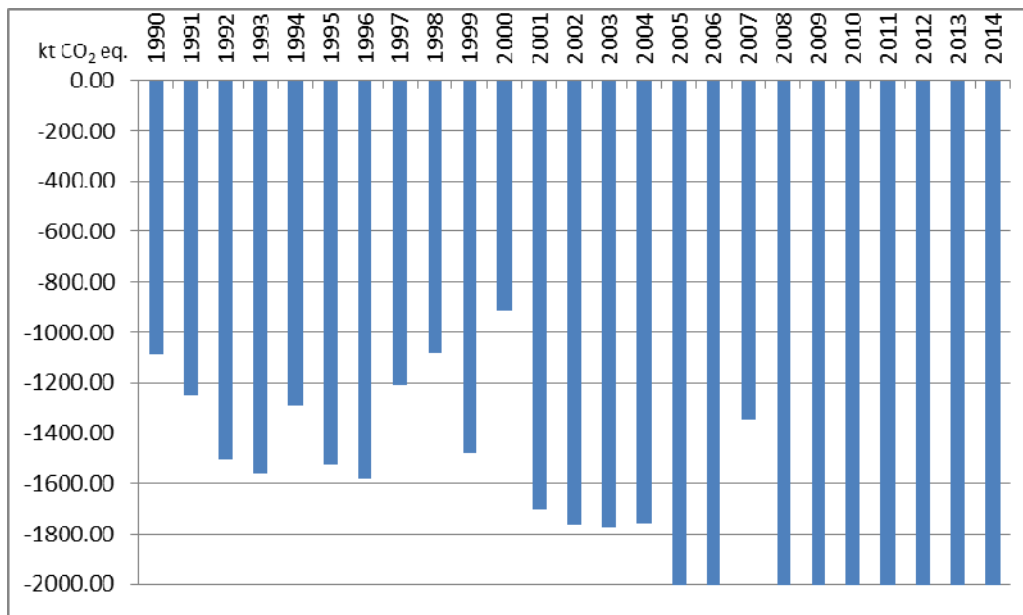


Figure 9.8 Emissions/removals from 4.A.1 Forest land remaining forest land category for the period 1990-2014 (equivalent to 3.4 forest management activity)

In the table below the relevant information on the FMRL technical correction are presented.

Table 9.7 Summary information of the Forest Management Reference Level Technical Correction

Summary Table Forest Management Reference Level Technical Correction		
	Instantaneous oxidation	FOD
	kt CO ₂ eq/yr	
FMRL	-1,830	0
FMRL _{corr}	-1,662	-1,733
Difference in per cent	-9%	-
Technical Correction	168	-1,733
Projected HWP contribution	-	-71

9.5.2.4 Information on Harvested Wood Products

The methodology applied for the estimation of carbon stock changes and CO₂ emissions and removals resulting from the Harvested Wood Products pool is consistent with 2006 GL AFOLU (Volume 4, chapter 12) and the KP Supplement, in accordance with Decision 2/CMP.7.

It is assumed that all HWPs originating from managed forests. The methodology followed for the estimation of emissions/removals under KP is the same applied for that pool under the UNFCCC as described in section 6.10.

More specifically, the production approach has been followed for the estimation of emissions/removals associated with carbon stock changes from HWP originating from the country's forest, using the tier 2 (First Order Decay) approach, using guidance and the equations 2.8.1, 2.8.2, 2.8.4, 2.8.5, and 2.8.6 of the KP Supplement.

Three harvested wood products categories have been addressed, namely sawnwood, wood-based panels, and paper and paperboard, and the change in carbon stocks was estimated separately for each product category. The necessary activity data for all three categories have been obtained from FAO statistics database. In particular data for production, import and export from 1961 onwards.

For the estimation of emission factors for each HWP category the default half-lives values from table 2.8.2 of the KP Supplement, namely 2 years for paper, 25 years for wood panels, and 35 years for sawnwood have been applied, while default values presented in table 2.8.1 (KP Supplement) have been used as conversion factors for the default HWP categories.

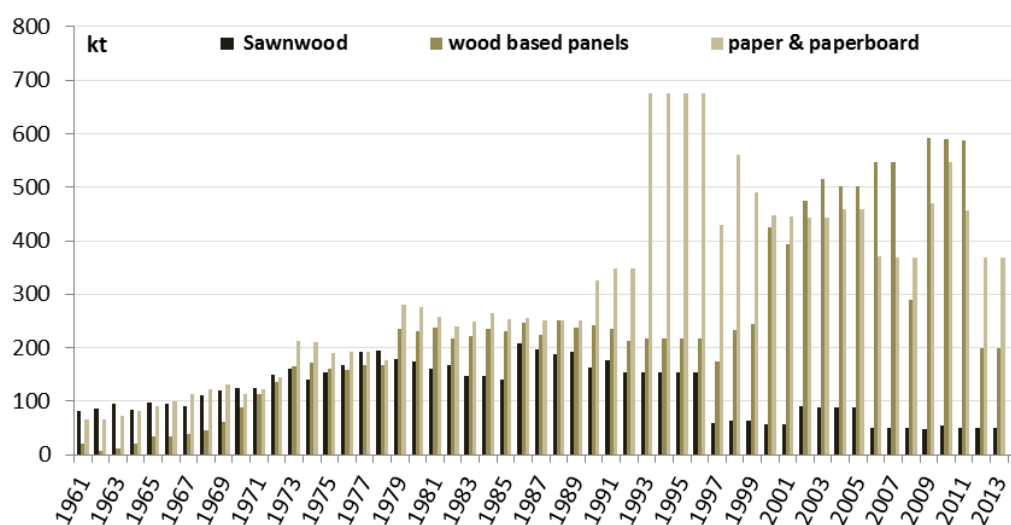


Figure 9.9 *Harvested wood products in use*

Given that no county specific policies and information about future HWP from domestic forests are available, and concerning the inflow from annual domestic harvest, there is no specific trend during the last years, it is assumed that the projected harvesting rates (inflow) of the years 2014-2020 will be equal to the last five years' average level.

Therefore, the emissions/removals from 2014 till 2020 were estimated using the methodology described above, while the inflow of each year is calculated according the equation below:

$$Inflow_{projected} = \left(\sum_{i=2010}^{t=2014} Inflow(i) \right) / 5$$

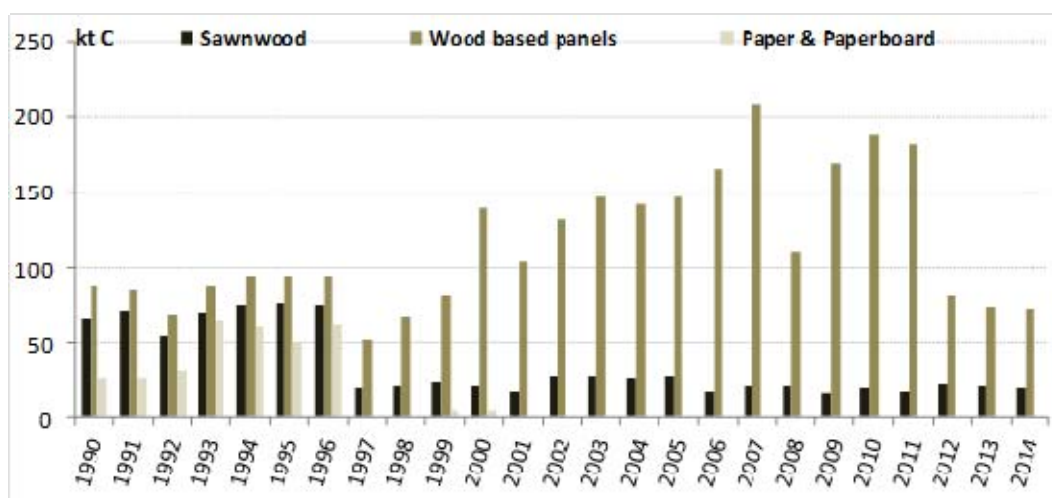


Figure 9.10 Annual inflow for each product category

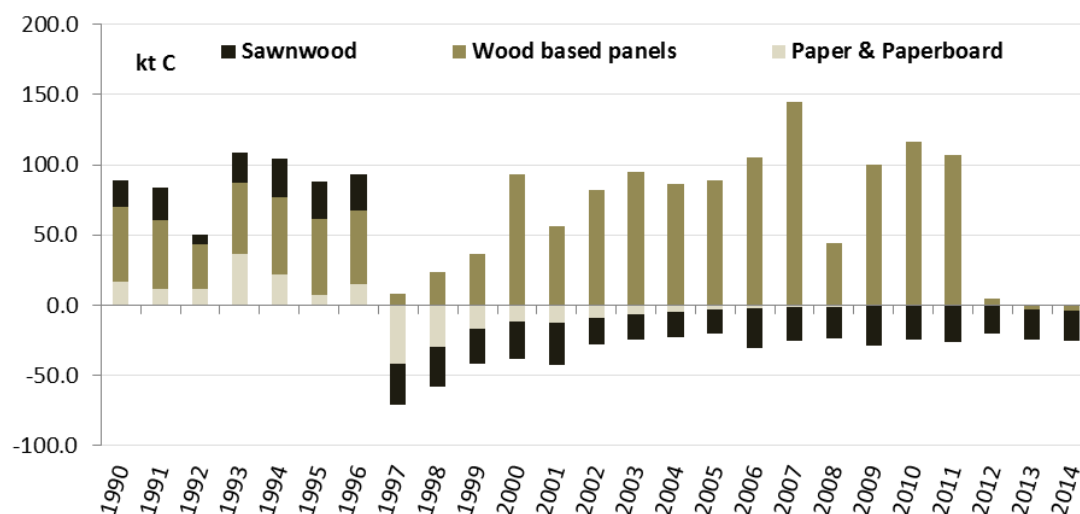


Figure 9.11 Annual change in carbon stocks (kt)

9.5.2.5 Conversion of natural forest to planted forest

Conversion of natural forest to planted forest is not occurring.

9.5.3 Information relating to Cropland Management, Grazing Land Management, Revegetation, and Wetland Drainage and Rewetting if elected, for the base year

None of these activities was elected by Greece for the second commitment period.

9.6 Other information

9.6.1 Key category analysis for Article 3.3 activities, forest management and any elected activities under Article 3.4

The assessment of key categories under article 3.3 and 3.4 of Kyoto Protocol was based on the assessment made for the UNFCCC inventory. In the cases where there is a clear correspondence between the UNFCCC categories and the Kyoto Protocol Activities (i.e. Forest Management), a Kyoto Protocol activity was considered as key when the associated category was identified as key in the UNFCCC inventory.

The Kyoto Protocol activity of Deforestation encompasses the UNFCCC subcategories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 (Forest land converted to other land uses). The sum of these subcategories is smaller than the smallest UNFCCC key category. Moreover, none of the categories 4.B.2.1, 4.C.2.1, 4.D.2.2.1, 4.E.2.1 and 4.F.2.1 has been identified as key, and hence Deforestation is not identified as a key category.

Table 9.8 *NIR 3. Key categories under Kyoto Protocol art. 3.3 and 3.4*

Key category	Gas	Criteria	Associated key category in UNFCCC inventory
KP-LULUCF			
Forest Management	CO ₂	Level, Trend	Forest Land remaining Forest Land

9.7 Information relating to Article 6

Not applicable to Greece.

10. Information on accounting of Kyoto units

10.1 Summary of information reported in the SEF tables

There are no CP2 transactions of Kyoto units for the years 2013, 2014 and 2015. Information on Kyoto Protocol units for the first commitment period for the reported year 2015 is included in the respective SEF tables (http://unfccc.int/kyoto_protocol/reporting/true-up_period_reports_under_the_kyoto_protocol/items/9049.php).

10.2 Discrepancies and notifications

With respect to the respective paragraphs of Annex to decision 15/CMP.1 the following information is provided for the registry:

- Paragraph 12: No discrepancies identified by the transaction log.
- Paragraph 13: No notifications directed to the Party to replace ICERs in accordance with Paragraph 49 of the annex to decision 5/CMP.1.
- Paragraph 14: No notifications directed to the Party to replace ICERs in accordance with para 50 of the annex to decision 5/CMP.1.
- Paragraph 15: No issue of non-replacement.
- Paragraph 16: No KP Units that are not valid.
- Paragraph 17: No actions were necessary to correct any problem causing a discrepancy.

10.3 Publicly accessible information

Publicly accessible information is provided through the link of the Greek Greenhouse Gas Registry in the corresponding web site of the Ministry of Environment and Energy:

<http://www.ypeka.gr/Default.aspx?tabid=775&locale=el-GR&language=en-US> (in Greek)

<http://www.ypeka.gr/Default.aspx?tabid=775&locale=en-US&language=el-GR> (in English)

Publicly accessible information is also provided from EUTL:

<http://ec.europa.eu/environment/ets/>

10.4 Calculation of the commitment period reserve (CPR)

For the calculation of the CPR we refer to the report of Greece which facilitates the calculation of the assigned amount and CPR.

11. Information on changes in national system

The following changes were performed:

1. It has been confirmed in writing to the UNFCCC Executive Secretary that the National UNFCCC Focal Points in the MEEN have changed, as follows:
 - The previous NFP (Ms Irini Nikolaou) has been replaced by Mr Kyriakos Psychas (Address: Patission 147, Athens, Greece, e-mail: k.psychas@prv.ypeka.gr, tel.: +30210 8665938).
 - The previous Alternate NFP (Ms Aikaterini Pelekasi) has been replaced by Mr Yiannis Markoudakis (Address: Patission 147, Athens, Greece, e-mail: j.markoudakis@prv.ypeka.gr, tel.: + 210 864 7008).
2. With regard to the LULUCF consultancy the change from the previous year is:
 - Until the 2015 GHG inventory submission, the compilation of the LULUCF inventory (UNFCCC and KP LULUCF) was a responsibility of the National Technical University of Athens (NTUA). For the 2016 submission, the responsibility for the compilation of the LULUCF inventory (UNFCCC and KP LULUCF) is assigned to Mr Iordanis Tzamtzis, which is an independent consultant.

12. Information on changes in national registry

The following changes to the national registry of Greece have therefore occurred in 2015:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	<p>There was no change to the database structure as it pertains to KP functionality in 2015.</p> <p>Versions of the CSEUR released after 6.3.3.2 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database.</p> <p>These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p>
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	<p>Changes introduced since version 6.3.3.2 of the national registry are listed in Annex B.</p> <p>Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was carried out in February 2016 and the test report is attached.</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change of security measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	<p>Changes introduced since version 6.3.3.2 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B.</p> <p>Annex H testing was carried out in February 2016 and the test report is attached.</p>

13. Minimization of adverse impacts in accordance with Article 3, paragraph 14

13.1 Information on how Greece is striving, under Article 3, paragraph 14, of the Kyoto Protocol, to implement the commitments mentioned in Article 3, paragraph 1, of the Kyoto Protocol in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention

In this section Greece provides information on how it is implementing its commitment under Article 3, paragraph 14 of the Kyoto Protocol, i.e. how it is striving to implement its commitment under Article 3, paragraph 1 of the Kyoto Protocol in such a way as to minimize potential adverse social, environmental and economic impacts on developing countries. In order to strive for such a minimization, an assessment of potential positive and negative impacts – both of direct and indirect nature - is necessary with a double objective to maximize positive impacts and to minimize adverse impacts.

Impacts on third countries are mostly indirect and frequently cannot be directly attributed to a specific policy. Therefore, an estimation of potential adverse social, environmental and economic impacts usually comes out as a result from complex assessments of indirect influences.

The majority of Greek policies is directly related to the implementation of EU policies on a national level. An impact assessment is carried out for every new policy initiative at an EU level, and is taking into account during the adoption process of the relative legislation. Greece, as a EU Member State, is participating in the development and adoption process of EU policies.

Two major EU policies, Directive 2009/28/EC on the promotion of the use of renewable energy and Directive 2008/101/EC concerning the extension of the EU emissions trading scheme (ETS) to the aviation sector, have been identified as having potential impacts on third countries. Both directives will be implemented in Greece and will be analyzed in the rest of the paragraph.

Directive on the promotion of the use of renewable energy - Promotion of biomass and biofuels

The Directive on renewable energy (Directive 2009/28/EC), a part of the EU's climate and energy package, sets ambitious targets for all Member States, such that the EU will reach a 20% share of energy from renewable sources in the overall energy consumption by 2020 (with individual targets for each Member State – 18% for Greece) and a 10% share of renewable energy specifically in the transport sector, which includes biofuels, biogas, hydrogen and electricity from renewable energy sources. Biomass is one of the renewable energy sources promoted by this Directive and the use of biofuels is important for the achievement of the renewable target in the transport sector.

The impact assessments related to enhanced biofuel and biomass use at a EU level showed that the cultivation of energy crops could have both positive and negative impacts. Positive impacts derive from the fact that the increase of domestic demand for bioenergy generates new export revenues and employment opportunities for developing countries and boosts rural economies. Thus, there could be clear economic and social benefits. At the same time, the new EU energy crop demand could increase the impact on biodiversity, soil and water resources and can have positive as well as negative effects on air pollutants. The extent of carbon reduction and other environmental effects from the promotion of biofuels can vary according to the feedstock employed, the way the feedstock and the biofuels are produced, how they are transported and how far. Growing future demand for biomass feedstock combined with growing global food consumption could add to the agricultural sector's pressure on land use and result in adverse land use changes.

To address the risk of such adverse impacts, Article 17 of the EU's Directive on renewable energy sources creates pioneering "sustainability criteria", applicable to all biofuels (biomass used in the transport sector) and bioliquids. The sustainability criteria adopted are:

- establish a threshold for GHG emission reductions that have to be achieved from the use of biofuels;
- exclude the use of biofuels from land with high biodiversity value (primary forest and wooded land, protected areas or highly biodiverse grasslands),
- exclude the use of biofuels from land with high C stocks, such as wetlands, peatlands or continuously forested areas.

Greece is in the process of transposing the Directive into national law, and under this process the implementation of the sustainability criteria will be defined. The issue of the sustainability criteria is of high importance to Greece, since it will define the market and use of solid and gaseous biomass energy sources.

In this context, Greece will adopt national measures in order to respect the sustainability criteria and assess the impact of the production of biofuels on soil, water and biodiversity, for which it will report to the EU every two years, according to the Directive. Such data shall be used by the Commission in order to prepare a report informing the third countries and the Member States on the application of the above-mentioned criteria.

The reporting obligation refers also to the potential positive and negative land use change effect on EU and Third countries, including the estimation of the availability of foodstuffs at affordable prices, in particular for people living in developing countries, as well as other development issues.

Another action describing the country's efforts to minimize adverse effects on third countries is the execution of research on second generation biomass technologies by its research centers and universities (e.g. National Technical University – School of Chemical Engineering). The goal of second generation biofuel processes is to extend the amount of biofuel that can be produced sustainably by using biomass consisting of the residual non-food parts of current crops, such as

stems, leaves and husks that are left behind once the food crop has been extracted, as well as other crops that are not used for food purposes (non food crops) and also industry waste such as woodchips, skins and pulp from fruit pressing. Second generation biofuels are expected to expand the biomass feedstock available for biofuel production.

The preparation for the implementation of Directive 2009/28/EC is supported by national legislation promoting the development of RES.

Inclusion of aviation in the EU emission trading scheme

The inclusion of aviation activities to and from EU airports in the EU emissions trading scheme, is likely to have adverse effects on aircraft operators from developing countries. Greece, as a member of the EU ETS system, has been appointed as administering Member state for a number of operators coming from developing countries.

The impacts of the above mentioned measure include impacts on the aircraft operators from developing countries that operate on route covered by the scheme. The inclusion of international flights and third countries' operators, avoid distortions of competition on specific routes and discrimination as to nationality. However, in order to reduce the aggregated costs for third country airlines especially from regions that include developing countries, airlines operating limited services are exempt from the Community scheme.

Indirect positive effects are to be expected by the inclusion of the aviation into the EU ETS, as it shall create additional demand for credits generating from JI and CDM projects, permitting therefore additional investments in clean technologies in developing countries. Similarly, additional finance for climate change mitigation and adaptation in developing countries should be raised through the auctioning of emissions allowances by the country. Proceeds of auctioning are to be contributed to the Global Energy Efficiency and Renewable Energy Fund, and measures to avoid deforestation and facilitate adaptation in developing countries.

13.2 Information on how Greece gives priority in implementing the commitments under Article 3. Paragraph 14 to specific actions

The current section addresses the subparagraphs (a) to (f) of paragraph 24 of the reporting requirements in Annex I to decision 15/CMP.1. In cases where the relation of specific actions to the minimization of adverse social, environmental and economic impacts resulting from policies and measures to mitigate GHG emissions is not clearly defined the respective subparagraphs have been omitted. In any case, the main ways how Greece is striving to minimize adverse impacts have been already described in the previous section.

- (a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities***

The current paragraph includes information on the means used by the country in order to enhance the progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies that run counter to the objectives of the Convention and on the application of market instruments.

Greece, as a Member of the EU, supports and makes the necessary steps to implement the EU Common Agricultural Policy. In the specific policy environmental concerns have been gradually incorporated. Such examples are the including "decoupled" direct payments which have replaced price support; environmental cross compliance; a substantial increase in budget for rural development. As part of 2008 Common Agriculture Policy Health Check, additional part of direct aid has been shifted to climate change, renewable energy, water management, biodiversity, innovation; - transparency of agricultural subsidies has improved. It is important to note that in the other areas most subsidies are within the competence of the country.

The energy market liberalisation (National Law 2773/1999) has been an important step to create a original internal energy market and can be considered as a mean to address market imperfections and to reflect externalities. The existence of a competitive internal energy market is a strategic instrument both in terms of giving local consumers a choice between different companies supplying gas and electricity at reasonable prices, but also in terms of making the market accessible for all suppliers, especially the smallest and those investing in renewable forms of energy.

In the same time, Greece participates in the EU Emissions Trading Scheme, which constitutes an important market instrument to implement the objectives of the Convention and Article 3, paragraph 1 of the Kyoto Protocol which aims at creating the right incentives for forward looking low carbon investment decisions by reinforcing a clear, undistorted and long-term carbon price signal.

Finally, the taxation on energy products and electricity, as defined by the Directive 2003/96/EC, contribute to establishment of rules for the taxation of energy products used as motor or heating fuel, taxes on energy consumption, and common minimum levels of taxation. The Directive has been transposed into Greek legislation with Laws 3336/2005 and 3340/2005. In addition, the National Customs Code (Law 2960/2001), as applicable, makes use of the options provided for in such Directive to exonerate, totally or partially, the electricity generated by renewable energy sources, as well as natural gas or biofuel. Further information on the implementation of the respective laws has already been reported in the 5th National Communication of Greece (January 2010).

(b) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

One of the main research priorities of EU is orientated to the development, diffusion and transfer of less-greenhouse-gas emitting fossil fuels technologies. Greece, as an EU Member State, supports financially the pilot projects on carbon capture and storage and the relative cooperation of EU and China.

Various bilateral and multilateral cooperations have been already mentioned in the 5th National Communication of Greece (January 2010). In the context of these cooperations a number of projects is implemented in order to facilitate and finance the transfer and access of developing countries to environmentally sound technologies.

It should be also noted that in the EU's 'Creation and Operation of an EU-GCC Clean Energy Network', created in December 2009, a special working group is oriented to CCS technologies. Greece is an official partner of the project (Institute of Communications and Computer Systems of the National Technical University of Athens).

(c) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

In the oil and gas industry the upstream sector is a term commonly used to refer to the exploration, drilling, recovery and production of crude oil and natural gas. The downstream sector includes the activities of refining, distillation, cracking, reforming, blending storage, mixing and shipping and distribution.

The EU contributes to strengthening of the capacities of fossil fuel exporting countries in the areas of energy efficiency via the work of the Energy Expert Group of the Gulf Cooperation Council (GCC), in particular in the working sub-group on energy efficiency. As part of the EU's research programme, a project called "EUROGULF" was launched with the objective of to analyse EU-GCC relations with respect to oil and gas issues and propose new policy initiatives and approaches to enhance cooperation between the two regional groupings. In Greece, the Energy Policy Unit of the National Technical University of Athens (NTUA) has actively participated in the EUROGULF Project ('EUROGULF: An EU-GCC Dialogue for Energy Stability and Sustainability'), as well as in other similar projects.

The European e-network on clean energy technologies, currently under development as part of the EU's research and development, is also aiming at the objective: promote research and technical development of clean energy technologies in the GCC countries. The Commission has recently started a project with the specific objective to create and facilitate the operation of an EU-GCC Clean Energy Network during the next three years. The network is to be set up to act as a catalyst and element of coordination for development of cooperation on clean energy.

The project has started in December 2009 and is structured in 5 working groups. Greece officially participates in the Network (Institute of Communications and Computer Systems of the National

Technical University of Athens). Further information can be found in the website <http://eugcc.epu.ntua.gr/Home.aspx>.

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

A number of activities aiming at the decrease of the dependence on the consumption of fossil fuels in developing countries have been supported and implemented by Greece. Most of the activities are oriented at the promotion of renewable energies and energy efficiency in those countries, contributing to the covering of rural electricity needs and the improvement of air quality. Such indicative projects have already been mentioned in the 7th chapter of the 5th national communication (January 2010), and include:

- Project “SYN-ENERGY” (Recipient countries: Albania, Bosnia-Herzegovina, Croatia, FYROM, Moldavia, Montenegro, Serbia, Georgia, Ukraine)
- Applications of Renewable Energy and Energy Savings Methods (Recipient country: Libanon)
- Renewable Energy Sources – Development and Implementation of Solar Energy (Recipient country: Armenia)
- Action Plan for Cooperation in the field of Renewable Energy Sources (Recipient country: Turkey)
- Installation of solar systems for household use in poor households in the region of Monaragala (Recipient country: Sri Lanka).

Greece, as an EU Member State, also supports and facilitates the EU Cooperation with Developing Countries. The programmes included in this respect are:

- Renewable energy cooperation with the Mediterranean and Gulf countries
- Africa, Caribbean and the Pacific (ACP-E) Energy Facility
- Euro-Solar Programme in Latin America
- Latin America Investment Facility (LAIF)
- Global Energy Efficiency and Renewable Energy Fund (GEEREF)

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ANNEXES

Annex I: Key categories

The 2006 IPCC Guidelines defines procedures (in the form of decision trees) for the choice of estimation methods within the context of the IPCC Guidelines. Decision trees formalize the choice of the estimation method most suited to national circumstances considering at the same time the need for accuracy and the available resources (both financial and human). Generally, inventory uncertainty is lower when emissions are estimated using the most rigorous methods, but due to finite resources, this may not be feasible for every source category. Therefore it is good practice to identify those source categories (key source categories) that have the greatest contribution to overall inventory uncertainty in order to make the most efficient use of available resources.

In that context, a “key source category” is one that is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct greenhouse gases in terms of the absolute level of emissions (level assessment) or/and to the trend of emissions (trend assessment).

As far as possible, key source categories should receive special consideration in terms of two important inventory aspects.

1. The use of source category-specific good practice methods is preferable, unless resources are unavailable.
2. The key source categories should receive additional attention with respect to quality assurance (QA) and quality control (QC).

The determination of the key categories without *LULUCF* for the Greek inventory system is based on the application of the Tier 1 methodology described in the 2006 IPCC GLs (**Tables I.1, I.3 and I.5**), adopting the categorization of sources that is presented in the GLs. Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms. It should be noted that, according to the 2006 IPCC GLs the trend is estimated on the basis of the base year (1990). The methodology for the determination of key categories with *LULUCF* is in fact the same as for the one for key sources without *LULUCF* (**Tables I.2, I.4 and I.6**).

The key categories analysis analysis has been performed for the total of the time series (years 1990-2014) on both level and trend analysis basis. Any differences between the key categories in the time-series are due to the fluctuation of the trend in specific categories and refer to trend analysis.

Table I.1 *Key categories analysis without LULUCF – Level assessment for 2014*

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Energy Industries: Solid fuels	CO2	35,200.91	33,954.82	33.48	33.48
Road Transportation	CO2	11,825.78	15,148.94	14.94	48.42
Energy Industries: Liquid fuels	CO2	7,790.77	8,817.08	8.70	57.12
ODS substitutes	HFC	0.00	5,758.13	5.68	62.80
Other Sectors: Liquid fuels	CO2	7,945.96	3,955.05	3.90	66.70
Manufacturing Industries & Construction: Liquid fuels	CO2	5,747.24	3,858.71	3.81	70.50
Cement Production	CO2	5,761.69	3,821.93	3.77	74.27
Solid waste disposal	CH4	2,243.85	3,182.24	3.14	77.41
Energy Industries: Gaseous fuels	CO2	102.03	3,012.72	2.97	80.38
Direct N2O from agr. soils	N2O	3,553.91	2,459.62	2.43	82.81
Enteric fermentation: Sheep	CH4	2,053.63	2,084.65	2.06	84.86
Wastewater Treatment and Discharge	CH4	3,976.02	1,537.87	1.52	86.38
Domestic Navigation	CO2	1,808.71	1,456.86	1.44	87.82
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,276.34	1.26	89.07
Coal Mining (surface)	CH4	1,130.04	1,107.15	1.09	90.17
Indirect N2O from nitrogen used in agr.	N2O	1,237.72	874.67	0.86	91.03
Enteric fermentation: Non Dairy Cattle	CH4	691.82	841.20	0.83	91.86
Other Sectors: Gaseous fuels	CO2	0.00	832.26	0.82	92.68
Manure management	CH4	884.47	822.21	0.81	93.49
Ferroalloys	CO2	622.23	701.41	0.69	94.18
Enteric fermentation: Other	CH4	748.56	674.20	0.66	94.85
Domestic Aviation	CO2	319.05	550.46	0.54	95.39
Enteric fermentation: Dairy Cattle	CH4	485.84	408.35	0.40	95.79
Other Process Uses of Carbonates	CO2	589.53	363.24	0.36	96.15
Other	CO2	0.00	328.08	0.32	96.47
Manure management	N2O	305.42	325.11	0.32	96.79
Wastewater Treatment and Discharge	N2O	279.29	323.15	0.32	97.11
Lime Production	CO2	404.00	292.61	0.29	97.40
Aluminium Production	CO2	225.39	276.87	0.27	97.68
Ammonia Production	CO2	652.04	241.31	0.24	97.91
Manufacturing Industries & Construction: Solid fuels	CO2	3,591.24	236.21	0.23	98.15
N2O from Product Uses	N2O	133.26	141.97	0.14	98.29
Rice Cultivation	CH4	82.26	140.00	0.14	98.42
Railways	CO2	198.94	134.62	0.13	98.56
Energy Industries: Solid fuels	N2O	128.97	123.17	0.12	98.68
Road Transportation	N2O	117.72	109.31	0.11	98.79
Other Sectors: Biomass	CH4	91.18	104.58	0.10	98.89
Oil, Natural Gas and Other sources	CH4	36.40	88.37	0.09	98.98
Other Product Manufacture and Use: Other	CO2	102.47	84.55	0.08	99.06
Aluminium Production	PFCs	190.26	79.59	0.08	99.14
Road Transportation	CH4	107.09	77.77	0.08	99.22
Navigation	N2O	129.19	75.67	0.07	99.29
Iron and Steel Production	CO2	104.89	70.33	0.07	99.36
Zinc Production	CO2	45.92	65.70	0.06	99.42
Manufacturing Industries & Construction: Liquid fuels	N2O	27.35	57.98	0.06	99.48
ODS substitutes	PFC	0.00	55.05	0.05	99.54
Other Sectors: Liquid fuels	N2O	313.23	44.93	0.04	99.58
Field Burning of Agricultural Residues	CH4	34.23	41.84	0.04	99.62
Other Sectors: Biomass	N2O	30.57	35.08	0.03	99.66
Enteric fermentation: Swine	CH4	37.33	32.40	0.03	99.69
Lubricant Use	CO2	77.83	28.30	0.03	99.72
Nitric Acid Production	N2O	1,066.11	26.81	0.03	99.74
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	26.07	0.03	99.77

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Urea Application	CO2	60.41	25.78	0.03	99.79
Other Sectors: Solid fuels	CO2	119.55	23.46	0.02	99.82
Biological Treatment of Solid Waste	CH4	0.00	19.90	0.02	99.84
Biological Treatment of Solid Waste	N2O	0.00	17.79	0.02	99.85
Glass Production	CO2	20.20	16.82	0.02	99.87
Railways	N2O	23.17	15.81	0.02	99.89
Energy Industries: Liquid fuels	N2O	15.88	13.50	0.01	99.90
Field Burning of Agricultural Residues	N2O	10.34	13.06	0.01	99.91
Lead Production	CO2	13.62	10.46	0.01	99.92
Other transportation	CO2	0.00	9.93	0.01	99.93
Civil Aviation	N2O	3.28	7.77	0.01	99.94
Manufacturing Industries & Construction: Biomass	N2O	9.53	7.40	0.01	99.95
Energy Industries: Solid fuels	CH4	7.21	6.89	0.01	99.95
Energy Industries: Liquid fuels	CH4	6.90	6.34	0.01	99.96
Other transportation	N2O	0.00	5.32	0.01	99.96
SF6 from electrical equipment	SF6	2.93	4.92	0.00	99.97
Manufacturing Industries & Construction: Biomass	CH4	5.99	4.65	0.00	99.97
Oil, Natural Gas and Other sources	CO2	42.70	3.75	0.00	99.98
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	3.55	0.00	99.98
Incineration and Open Burning of Waste]	CO2	0.22	3.11	0.00	99.98
Navigation	CH4	3.05	2.70	0.00	99.99
Other Sectors: Liquid fuels	CH4	11.01	2.37	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH4	5.00	2.22	0.00	99.99
Energy Industries: Gaseous fuels	N2O	0.05	1.62	0.00	99.99
Energy Industries: Gaseous fuels	CH4	0.04	1.36	0.00	99.99
Manufacturing Industries & Construction: Solid fuels	N2O	16.87	1.12	0.00	100.00
Incineration and Open Burning of Waste]	N2O	0.12	0.66	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH4	0.00	0.57	0.00	100.00
Paraffin Wax Use	CO2	1.77	0.52	0.00	100.00
Other Sectors: Gaseous fuels	N2O	0.00	0.45	0.00	100.00
Other Sectors: Gaseous fuels	CH4	0.00	0.37	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.35	0.00	100.00
Iron and Steel Production	CH4	0.25	0.26	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.22	0.00	100.00
Civil Aviation	CH4	0.15	0.21	0.00	100.00
Railways	CH4	0.28	0.19	0.00	100.00
Other Sectors: Solid fuels	N2O	0.49	0.11	0.00	100.00
Energy Industries: Biomass	N2O	0.00	0.09	0.00	100.00
Energy Industries: Biomass	CH4	0.00	0.07	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.96	0.06	0.00	100.00
Incineration and Open Burning of Waste]	CH4	0.01	0.03	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.17	0.01	0.00	100.00
Other Sectors: Solid fuels	CH4	0.03	0.01	0.00	100.00
Other transportation	CH4	0.00	0.00	0.00	100.00
Petrochemical and Carbon Black Production	CO2	28.61	0.00	0.00	100.00
Petrochemical and Carbon Black Production	CH4	1.13	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	1,182.82	0.00	0.00	100.00
TOTAL		104,827.11		100.00	

Table I.2 *Key categories analysis with LULUCF – Level assessment for 2014*

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Energy Industries: Solid fuels	CO2	33,954.82	32.33	32.33
Road Transportation	CO2	15,148.94	14.42	46.75
Energy Industries: Liquid fuels	CO2	8,817.08	8.39	55.14
ODS substitutes	HFC	5,758.13	5.48	60.63
Other Sectors: Liquid fuels	CO2	3,955.05	3.77	64.39
Manufacturing Industries & Construction: Liquid fuels	CO2	3,858.71	3.67	68.06
Cement Production	CO2	3,821.93	3.64	71.70
Solid waste disposal	CH4	3,182.24	3.03	74.73
Energy Industries: Gaseous fuels	CO2	3,012.72	2.87	77.60
Direct N2O from agr. soils	N2O	2,459.62	2.34	79.94
Forest Land remaining Forest Land	CO2	2,142.98	2.04	81.98
Enteric fermentation: Sheep	CH4	2,084.65	1.98	83.97
Wastewater Treatment and Discharge	CH4	1,537.87	1.46	85.43
Domestic Navigation	CO2	1,456.86	1.39	86.82
Manufacturing Industries & Construction: Gaseous fuels	CO2	1,276.34	1.22	88.03
Coal Mining (surface)	CH4	1,107.15	1.05	89.09
Indirect N2O from nitrogen used in agr.	N2O	874.67	0.83	89.92
Conversion to Grassland	CO2	850.68	0.81	90.73
Enteric fermentation: Non Dairy Cattle	CH4	841.20	0.80	91.53
Other Sectors: Gaseous fuels	CO2	832.26	0.79	92.32
Manure management	CH4	822.21	0.78	93.11
Ferroalloys	CO2	701.41	0.67	93.77
Enteric fermentation: Other	CH4	674.20	0.64	94.42
Domestic Aviation	CO2	550.46	0.52	94.94
Enteric fermentation: Dairy Cattle	CH4	408.35	0.39	95.33
Other Process Uses of Carbonates	CO2	363.24	0.35	95.68
Other	CO2	328.08	0.31	95.99
Manure management	N2O	325.11	0.31	96.30
Wastewater Treatment and Discharge	N2O	323.15	0.31	96.60
Cropland remaining Cropland	CO2	317.27	0.30	96.91
Lime Production	CO2	292.61	0.28	97.19
Aluminium Production	CO2	276.87	0.26	97.45
Ammonia Production	CO2	241.31	0.23	97.68
Manufacturing Industries & Construction: Solid fuels	CO2	236.21	0.22	97.90
N2O from Product Uses	N2O	141.97	0.14	98.04
Rice Cultivation	CH4	140.00	0.13	98.17
Railways	CO2	134.62	0.13	98.30
Land Converted to Forest Land	CO2	123.87	0.12	98.42
Energy Industries: Solid fuels	N2O	123.17	0.12	98.54
Road Transportation	N2O	109.31	0.10	98.64
Other Sectors: Biomass	CH4	104.58	0.10	98.74
Harvested Wood Products	CO2	93.27	0.09	98.83
Oil, Natural Gas and Other sources	CH4	88.37	0.08	98.91
Other Product Manufacture and Use: Other	CO2	84.55	0.08	98.99
Land Converted to Other Land	CO2	82.47	0.08	99.07
Aluminium Production	PFCs	79.59	0.08	99.15
Road Transportation	CH4	77.77	0.07	99.22
Navigation	N2O	75.67	0.07	99.29
Iron and Steel Production	CO2	70.33	0.07	99.36
Zinc Production	CO2	65.70	0.06	99.42

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	57.98	0.06	99.48
ODS substitutes	PFC	55.05	0.05	99.53
Other Sectors: Liquid fuels	N ₂ O	44.93	0.04	99.57
Field Burning of Agricultural Residues	CH ₄	41.84	0.04	99.61
Other Sectors: Biomass	N ₂ O	35.08	0.03	99.65
Enteric fermentation: Swine	CH ₄	32.40	0.03	99.68
Lubricant Use	CO ₂	28.30	0.03	99.70
Nitric Acid Production	N ₂ O	26.81	0.03	99.73
Manufacturing Industries & Construction: Other Fuels	CO ₂	26.07	0.02	99.75
Urea Application	CO ₂	25.78	0.02	99.78
Other Sectors: Solid fuels	CO ₂	23.46	0.02	99.80
Biological Treatment of Solid Waste	CH ₄	19.90	0.02	99.82
Biological Treatment of Solid Waste	N ₂ O	17.79	0.02	99.84
Glass Production	CO ₂	16.82	0.02	99.85
Railways	N ₂ O	15.81	0.02	99.87
Energy Industries: Liquid fuels	N ₂ O	13.50	0.01	99.88
Field Burning of Agricultural Residues	N ₂ O	13.06	0.01	99.89
Conversion to Settlements	CO ₂	11.33	0.01	99.90
Lead Production	CO ₂	10.46	0.01	99.91
Other transportation	CO ₂	9.93	0.01	99.92
Grassland remaining Grassland	CH ₄	8.32	0.01	99.93
Civil Aviation	N ₂ O	7.77	0.01	99.94
Manufacturing Industries & Construction: Biomass	N ₂ O	7.40	0.01	99.95
Energy Industries: Solid fuels	CH ₄	6.89	0.01	99.95
Energy Industries: Liquid fuels	CH ₄	6.34	0.01	99.96
Other transportation	N ₂ O	5.32	0.01	99.96
SF ₆ from electrical equipment	SF ₆	4.92	0.00	99.97
Manufacturing Industries & Construction: Biomass	CH ₄	4.65	0.00	99.97
Oil, Natural Gas and Other sources	CO ₂	3.75	0.00	99.98
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	3.55	0.00	99.98
Incineration and Open Burning of Waste]	CO ₂	3.11	0.00	99.98
Navigation	CH ₄	2.70	0.00	99.99
Other Sectors: Liquid fuels	CH ₄	2.37	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH ₄	2.22	0.00	99.99
Energy Industries: Gaseous fuels	N ₂ O	1.62	0.00	99.99
Energy Industries: Gaseous fuels	CH ₄	1.36	0.00	99.99
Manufacturing Industries & Construction: Solid fuels	N ₂ O	1.12	0.00	99.99
Forest Land remaining Forest Land	CH ₄	1.06	0.00	99.99
Grassland remaining Grassland	N ₂ O	0.68	0.00	100.00
Incineration and Open Burning of Waste]	N ₂ O	0.66	0.00	100.00
Land Converted to Cropland	CO ₂	0.62	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.57	0.00	100.00
Paraffin Wax Use	CO ₂	0.52	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.45	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.37	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.35	0.00	100.00
Iron and Steel Production	CH ₄	0.26	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.22	0.00	100.00
Civil Aviation	CH ₄	0.21	0.00	100.00
Railways	CH ₄	0.19	0.00	100.00
Grassland remaining Grassland	CO ₂	0.15	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.11	0.00	100.00
Land Converted to Wetlands	CO ₂	0.09	0.00	100.00

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Energy Industries: Biomass	N ₂ O	0.09	0.00	100.00
Forest Land remaining Forest Land	N ₂ O	0.09	0.00	100.00
Energy Industries: Biomass	CH ₄	0.07	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.06	0.00	100.00
Incineration and Open Burning of Waste]	CH ₄	0.03	0.00	100.00
Land Converted to Cropland	N ₂ O	0.03	0.00	100.00
Oil, Natural Gas and Other sources	N ₂ O	0.01	0.00	100.00
Other Sectors: Solid fuels	CH ₄	0.01	0.00	100.00
Other transportation	CH ₄	0.00	0.00	100.00
Petrochemical and Carbon Black Production	CO ₂	0.00	0.00	100.00
Petrochemical and Carbon Black Production	CH ₄	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	0.00	0.00	100.00
TOTAL		105,036.21	100.00	

Table I.3 *Key categories analysis without LULUCF – Level assessment for 1990*

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Energy Industries: Solid fuels	CO ₂	35,200.91	33.58	33.58
Road Transportation	CO ₂	11,825.78	11.28	44.86
Other Sectors: Liquid fuels	CO ₂	7,945.96	7.58	52.44
Energy Industries: Liquid fuels	CO ₂	7,790.77	7.43	59.87
Cement Production	CO ₂	5,761.69	5.50	65.37
Manufacturing Industries & Construction: Liquid fuels	CO ₂	5,747.24	5.48	70.85
Wastewater Treatment and Discharge	CH ₄	3,976.02	3.79	74.65
Manufacturing Industries & Construction: Solid fuels	CO ₂	3,591.24	3.43	78.07
Direct N ₂ O from agr. soils	N ₂ O	3,553.91	3.39	81.46
Solid waste disposal	CH ₄	2,243.85	2.14	83.60
Enteric fermentation: Sheep	CH ₄	2,053.63	1.96	85.56
Domestic Navigation	CO ₂	1,808.71	1.73	87.29
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	1,237.72	1.18	88.47
HFC-23 Emissions from HCFC-22 Manufacture	HFC	1,182.82	1.13	89.60
Coal Mining (surface)	CH ₄	1,130.04	1.08	90.67
Nitric Acid Production	N ₂ O	1,066.11	1.02	91.69
Manure management	CH ₄	884.47	0.84	92.53
Enteric fermentation: Other	CH ₄	748.56	0.71	93.25
Enteric fermentation: Non Dairy Cattle	CH ₄	691.82	0.66	93.91
Ammonia Production	CO ₂	652.04	0.62	94.53
Ferroalloys	CO ₂	622.23	0.59	95.12
Other Process Uses of Carbonates	CO ₂	589.53	0.56	95.69
Enteric fermentation: Dairy Cattle	CH ₄	485.84	0.46	96.15
Lime Production	CO ₂	404.00	0.39	96.54
Domestic Aviation	CO ₂	319.05	0.30	96.84
Other Sectors: Liquid fuels	N ₂ O	313.23	0.30	97.14
Manure management	N ₂ O	305.42	0.29	97.43
Wastewater Treatment and Discharge	N ₂ O	279.29	0.27	97.70
Aluminium Production	CO ₂	225.39	0.22	97.91
Railways	CO ₂	198.94	0.19	98.10
Aluminium Production	PFCs	190.26	0.18	98.28
N ₂ O from Product Uses	N ₂ O	133.26	0.13	98.41
Navigation	N ₂ O	129.19	0.12	98.53
Energy Industries: Solid fuels	N ₂ O	128.97	0.12	98.66
Other Sectors: Solid fuels	CO ₂	119.55	0.11	98.77
Road Transportation	N ₂ O	117.72	0.11	98.88
Road Transportation	CH ₄	107.09	0.10	98.98
Iron and Steel Production	CO ₂	104.89	0.10	99.08
Other Product Manufacture and Use: Other	CO ₂	102.47	0.10	99.18
Energy Industries: Gaseous fuels	CO ₂	102.03	0.10	99.28
Other Sectors: Biomass	CH ₄	91.18	0.09	99.37
Rice Cultivation	CH ₄	82.26	0.08	99.44
Lubricant Use	CO ₂	77.83	0.07	99.52
Urea Application	CO ₂	60.41	0.06	99.58
Zinc Production	CO ₂	45.92	0.04	99.62
Oil, Natural Gas and Other sources	CO ₂	42.70	0.04	99.66
Enteric fermentation: Swine	CH ₄	37.33	0.04	99.70
Oil, Natural Gas and Other sources	CH ₄	36.40	0.03	99.73
Field Burning of Agricultural Residues	CH ₄	34.23	0.03	99.76
Other Sectors: Biomass	N ₂ O	30.57	0.03	99.79
Petrochemical and Carbon Black Production	CO ₂	28.61	0.03	99.82
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	27.35	0.03	99.85

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Railways	N ₂ O	23.17	0.02	99.87
Glass Production	CO ₂	20.20	0.02	99.89
Manufacturing Industries & Construction: Solid fuels	N ₂ O	16.87	0.02	99.90
Energy Industries: Liquid fuels	N ₂ O	15.88	0.02	99.92
Lead Production	CO ₂	13.62	0.01	99.93
Other Sectors: Liquid fuels	CH ₄	11.01	0.01	99.94
Field Burning of Agricultural Residues	N ₂ O	10.34	0.01	99.95
Manufacturing Industries & Construction: Biomass	N ₂ O	9.53	0.01	99.96
Energy Industries: Solid fuels	CH ₄	7.21	0.01	99.97
Energy Industries: Liquid fuels	CH ₄	6.90	0.01	99.98
Manufacturing Industries & Construction: Biomass	CH ₄	5.99	0.01	99.98
Manufacturing Industries & Construction: Liquid fuels	CH ₄	5.00	0.00	99.99
Civil Aviation	N ₂ O	3.28	0.00	99.99
Navigation	CH ₄	3.05	0.00	99.99
SF ₆ from electrical equipment	SF ₆	2.93	0.00	99.99
Paraffin Wax Use	CO ₂	1.77	0.00	100.00
Petrochemical and Carbon Black Production	CH ₄	1.13	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.96	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.49	0.00	100.00
Railways	CH ₄	0.28	0.00	100.00
Iron and Steel Production	CH ₄	0.25	0.00	100.00
Incineration and Open Burning of Waste]	CO ₂	0.22	0.00	100.00
Oil, Natural Gas and Other sources	N ₂ O	0.17	0.00	100.00
Civil Aviation	CH ₄	0.15	0.00	100.00
Incineration and Open Burning of Waste]	N ₂ O	0.12	0.00	100.00
Energy Industries: Gaseous fuels	N ₂ O	0.05	0.00	100.00
Energy Industries: Gaseous fuels	CH ₄	0.04	0.00	100.00
Other Sectors: Solid fuels	CH ₄	0.03	0.00	100.00
Incineration and Open Burning of Waste]	CH ₄	0.01	0.00	100.00
Energy Industries: Biomass	CH ₄	0.00	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.00	0.00	100.00
Other transportation	CO ₂	0.00	0.00	100.00
Other transportation	CH ₄	0.00	0.00	100.00
Other transportation	N ₂ O	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CO ₂	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.00	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Other	CO ₂	0.00	0.00	100.00
ODS substitutes	HFC	0.00	0.00	100.00
ODS substitutes	PFC	0.00	0.00	100.00
Biological Treatment of Solid Waste	CH ₄	0.00	0.00	100.00
Biological Treatment of Solid Waste	N ₂ O	0.00	0.00	100.00
TOTAL		104,827.11	100.00	

Table I.4 *Key categories analysis with LULUCF – Level assessment for 1990*

IPCC source categories	GHG	Base year (Gg CO ₂ eq (absolute values))	Level Assessment with LULUCF	Cumulative total
Energy Industries: Solid fuels	CO2	35,200.91	32.81	32.81
Road Transportation	CO2	11,825.78	11.02	43.83
Other Sectors: Liquid fuels	CO2	7,945.96	7.41	51.24
Energy Industries: Liquid fuels	CO2	7,790.77	7.26	58.50
Cement Production	CO2	5,761.69	5.37	63.87
Manufacturing Industries & Construction: Liquid fuels	CO2	5,747.24	5.36	69.22
Wastewater Treatment and Discharge	CH4	3,976.02	3.71	72.93
Manufacturing Industries & Construction: Solid fuels	CO2	3,591.24	3.35	76.28
Direct N2O from agr. soils	N2O	3,553.91	3.31	79.59
Solid waste disposal	CH4	2,243.85	2.09	81.68
Enteric fermentation: Sheep	CH4	2,053.63	1.91	83.59
Domestic Navigation	CO2	1,808.71	1.69	85.28
Indirect N2O from nitrogen used in agr.	N2O	1,237.72	1.15	86.43
HFC-23 Emissions from HCFC-22 Manufacture	HFC	1,182.82	1.10	87.54
Forest Land remaining Forest Land	CO2	1,139.19	1.06	88.60
Coal Mining (surface)	CH4	1,130.04	1.05	89.65
Nitric Acid Production	N2O	1,066.11	0.99	90.64
Cropland remaining Cropland	CO2	908.14	0.85	91.49
Manure management	CH4	884.47	0.82	92.32
Enteric fermentation: Other	CH4	748.56	0.70	93.01
Enteric fermentation: Non Dairy Cattle	CH4	691.82	0.64	93.66
Ammonia Production	CO2	652.04	0.61	94.27
Ferroalloys	CO2	622.23	0.58	94.85
Other Process Uses of Carbonates	CO2	589.53	0.55	95.40
Enteric fermentation: Dairy Cattle	CH4	485.84	0.45	95.85
Lime Production	CO2	404.00	0.38	96.22
Harvested Wood Products	CO2	324.95	0.30	96.53
Domestic Aviation	CO2	319.05	0.30	96.82
Other Sectors: Liquid fuels	N2O	313.23	0.29	97.12
Manure management	N2O	305.42	0.28	97.40
Wastewater Treatment and Discharge	N2O	279.29	0.26	97.66
Aluminium Production	CO2	225.39	0.21	97.87
Railways	CO2	198.94	0.19	98.06
Aluminium Production	PFCs	190.26	0.18	98.23
N2O from Product Uses	N2O	133.26	0.12	98.36
Navigation	N2O	129.19	0.12	98.48
Energy Industries: Solid fuels	N2O	128.97	0.12	98.60
Other Sectors: Solid fuels	CO2	119.55	0.11	98.71
Road Transportation	N2O	117.72	0.11	98.82
Road Transportation	CH4	107.09	0.10	98.92
Iron and Steel Production	CO2	104.89	0.10	99.02
Other Product Manufacture and Use: Other	CO2	102.47	0.10	99.11
Energy Industries: Gaseous fuels	CO2	102.03	0.10	99.21
Other Sectors: Biomass	CH4	91.18	0.08	99.29
Rice Cultivation	CH4	82.26	0.08	99.37
Lubricant Use	CO2	77.83	0.07	99.44
Urea Application	CO2	60.41	0.06	99.50
Forest Land remaining Forest Land	CH4	46.53	0.04	99.54
Zinc Production	CO2	45.92	0.04	99.59
Oil, Natural Gas and Other sources	CO2	42.70	0.04	99.63

IPCC source categories	GHG	Base year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Enteric fermentation: Swine	CH ₄	37.33	0.03	99.66
Oil, Natural Gas and Other sources	CH ₄	36.40	0.03	99.69
Field Burning of Agricultural Residues	CH ₄	34.23	0.03	99.73
Other Sectors: Biomass	N ₂ O	30.57	0.03	99.75
Petrochemical and Carbon Black Production	CO ₂	28.61	0.03	99.78
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	27.35	0.03	99.81
Railways	N ₂ O	23.17	0.02	99.83
Glass Production	CO ₂	20.20	0.02	99.85
Land Converted to Other Land	CO ₂	19.79	0.02	99.87
Manufacturing Industries & Construction: Solid fuels	N ₂ O	16.87	0.02	99.88
Energy Industries: Liquid fuels	N ₂ O	15.88	0.01	99.90
Grassland remaining Grassland	CH ₄	15.70	0.01	99.91
Lead Production	CO ₂	13.62	0.01	99.92
Other Sectors: Liquid fuels	CH ₄	11.01	0.01	99.93
Field Burning of Agricultural Residues	N ₂ O	10.34	0.01	99.94
Manufacturing Industries & Construction: Biomass	N ₂ O	9.53	0.01	99.95
Energy Industries: Solid fuels	CH ₄	7.21	0.01	99.96
Energy Industries: Liquid fuels	CH ₄	6.90	0.01	99.97
Conversion to Settlements	CO ₂	6.08	0.01	99.97
Manufacturing Industries & Construction: Biomass	CH ₄	5.99	0.01	99.98
Manufacturing Industries & Construction: Liquid fuels	CH ₄	5.00	0.00	99.98
Forest Land remaining Forest Land	N ₂ O	3.81	0.00	99.98
Civil Aviation	N ₂ O	3.28	0.00	99.99
Navigation	CH ₄	3.05	0.00	99.99
SF ₆ from electrical equipment	SF ₆	2.93	0.00	99.99
Paraffin Wax Use	CO ₂	1.77	0.00	99.99
Grassland remaining Grassland	N ₂ O	1.29	0.00	100.00
Petrochemical and Carbon Black Production	CH ₄	1.13	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.96	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.49	0.00	100.00
Railways	CH ₄	0.28	0.00	100.00
Iron and Steel Production	CH ₄	0.25	0.00	100.00
Incineration and Open Burning of Waste]	CO ₂	0.22	0.00	100.00
Grassland remaining Grassland	CO ₂	0.19	0.00	100.00
Oil, Natural Gas and Other sources	N ₂ O	0.17	0.00	100.00
Civil Aviation	CH ₄	0.15	0.00	100.00
Incineration and Open Burning of Waste]	N ₂ O	0.12	0.00	100.00
Land Converted to Cropland	CO ₂	0.07	0.00	100.00
Energy Industries: Gaseous fuels	N ₂ O	0.05	0.00	100.00
Energy Industries: Gaseous fuels	CH ₄	0.04	0.00	100.00
Other Sectors: Solid fuels	CH ₄	0.03	0.00	100.00
Conversion to Grassland	CO ₂	0.03	0.00	100.00
Incineration and Open Burning of Waste]	CH ₄	0.01	0.00	100.00
Land Converted to Cropland	N ₂ O	0.00	0.00	100.00
Energy Industries: Biomass	CH ₄	0.00	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.00	0.00	100.00
Other transportation	CO ₂	0.00	0.00	100.00

IPCC source categories	GHG	Base year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Other transportation	CH ₄	0.00	0.00	100.00
Other transportation	N ₂ O	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CO ₂	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.00	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Other	CO ₂	0.00	0.00	100.00
ODS substitutes	HFC	0.00	0.00	100.00
ODS substitutes	PFC	0.00	0.00	100.00
Biological Treatment of Solid Waste	CH ₄	0.00	0.00	100.00
Biological Treatment of Solid Waste	N ₂ O	0.00	0.00	100.00
Land Converted to Forest Land	CO ₂	0.00	0.00	100.00
Land Converted to Wetlands	CO ₂	0.00	0.00	100.00
TOTAL		107,292.87	100.00	

Table I.5 *Key categories analysis without LULUCF – Trend assessment for 2014*

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment	Contribution to trend	Cumulative total
ODS substitutes	HFC	0.00	5,758.13	0.06	0.16	0.16
Other Sectors: Liquid fuels	CO ₂	7,945.96	3,955.05	0.04	0.11	0.27
Road Transportation	CO ₂	11,825.78	15,148.94	0.04	0.10	0.37
Manufacturing Industries & Construction: Solid fuels	CO ₂	3,591.24	236.21	0.03	0.09	0.46
Energy Industries: Gaseous fuels	CO ₂	102.03	3,012.72	0.03	0.08	0.55
Wastewater Treatment and Discharge	CH ₄	3,976.02	1,537.87	0.02	0.07	0.61
Cement Production	CO ₂	5,761.69	3,821.93	0.02	0.05	0.66
Manufacturing Industries & Construction: Liquid fuels	CO ₂	5,747.24	3,858.71	0.02	0.05	0.71
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	0.00	1,276.34	0.01	0.04	0.75
Energy Industries: Liquid fuels	CO ₂	7,790.77	8,817.08	0.01	0.04	0.78
Solid waste disposal	CH ₄	2,243.85	3,182.24	0.01	0.03	0.81
Nitric Acid Production	N ₂ O	1,066.11	26.81	0.01	0.03	0.84
Direct N ₂ O from agr. soils	N ₂ O	3,553.91	2,459.62	0.01	0.03	0.87
Other Sectors: Gaseous fuels	CO ₂	0.00	832.26	0.01	0.02	0.89
Ammonia Production	CO ₂	652.04	241.31	0.00	0.01	0.90
Other	CO ₂	0.00	328.08	0.00	0.01	0.91
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	1,237.72	874.67	0.00	0.01	0.92
Domestic Navigation	CO ₂	1,808.71	1,456.86	0.00	0.01	0.93
Domestic Aviation	CO ₂	319.05	550.46	0.00	0.01	0.94
Other Process Uses of Carbonates	CO ₂	589.53	363.24	0.00	0.01	0.95
Other Sectors: Liquid fuels	N ₂ O	313.23	44.93	0.00	0.01	0.94
Enteric fermentation: Non Dairy Cattle	CH ₄	691.82	841.20	0.00	0.00	0.95
Energy Industries: Solid fuels	CO ₂	35,200.91	33,954.82	0.00	0.00	0.96
Aluminium Production	PFCs	190.26	79.59	0.00	0.00	0.96
Ferroalloys	CO ₂	622.23	701.41	0.00	0.00	0.96
Lime Production	CO ₂	404.00	292.61	0.00	0.00	0.97
Enteric fermentation: Sheep	CH ₄	2,053.63	2,084.65	0.00	0.00	0.97
Other Sectors: Solid fuels	CO ₂	119.55	23.46	0.00	0.00	0.97
Enteric fermentation: Dairy Cattle	CH ₄	485.84	408.35	0.00	0.00	0.97
Rice Cultivation	CH ₄	82.26	140.00	0.00	0.00	0.97
Aluminium Production	CO ₂	225.39	276.87	0.00	0.00	0.98
Railways	CO ₂	198.94	134.62	0.00	0.00	0.98
ODS substitutes	PFC	0.00	55.05	0.00	0.00	0.98
Oil, Natural Gas and Other sources	CH ₄	36.40	88.37	0.00	0.00	0.98
Wastewater Treatment and Discharge	N ₂ O	279.29	323.15	0.00	0.00	0.98
Enteric fermentation: Other	CH ₄	748.56	674.20	0.00	0.00	0.98
Navigation	N ₂ O	129.19	75.67	0.00	0.00	0.99
Lubricant Use	CO ₂	77.83	28.30	0.00	0.00	0.99
Oil, Natural Gas and Other sources	CO ₂	42.70	3.75	0.00	0.00	0.99
Manure management	CH ₄	884.47	822.21	0.00	0.00	0.99
Urea Application	CO ₂	60.41	25.78	0.00	0.00	0.99
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	27.35	57.98	0.00	0.00	0.99
Iron and Steel Production	CO ₂	104.89	70.33	0.00	0.00	0.99
Manure management	N ₂ O	305.42	325.11	0.00	0.00	0.99
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	26.07	0.00	0.00	0.99
Road Transportation	CH ₄	107.09	77.77	0.00	0.00	0.99
Zinc Production	CO ₂	45.92	65.70	0.00	0.00	0.99
Biological Treatment of Solid Waste	CH ₄	0.00	19.90	0.00	0.00	0.99
Biological Treatment of Solid Waste	N ₂ O	0.00	17.79	0.00	0.00	1.00
Other Sectors: Biomass	CH ₄	91.18	104.58	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N ₂ O	16.87	1.12	0.00	0.00	1.00

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment	Contribution to trend	Cumulative total
Other Product Manufacture and Use: Other	CO2	102.47	84.55	0.00	0.00	1.00
N2O from Product Uses	N2O	133.26	141.97	0.00	0.00	1.00
Coal Mining (surface)	CH4	1,130.04	1,107.15	0.00	0.00	1.00
Other transportation	CO2	0.00	9.93	0.00	0.00	1.00
Field Burning of Agricultural Residues	CH4	34.23	41.84	0.00	0.00	1.00
Other Sectors: Liquid fuels	CH4	11.01	2.37	0.00	0.00	1.00
Railways	N2O	23.17	15.81	0.00	0.00	1.00
Other Sectors: Biomass	N2O	30.57	35.08	0.00	0.00	1.00
Other transportation	N2O	0.00	5.32	0.00	0.00	1.00
Road Transportation	N2O	117.72	109.31	0.00	0.00	1.00
Civil Aviation	N2O	3.28	7.77	0.00	0.00	1.00
Enteric fermentation: Swine	CH4	37.33	32.40	0.00	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	3.55	0.00	0.00	1.00
Field Burning of Agricultural Residues	N2O	10.34	13.06	0.00	0.00	1.00
Incineration and Open Burning of Waste]	CO2	0.22	3.11	0.00	0.00	1.00
Glass Production	CO2	20.20	16.82	0.00	0.00	1.00
Lead Production	CO2	13.62	10.46	0.00	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	5.00	2.22	0.00	0.00	1.00
SF6 from electrical equipment	SF6	2.93	4.92	0.00	0.00	1.00
Energy Industries: Liquid fuels	N2O	15.88	13.50	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.53	7.40	0.00	0.00	1.00
Energy Industries: Solid fuels	N2O	128.97	123.17	0.00	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	1.62	0.00	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.36	0.00	0.00	1.00
Paraffin Wax Use	CO2	1.77	0.52	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.99	4.65	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.96	0.06	0.00	0.00	1.00
Manufacturing Industries & Construction:Gaseous fuels	CH4	0.00	0.57	0.00	0.00	1.00
Incineration and Open Burning of Waste]	N2O	0.12	0.66	0.00	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.45	0.00	0.00	1.00
Other Sectors:Gaseous fuels	CH4	0.00	0.37	0.00	0.00	1.00
Other Sectors: Solid fuels	N2O	0.49	0.11	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.35	0.00	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.90	6.34	0.00	0.00	1.00
Navigation	CH4	3.05	2.70	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.22	0.00	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.17	0.01	0.00	0.00	1.00
Energy Industries: Solid fuels	CH4	7.21	6.89	0.00	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.09	0.00	0.00	1.00
Railways	CH4	0.28	0.19	0.00	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.07	0.00	0.00	1.00
Civil Aviation	CH4	0.15	0.21	0.00	0.00	1.00
Incineration and Open Burning of Waste]	CH4	0.01	0.03	0.00	0.00	1.00
Other Sectors: Solid fuels	CH4	0.03	0.01	0.00	0.00	1.00
Iron and Steel Production	CH4	0.25	0.26	0.00	0.00	1.00
Other transportation	CH4	0.00	0.00	0.00	0.00	1.00
Petrochemical and Carbon Black Production	CO2	28.61	0.00	0.00	0.00	1.00
Petrochemical and Carbon Black Production	CH4	1.13	0.00	0.00	0.00	1.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	1,182.82	0.00	0.00	0.00	1.00
TOTAL		104,827.11	101,403.31	0.36	1.00	

Table I.6 *Key categories analysis with LULUCF – Trend assessment for 2014*

IPCC source / sink categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment (Absolute)	Contribution to trend	Cumulative total
ODS substitutes	HFC	0.00	5,758.13	0.06127	0.15	0.15
Road Transportation	CO ₂	11,825.78	15,148.94	0.04074	0.10	0.25
Other Sectors: Liquid fuels	CO ₂	7,945.96	3,955.05	0.03886	0.09	0.34
Manufacturing Industries & Construction: Solid fuels	CO ₂	3,591.24	236.21	0.03407	0.08	0.43
Energy Industries: Gaseous fuels	CO ₂	102.03	3,012.72	0.03102	0.08	0.50
Wastewater Treatment and Discharge	CH ₄	3,976.02	1,537.87	0.02414	0.06	0.56
Cement Production	CO ₂	5,761.69	3,821.93	0.01802	0.04	0.61
Manufacturing Industries & Construction: Liquid fuels	CO ₂	5,747.24	3,858.71	0.01748	0.04	0.65
Energy Industries: Liquid fuels	CO ₂	7,790.77	8,817.08	0.01446	0.04	0.68
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	0.00	1,276.34	0.01358	0.03	0.72
Forest Land remaining Forest Land	CO ₂	-1,139.19	-2,142.98	0.01120	0.03	0.74
Solid waste disposal	CH ₄	2,243.85	3,182.24	0.01101	0.03	0.77
Nitric Acid Production	N ₂ O	1,066.11	26.81	0.01057	0.03	0.80
Direct N ₂ O from agr. soils	N ₂ O	3,553.91	2,459.62	0.01003	0.02	0.82
Conversion to Grassland	CO ₂	0.03	-850.68	0.00905	0.02	0.84
Other Sectors: Gaseous fuels	CO ₂	0.00	832.26	0.00886	0.02	0.87
Cropland remaining Cropland	CO ₂	-908.14	-317.27	0.00587	0.01	0.88
Harvested Wood Products	CO ₂	-324.95	93.27	0.00430	0.01	0.89
Ammonia Production	CO ₂	652.04	241.31	0.00407	0.01	0.90
Other	CO ₂	0.00	328.08	0.00349	0.01	0.91
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	1,237.72	874.67	0.00330	0.01	0.92
Domestic Navigation	CO ₂	1,808.71	1,456.86	0.00292	0.01	0.92
Energy Industries: Solid fuels	CO ₂	35,200.91	33,954.82	0.00275	0.01	0.93
Domestic Aviation	CO ₂	319.05	550.46	0.00261	0.01	0.94
Other Process Uses of Carbonates	CO ₂	589.53	363.24	0.00214	0.01	0.95
Other Sectors: Liquid fuels	N ₂ O	313.23	44.93	0.00271	0.01	0.94
Enteric fermentation:Non Dairy Cattle	CH ₄	691.82	841.20	0.00190	0.00	0.95
Land Converted to Forest Land	CO ₂	0.00	-123.87	0.00132	0.00	0.96
Enteric fermentation: Sheep	CH ₄	2,053.63	2,084.65	0.00126	0.00	0.96
Ferroalloys	CO ₂	622.23	701.41	0.00113	0.00	0.96
Aluminium Production	PFCs	190.26	79.59	0.00109	0.00	0.97
Lime Production	CO ₂	404.00	292.61	0.00100	0.00	0.97
Other Sectors: Solid fuels	CO ₂	119.55	23.46	0.00097	0.00	0.97
Land Converted to Other Land	CO ₂	19.79	82.47	0.00068	0.00	0.97
Rice Cultivation	CH ₄	82.26	140.00	0.00065	0.00	0.97
Aluminium Production	CO ₂	225.39	276.87	0.00065	0.00	0.98
Enteric fermentation:Dairy Cattle	CH ₄	485.84	408.35	0.00060	0.00	0.98
Railways	CO ₂	198.94	134.62	0.00059	0.00	0.98
Wastewater Treatment and Discharge	N ₂ O	279.29	323.15	0.00059	0.00	0.98
ODS substitutes	PFC	0.00	55.05	0.00059	0.00	0.98
Oil, Natural Gas and Other sources	CH ₄	36.40	88.37	0.00057	0.00	0.98
Navigation	N ₂ O	129.19	75.67	0.00051	0.00	0.98
Lubricant Use	CO ₂	77.83	28.30	0.00049	0.00	0.99
Forest Land remaining Forest Land	CH ₄	46.53	1.06	0.00046	0.00	0.99
Enteric fermentation: Other	CH ₄	748.56	674.20	0.00045	0.00	0.99
Oil, Natural Gas and Other sources	CO ₂	42.70	3.75	0.00040	0.00	0.99
Manure management	N ₂ O	305.42	325.11	0.00035	0.00	0.99
Urea Application	CO ₂	60.41	25.78	0.00034	0.00	0.99
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	27.35	57.98	0.00034	0.00	0.99
Iron and Steel Production	CO ₂	104.89	70.33	0.00032	0.00	0.99

IPCC source / sink categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment (Absolute)	Contribution to trend	Cumulative total
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	26.07	0.00028	0.00	0.99
Coal Mining (surface)	CH4	1,130.04	1,107.15	0.00027	0.00	0.99
Road Transportation	CH4	107.09	77.77	0.00026	0.00	0.99
Manure management	CH4	884.47	822.21	0.00026	0.00	0.99
Zinc Production	CO2	45.92	65.70	0.00023	0.00	0.99
Biological Treatment of Solid Waste	CH4	0.00	19.90	0.00021	0.00	1.00
Biological Treatment of Solid Waste	N2O	0.00	17.79	0.00019	0.00	1.00
Other Sectors: Biomass	CH4	91.18	104.58	0.00018	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N2O	16.87	1.12	0.00016	0.00	1.00
N2O from Product Uses	N2O	133.26	141.97	0.00015	0.00	1.00
Other Product Manufacture and Use: Other	CO2	102.47	84.55	0.00014	0.00	1.00
Other transportation	CO2	0.00	9.93	0.00011	0.00	1.00
Field Burning of Agricultural Residues	CH4	34.23	41.84	0.00010	0.00	1.00
Other Sectors: Liquid fuels	CH4	11.01	2.37	0.00009	0.00	1.00
Grassland remaining Grassland	CH4	15.70	8.32	0.00007	0.00	1.00
Railways	N2O	23.17	15.81	0.00007	0.00	1.00
Other Sectors: Biomass	N2O	30.57	35.08	0.00006	0.00	1.00
Conversion to Settlements	CO2	6.08	11.33	0.00006	0.00	1.00
Other transportation	N2O	0.00	5.32	0.00006	0.00	1.00
Civil Aviation	N2O	3.28	7.77	0.00005	0.00	1.00
Forest Land remaining Forest Land	N2O	3.81	0.09	0.00004	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	3.55	0.00004	0.00	1.00
Road Transportation	N2O	117.72	109.31	0.00004	0.00	1.00
Enteric fermentation: Swine	CH4	37.33	32.40	0.00004	0.00	1.00
Field Burning of Agricultural Residues	N2O	10.34	13.06	0.00003	0.00	1.00
Incineration and Open Burning of Waste]	CO2	0.22	3.11	0.00003	0.00	1.00
Lead Production	CO2	13.62	10.46	0.00003	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	5.00	2.22	0.00003	0.00	1.00
Glass Production	CO2	20.20	16.82	0.00003	0.00	1.00
SF6 from electrical equipment	SF6	2.93	4.92	0.00002	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.53	7.40	0.00002	0.00	1.00
Energy Industries: Liquid fuels	N2O	15.88	13.50	0.00002	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	1.62	0.00002	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.36	0.00001	0.00	1.00
Paraffin Wax Use	CO2	1.77	0.52	0.00001	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.99	4.65	0.00001	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.96	0.06	0.00001	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	CH4	0.00	0.57	0.00001	0.00	1.00
Land Converted to Cropland	CO2	0.07	0.62	0.00001	0.00	1.00
Grassland remaining Grassland	N2O	1.29	0.68	0.00001	0.00	1.00
Incineration and Open Burning of Waste]	N2O	0.12	0.66	0.00001	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.45	0.00000	0.00	1.00
Other Sectors: Gaseous fuels	CH4	0.00	0.37	0.00000	0.00	1.00
Other Sectors: Solid fuels	N2O	0.49	0.11	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.35	0.00000	0.00	1.00
Energy Industries: Solid fuels	N2O	128.97	123.17	0.00000	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.90	6.34	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.22	0.00000	0.00	1.00
Navigation	CH4	3.05	2.70	0.00000	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.17	0.01	0.00000	0.00	1.00
Land Converted to Wetlands	CO2	0.00	0.09	0.00000	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.09	0.00000	0.00	1.00
Railways	CH4	0.28	0.19	0.00000	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.07	0.00000	0.00	1.00

IPCC source / sink categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment (Absolute)	Contribution to trend	Cumulative total
Civil Aviation	CH4	0.15	0.21	0.00000	0.00	1.00
Grassland remaining Grassland	CO2	0.19	0.15	0.00000	0.00	1.00
Land Converted to Cropland	N2O	0.00	0.03	0.00000	0.00	1.00
Incineration and Open Burning of Waste]	CH4	0.01	0.03	0.00000	0.00	1.00
Other Sectors: Solid fuels	CH4	0.03	0.01	0.00000	0.00	1.00
Iron and Steel Production	CH4	0.25	0.26	0.00000	0.00	1.00
Energy Industries: Solid fuels	CH4	7.21	6.89	0.00000	0.00	1.00
Other transportation	CH4	0.00	0.00	0.00000	0.00	1.00
Petrochemical and Carbon Black Production	CO2	28.61	0.00	0.00000	0.00	1.00
Petrochemical and Carbon Black Production	CH4	1.13	0.00	0.00000	0.00	1.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	1,182.82	0.00	0.00000	0.00	1.00
TOTAL		102,548.33	98,166.63	0.41	1.00	

The results of the key categories analysis for the year 2014 are summed up in **Table I.7**.

Table I.7 *Source Category Analysis Summary for 2014*

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
ENERGY SECTOR				
Energy Industries: Liquid fuels	CO2	YES	Level, Trend	T2
Energy Industries: Liquid fuels	CH4	NO		
Energy Industries: Liquid fuels	N2O	NO		
Energy Industries: Solid fuels	CO2	YES	Level, Trend	T2
Energy Industries: Solid fuels	CH4	NO		
Energy Industries: Solid fuels	N2O	NO		
Energy Industries: Gaseous fuels	CO2	YES	Level, Trend	T2
Energy Industries: Gaseous fuels	CH4	NO		
Energy Industries: Gaseous fuels	N2O	NO		
Energy Industries: Biomass	CH4	NO		
Energy Industries: Biomass	N2O	NO		
Manufacturing Industries & Construction: Liquid fuels	CO2	YES	Level, Trend	T2
Manufacturing Industries & Construction: Liquid fuels	CH4	NO		
Manufacturing Industries & Construction: Liquid fuels	N2O	NO		
Manufacturing Industries & Construction: Solid fuels	CO2	YES	Trend	T2
Manufacturing Industries & Construction: Solid fuels	CH4	NO		
Manufacturing Industries & Construction: Solid fuels	N2O	NO		
Manufacturing Industries & Construction: Gaseous fuels	CO2	YES	Level, Trend	T2
Manufacturing Industries & Construction: Gaseous fuels	CH4	NO		
Manufacturing Industries & Construction: Gaseous fuels	N2O	NO		
Manufacturing Industries & Construction: Biomass	CH4	NO		
Manufacturing Industries & Construction: Biomass	N2O	NO		
Manufacturing Industries & Construction: Other Fuels	CO2	NO		
Manufacturing Industries & Construction: Other Fuels	CH4	NO		
Manufacturing Industries & Construction: Other Fuels	N2O	NO		
Road Transportation	CO2	YES	Level, Trend	T1
Road Transportation	CH4	NO		
Road Transportation	N2O	NO		
Domestic Aviation	CO2	YES	Level, Trend	T2
Civil Aviation	CH4	NO		
Civil Aviation	N2O	NO		
Domestic Navigation	CO2	YES	Level, Trend	T1
Navigation	CH4	NO		
Navigation	N2O	NO		
Railways	CO2	NO		
Railways	CH4	NO		
Railways	N2O	NO		
Other transportation	CO2	NO		
Other transportation	CH4	NO		
Other transportation	N2O	NO		
Other Sectors: Liquid fuels	CO2	YES	Level, Trend	T2
Other Sectors: Liquid fuels	CH4	NO		
Other Sectors: Liquid fuels	N2O	NO		
Other Sectors: Solid fuels	CO2	NO		
Other Sectors: Solid fuels	CH4	NO		
Other Sectors: Solid fuels	N2O	NO		

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
Other Sectors: Gaseous fuels	CO2	YES	Level, Trend	T2
Other Sectors: Gaseous fuels	CH4	NO		
Other Sectors: Gaseous fuels	N2O	NO		
Other Sectors: Biomass	CH4	NO		
Other Sectors: Biomass	N2O	NO		
Coal Mining (surface)	CH4	YES	Level	T1
Oil, Natural Gas and Other sources	CO2	NO		
Oil, Natural Gas and Other sources	CH4	NO		
Oil, Natural Gas and Other sources	N2O	NO		
INDUSTRIAL PROCESSES SECTOR				
Cement Production	CO2	YES	Level, Trend	CS
Lime Production	CO2	NO		
Glass Production	CO2	NO		
Other Process Uses of Carbonates	CO2	YES	Trend	CS, T1
Ammonia Production	CO2	YES	Trend	T1a
Nitric Acid Production	N2O	YES	Trend	D
Petrochemical and Carbon Black Production	CO2	NO		
Petrochemical and Carbon Black Production	CH4	NO		
HFC-23 Emissions from HCFC-22 Manufacture	HFC	NO		
Other	CO2	YES	Trend	T1
Iron and Steel Production	CO2	NO		
Iron and Steel Production	CH4	NO		
Ferroalloys	CO2	YES	Level	CS
Aluminium Production	CO2	NO		
Aluminium Production	PFCs	NO		
Lead Production	CO2	NO		
Zinc Production	CO2	NO		
Lubricant Use	CO2	NO		
Paraffin Wax Use	CO2			
ODS substitutes	HFC	YES	Level, Trend	CS, T2
ODS substitutes	PFC	NO		
SF6 from electrical equipment	SF6	NO		
N2O from Product Uses	N2O	NO		
Other Product Manufacture and Use: Other	CO2	NO		
AGRICULTURE				
Enteric fermentation: Dairy Cattle	CH4	YES	Level	T2
Enteric fermentation: Non Dairy Cattle	CH4	YES	Level	T2
Enteric fermentation: Sheep	CH4	YES	Level	T2
Enteric fermentation: Swine	CH4	NO		
Enteric fermentation: Other	CH4	YES	Level	T1
Manure management	CH4	YES	Level	T2
Manure management	N2O	NO		
Rice Cultivation	CH4	NO		
Direct N2O from agr. soils	N2O	YES	Level, Trend	T1, T1a, T1b
Indirect N2O from nitrogen used in agr.	N2O	YES	Level, Trend	T1a
Field Burning of Agricultural Residues	CH4	NO		
Field Burning of Agricultural Residues	N2O	NO		
Urea Application	CO2	NO		
WASTE				
Solid waste disposal	CH4	YES	Level, Trend	T2
Biological Treatment of Solid Waste	CH4	NO		
Biological Treatment of Solid Waste	N2O	NO		

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
Incineration and Open Burning of Waste]	CO2	NO		
Incineration and Open Burning of Waste]	CH4	NO		
Incineration and Open Burning of Waste]	N2O	NO		
Wastewater Treatment and Discharge	CH4	YES	Level, Trend	D
Wastewater Treatment and Discharge	N2O	NO		
LULUCF				
Forest Land remaining Forest Land	CO2	YES	Level, Trend	T2
Forest Land remaining Forest Land	CH4	NO		
Forest Land remaining Forest Land	N2O	NO		
Land Converted to Forest Land	CO2	NO		
Cropland remaining Cropland	CO2	YES	Trend	T1, T2
Land Converted to Cropland	CO2	NO		
Land Converted to Cropland	N2O	NO		
Grassland remaining Grassland	CO2	NO		
Grassland remaining Grassland	CH4	NO		
Grassland remaining Grassland	N2O	NO		
Conversion to Grassland	CO2	YES	Level, Trend	T1, T2
Land Converted to Wetlands	CO2	NO		
Conversion to Settlements	CO2	NO		
Land Converted to Other Land	CO2	NO		
Harvested Wood Products	CO2	YES	Trend	T2

Annex II: Detailed discussion of methodology and data for estimating CO₂ and other GHG emissions from fossil fuel combustion

General discussion

The calculation of CO₂ emissions from the energy sector is mainly performed by the application of a Tier 2 methodology based on 2006 IPCC guidelines. Emissions are estimated multiplying the consumption per fuel with the relative emission factor.

- ↳ The national energy balance is the main source of information regarding fuel consumption per fuel and sub-sector. Further analysis of fuel consumption by technology within each sub-sector is made on the basis of the assumptions presented in Chapter 3.
- ↳ Verified reports from installations under the EU ETS were used as a source of plant specific activity data and in order to calculate plant specific CO₂ emission factors per sector (IPCC source category) and fuel.
- ↳ Emission factors of carbon dioxide by fuel depend exclusively on fuel characteristics (see Table 3.13 which presents emission factors of carbon dioxide by fuel).

The national energy balance could be found in the following link:

http://195.251.42.2/cgi-bin/nisehist.sh?objtype=stats_query

Use of data from EU-ETS verified reports in Energy sector

In 2004 the first guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to the EU Emission Trading Scheme (ETS) Directive (2003/87/EC) were implemented.

These were updated in 2007 and are available from the EU Commission website. The Greek emission inventory only includes data from plants using higher tier methods as defined in the EU decision establishing guidelines for monitoring and reporting. In the Guidelines the specific methods for determining carbon contents, oxidation factor and calorific value are specified. In the Greek inventory plant based CO₂ emission factors have been derived for power plants combusting lignite, oil and natural gas, refineries combusting LPG, refinery gas, petcoke, naphtha, HFO and natural gas, manufacturing industries (cement, lime ceramics etc) combusting coal, petcoke, HFO and alternative fuels (e.g. scrap tyres). For all these sources the EU ETS reports use only high tier methods. The EU ETS data have been applied for the years 2005 - 2014. The EU ETS reporting guidelines emphasizes the need for a high quality reporting through ensuring completeness, consistency, accuracy, transparency and faithfulness. The quality criteria as defined under the EU ETS reporting guidelines are in complete agreement with the principles in the IPCC good practice guidance.

The determination of the variables needed for the emission calculation has to be done in accordance with international standards. It is not possible to list all the relevant standards here, but an overview is available in annex 1, chapter 13 of the EU ETS guidelines. There are also demands concerning sampling methods and frequency of analysis. As an example the tier 3 regarding fuel flow for fuel combustion, corresponds to a determination of the fuel consumption with an maximum uncertainty of 2.5 % taking into account

possible effects of stock change. Tier 4 is a maximum uncertainty of 1.5 %. These uncertainties are very low and are in line with what could be expected from a well functioning energy statistics system. The operators shall establish, document, implement and maintain effective data acquisition and handling activities. This means assigning responsibilities for the quality process, as well as quality assurance, reviews and validation of data. Furthermore an independent verification ensuring that emissions have been monitored in accordance with the EU ETS guidelines and that reliable and correct emission data are reported. The demands for the QA/QC system in the EU ETS guidelines are fully comparable to the requirements in the IPCC good practice guidance.

The EU-ETS reporting is also a source of plant specific activity data. The procedure followed for reconciling the use of bottom up data with the energy balance (in order to ensure no double counting/omissions) is the following: A cross-checking between energy consumption data derived from national energy balance and plant specific energy consumption data of major industrial plants derived from verified ETS reports is performed. In order to avoid any double counting/omissions of fuel used, the findings of the above quality check are communicated to the competent department of MEEN that is the compiler of national energy balance. Then, jointly it is decided, which fuel quantities will be used as activity data for emission calculations. By this annual quality check both the national energy balance and the energy consumption used in emission calculations is verified and get improved

Other information

The alternative fuels (scrap tires, cable coating etc) that are used in greek cement plants are reported under source category 1A2f – other fuels. The variation of CO₂ IEF of alternative fuels along the time series is due to the following reasons:

- The amount of each type of alternative fuel consumed per year may vary due to operational conditions / limitations of the cement plants.
- The properties, as NCV and carbon content, of each alternative fuel type present significant fluctuations, depending their previous use, origin etc.

Annex III: CO₂ reference approach and comparison with sectoral approach, and relevant information on the national energy balance

The Reference Approach requires statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of figures for the consumption of fuels used for non-energy purposes where carbon may be stored. It uses a simple assumption: once carbon is brought into a national economy in fuel, it is either saved in some way (e.g., in increases of fuel stocks, stored in products, left unoxidised in ash) or it must be released to the atmosphere.

The estimation process is divided in six steps that are described below.

Step 1: Estimation of apparent consumption.

This step concerns the estimation of apparent consumption in natural units or in the units commonly used for the recording of the relative fuel amounts. For secondary fuels production data are not included in the apparent consumption calculation, since they are already accounted for in the primary fuel consumption, from which they derive. Therefore, the apparent consumption of primary fuels is estimated by the following equation:

$$\text{Apparent consumption} = \text{Primary production} + \text{Imports} - \text{Exports} - \text{International bunkers} + \text{Stock change}$$

The apparent consumption of secondary fuels is estimated by the following equation:

$$\text{Apparent consumption} = \text{Imports} - \text{Exports} - \text{International bunkers} + \text{Stock change}$$

Step 2: Conversion of fuel data to a common energy unit.

This step concerns the conversion of apparent consumption, which was estimated in the first step in natural units, in a common energy unit (e.g. TJ). This conversion is based on net calorific value of fuels (see *Tables III.1*).

Step 3: Estimation of carbon content.

Total carbon included in each fuel is calculated by multiplying energy consumption by an emission factor (see *Table III.1*) that reflects the amount of carbon per energy unit for each fuel. The result gives the maximum amount of carbon that could be potentially released if all carbon in the fuels were converted to CO₂.

Step 4: Estimation of carbon stored in products.

Depending on the end use, non-energy uses of fuels can result in the storage of some or all of the carbon contained in the fuel to the non-energy product. The non-energy consumption of fuels is multiplied by an emission factor that reflects the amount of the carbon content of the fuel stored in non-energy product (see *Table III.1*). The result is the maximum amount of carbon that could potentially be sequestered if that amount of carbon were stored in the non-energy product. By subtracting this amount from the total carbon calculated in step 3, the amount of carbon that could be theoretically converted in CO₂ is calculated.

Step 5: Estimation of carbon unoxidised during fuel use.

The amount of carbon that was previously calculated is reduced by a fraction up to 2%, depending on fuel type, in order to take account of the fact that a small part of the fuel carbon entering combustion escapes oxidation (see *Table 3.13*). It is assumed that the carbon that remains unoxidised is stored indefinitely.

Step 6: Estimation of CO₂ emissions.

Carbon emissions from all fuels are multiplied by 44/12 to be converted to CO₂ emissions, and are summed, giving the total amount of CO₂ released in the atmosphere.

As it was mentioned in Section 3.2, the net calorific value of lignite is differentiated on an annual basis according to the characteristics of the mining field from which it is extracted.

The application of the reference approach for 2014 is presented hereafter (Tables 1.A(b) of the Common Reporting Format).

Table III.1 Reference approach for 2014

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit) ¹	NCV/ GCV ⁽²⁾	Apparent consumption (TJ)	Carbon emission factor (t C/TJ)	Carbon content (kt)	Carbon stored[C excluded] (kt C)	Net carbon emissions (kt) C	Fraction of carbon oxidized	Actual CO ₂ emissions (kt) CO ₂	
Liquid fossil	Primary fuels	Crude oil	Mg	64000.00	#####	59000.00		140000.00	20691000.00	42.30	NCV	875229.30	20.00	17504.59	NO	17504.59	1.00	64183.48	
		Orimulsion	TJ	NO	NO	NO		NO	NO	NO		NO	NO	NO	NO	NO	NO	NO	
		Natural gas liquids	Mg	NO	NO	NO		NO	NO	41.56	NCV	NO	17.50	NO	NO	NO	1.00	NO	
	Secondary fuels	Gasoline	Mg	#####	#####		NO	-21000.00	-2199000.00	42.79	NCV	-94095.21	19.98	-1879.93	NO	-1879.93	1.00	-6893.06	
		Jet kerosene	Mg	#####	#####	757000.00		68000.00	-1728000.00	44.10	NCV	-76204.80	19.50	-1485.99	NO	-1485.99	1.00	-5448.64	
		Other kerosene	Mg		NO	6000.00	NO	-1000.00	-5000.00	43.80	NCV	-219.00	19.60	-4.29	NO	-4.29	1.00	-15.74	
		Shale oil	TJ	NO	NO	NO		NO	NO	NO		NO	NO	NO	NO	NO	NO	NO	
		Gas/diesel oil	Mg	#####	#####	264000.00		-316000.00	-5595000.00	42.78	NCV	-239326.13	20.05	-4797.70	NO	-4797.70	1.00	-17591.57	
		Residual fuel oil	Mg	#####	#####	1653000.00		149000.00	-3785000.00	40.58	NCV	-153595.30	21.37	-3282.37	NO	-3282.37	1.00	-12035.37	
		Liquefied petroleum gases (LPG)	Mg	39000.00	244000.00			-2000.00	-203000.00	47.30	NCV	-9601.90	17.20	-165.15	NO	-165.15	1.00	-605.56	
		Ethane	TJ	NO	NO	NO		NO	NO	NO		NO	NO	NO	NO	NO	NO	NO	
		Naphtha	Mg		NO	721000.00		18000.00	-739000.00	44.50	NCV	-32885.50	20.00	-657.71	3.61	-661.32	1.00	-2424.83	
		Bitumen	Mg	38000.00	398000.00			12000.00	-372000.00	40.20	NCV	-14954.40	22.00	-329.00	126.20	-455.19	1.00	-1669.04	
		Lubricants	Mg	24000.00	212000.00		17000.00	6000.00	-211000.00	40.20	NCV	-8482.20	20.00	-169.64	38.59	-208.24	1.00	-763.53	
		Petroleum coke	Mg	#####	21000.00			26000.00	635000.00	32.32	NCV	20522.56	25.63	525.97	16.57	509.40	1.00	1867.80	
		Refinery feedstocks	Mg	#####	NO			-118000.00	4915000.00	43.00	NCV	211345.00	20.00	4226.90	NO	4226.90	1.00	15498.63	
		Other oil	Mg		2000.00	268000.00		124000.00	-390000.00	40.20	NCV	-15678.00	20.00	-313.56	162.41	-475.97	1.00	-1745.22	
Other liquid fossil												NO							
Liquid fossil totals												462054.42		9172.10		347.37	8824.73		32357.34
Solid fossil	Primary fuels	Anthracite ⁽³⁾	TJ	NO	NO	NO		NO	NO	NO			NO	NO	NO	NO	NO	NO	
		Coking coal	TJ	NO	NO	NO		NO	NO	NO			NO	NO	NO	NO	NO	NO	
		Other bituminous coal	Mg	NO	#####	9000.00	NO	27000.00	274000.00	25.87	NCV	7087.95	25.53	180.95	120.86	60.09	1.00	220.34	
		Sub-bituminous coal	TJ	NO	NO	NO	NO	NO	NO	NO			NO	NO	NO	NO	NO	NO	
		Lignite	Mg	50845000.00	26000.00	NO		-1007000.00	51878000.00	5.34	NCV	276872.89	34.29	9494.66	36.05	9458.61	0.98	33987.93	
	Secondary fuels	Oil shale and tar sand	TJ	NO	NO	NO		NO	NO	NO			NO	NO	NO	NO	NO	NO	
		BKB ⁽⁴⁾ and patent fuel	Mg		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	
		Coke oven/gas coke	Mg		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	1.00	NO	
		Coal tar	Mg		NO	NO		NO	NO	NO			NO	NO	NO	NO	NO	NO	
Other solid fossil																			
Solid fossil totals												283960.84		9675.61		156.91	9518.70		34208.27
Gaseous fossil		Natural gas (dry)	TJ	227.70	#####	NO		-513.00	104013.00	1.00	NCV	104013.00	15.18	1579.20	162.54	1416.66	1.00	5194.42	
Other gaseous fossil												NO							
Gaseous fossil totals												104013.00		1579.20		162.54	1416.66		5194.42
Waste (non-biomass fraction)			TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Other fossil fuels																			
Peat ^(5,6)			TJ	NO	NO	NO	NO	NO	NO	NO			NO	NO	NO	NO	NO	NO	
Total												850028.26		20426.91		666.82	19760.09		71760.03
Biomass total												NO		NO		NO		NO	
		Solid biomass																	
		Liquid biomass																	
		Gas biomass																	
Other non-fossil fuels (biogenic waste)		TJ	NO	NO	NO		NO	NO	NO	NO		NO	NO	NO	NO	NO	NO	NO	

Annex IV: Uncertainty analysis

Uncertainty analysis constitutes a key activity in the annual inventory cycle. The realisation of such an analysis is foreseen in the reporting guidelines under the Convention and represents a specific function to be performed by a National System (Decision 24/CP.19).

Uncertainty information is not intended to dispute the validity of the inventory estimates, but to help prioritize efforts to improve the accuracy of inventories and guide decisions on methodological choice. This will be achieved with the correct application of the analytic calculating methods at least for the key categories.

There are two methods for the uncertainty estimation suggested by the 2006 IPCC Guidelines. a basic method (Tier 1) which is mandatory and an analytic one (Tier 2).

The Tier 2 methodology is based on Monte Carlo analysis. The principle of Monte Carlo analysis is to select random values of emission factor and activity data from within their individual probability density functions, and to calculate the corresponding emission values. This procedure is repeated many times, and the results of each calculation run build up the overall emission probability density function. Monte Carlo analysis can be performed at the source category level, for aggregations of source categories or for the inventory as a whole. This analysis is suitable for a composite system such as the calculation of GHG emissions in national level. but its application requires significant resources and time.

The application of the Tier 1 methodology for uncertainty analysis is based on the following equations.

A. Uncertainty of total emissions

$$u_{i,g} = \sqrt{u_{AD,i}^2 + u_{EF,i,g}^2}$$

$$U_{i,g} = \frac{u_{i,g} \cdot E_{i,g}}{\sum_{i,g} E_{i,g}}$$

$$U_{tot} = \sqrt{\sum_{i,g} U_{i,g}^2}$$

where. i is the index referring to emission sources, g is the index referring to GHG, $u_{i,g}$ is the combined uncertainty for emissions of g-gas and i-source, $u_{AD,i}$ is the uncertainty of activity data of the i-source, $u_{EF,i,g}$ is the uncertainty of the emission factor of g-gas and i-source, $U_{i,g}$ is the uncertainty of the calculated emissions of g-gas and i-source, $E_{i,g}$ are the emissions of g-gas and i-source and U_{tot} is the uncertainty of total emissions. Uncertainty estimations on activity data ($u_{AD,i}$) and on the emission factors ($u_{EF,i,g}$) are based on IPCC defaults using expert judgement and

reasoning details and detailed explanation regarding their choice for each sector is presented in *Table IV.1*.

B. Uncertainty in trend in emissions

$$A_{i,g} = \frac{0,01 \cdot E_{i,g,t} + \sum_{i,g} E_{i,g,t} - \left(0,01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0} \right)}{0,01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0}} \cdot 100 - \frac{\sum_{i,g} E_{i,g,t} - \sum_{i,g} E_{i,g,0}}{\sum_{i,g} E_{i,g,0}} \cdot 100$$

$$B_{i,g} = \frac{E_{i,g,t}}{\sum_{i,g} E_{i,g,0}}$$

$$TREF_{i,g} = A_{i,g} \cdot u_{EF,i,g}$$

$$TRAD_i = B_{i,g} \cdot u_{AD,i} \cdot \sqrt{2}$$

$$U_{TR} = \sqrt{\sum_{i,g} TREF_{i,g}^2 + TRAD_i^2}$$

where, t is the index referring to the inventory year, 0 is the index referring to the base year, $A_{i,g}$ is the difference (%) of emissions of g -gas and i -source in response to a 1% increase of emissions in the base year and inventory year, $E_{i,g,t}$ emissions of g -gas and i -source in the inventory year, $E_{i,g,0}$ emissions of g -gas and i -source in the base year, $B_{i,g}$ the difference (%) of emissions of g -gas and i -source in response to a 1% increase of emissions in the inventory year, $TREF_{i,g}$ the contribution of EF uncertainty of g -gas and i -source to the uncertainty in the trend of emissions, $TRAD_i$ the contribution of AD uncertainty i -source to the uncertainty in the trend of emissions and U_{TR} is the uncertainty in the trend of emissions.

The uncertainty analysis for the Greek GHG inventory is based on Tier 1 methodology with 1990 as base year for CO₂, CH₄, N₂O and F-gases emissions.

Moreover:

- ↳ For the estimation of uncertainties per gas, a combination of the information provided by the IPCC and critical evaluation of information from indigenous sources was applied.
- ↳ 100% of emissions are used for the uncertainty analysis.
- ↳ The uncertainty analysis was carried out both without and with the *LULUCF* sector.

In the **Tables IV.2** and **IV.3**, the analytical calculations of the emissions estimates uncertainty are presented, without and with the sector of *LULUCF* respectively.

Table IV.1 Reasoning for activity data and emission factor uncertainty value

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Stationary Combustion - solid fuels	CO ₂	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Stationary Combustion - liquid fuels	CO ₂	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Stationary Combustion - gaseous fuels	CO ₂	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports and CS data from DESFA are used for the calculation of EF of NG. We estimate the EF uncertainty to be 2%.
Stationary Combustion - Other fuels	CO ₂	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Road transport	CO ₂	Default IPCC uncertainty is 5%.	Uncertainty of emissions of CO ₂ is 5% (IPCC default)
Navigation	CO ₂	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Civil Aviation	CO ₂	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Railway	CO ₂	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	CO ₂	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Oil and Natural gas	CO ₂	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	In IPCC GPG is mentioned that the EF used (from Table 2.16 p. 2.84) may be expected to limit uncertainties to within an order of magnitude. However, in order to be conservative, the value 300% is selected.
Cement Production	CO ₂	Plant level production data (IPCC GPG).	Plant level production data (IPCC GPG)
Lime Production	CO ₂	According to IPCC GPG is higher than EF's uncertainty.	IPCC default uncertainty.
Limestone &	CO ₂	Uncertainty of plant-level weighing of raw materials.	Stoichiometric EF. CS assessment.

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Dolomite Use		Correction for LKD. CS assessment.	
Glass Production	CO ₂	Uncertainty associated with weighing or proportioning the carbonates for any given industry. Increased CS assessment in order to account for any missed non marketed products.	The emission factor is the stoichiometric ratio reflecting the amount of CO ₂ released upon calcination of the carbonate. CS assessment.
Ammonia Production	CO ₂	Uncertainty of plant level weighting of glass production data. CS assessment.	Stoichiometric EF. CS assessment.
Other Chemicals (Hydrogen Production)	CO ₂	Plant specific data (verified ETS reports)	Plant specific data (verified ETS reports)
Iron and Steel Production	CO ₂	Data obtained by the plant and therefore low uncertainty of AD is assumed.	Gaseous inputs and outputs have generally higher uncertainties than for solid or liquid inputs and outputs, so the E's uncertainty is a little higher than the one in the mineral production. CS assessment.
Ferroalloys	CO ₂	Plant specific data (IPCC GPG)	The exact carbon content of all sources is reported. CS assessment.
Aluminium Production	CO ₂	Detailed plant specific AD for years 2000-2008. Uncertainty is reported higher due to the estimation of the previous years. CS assessment.	Plant specific, source-specific carbon content availability for years 2000-2008. However the previous years have been estimated using the Ni production as a driver. CS assessment.
Waste incineration	CO ₂	According to Good Practice Guidance. Page 5.30	According to Good Practice Guidance. Page 5.30
Forest Land remaining Forest Land	CO ₂	Conservative expert judgement based on a national research study	Uncertainty from IPCC Guidance and data provider
Conversion to Forest Land	CO ₂	Conservative expert judgement based on suggestions by IPCC Guidance.	The respective EF uncertainty was combined based on suggestions by IPCC Guidance.
Cropland remaining Cropland	CO ₂	The respective AD uncertainty was combined based on suggestions by IPCC Guidance.	The respective EF uncertainty was combined based on suggestions by IPCC Guidance.
Stationary Combustion - all fuels	CH ₄	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	Acc to Table 2.5 of IPCC GPG p 2.41 the default uncertainty for stationary combustion EF is 50-150%. We select the mean 100%.
Road transport	CH ₄	Default IPCC uncertainty is 5%.	IPCC default
Navigation	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Civil Aviation	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Railway	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Oil and Natural gas	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	In IPCC GPG is mentioned that the EF used (from Table 2.16 p. 2.84) may be expected to limit uncertainties to within an order of magnitude. However, in order to be conservative, the value 300% is selected.
Coal Mining	CH ₄	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range. Data are checked with plant level data from PPC, so the uncertainty is improved to 2%.	Acc to Table 2.14 of IPCC GPG p 2.77 the default uncertainty for surface Tier 1 methodology was used.
Organic chemicals production	CH ₄	Values provided by the NSSG. CS assessment.	Use of default EF. CS assessment.
Iron and Steel Production	CH ₄	Plant specific production data (IPCC GPG)	Default (SNAP 040207).
Enteric fermentation	CH ₄	Uncertainty given by NSSG for the livestock population data	According to Good Practice Guidance. Page 4.27
Manure management	CH ₄	Uncertainty given by NSSG for the livestock population data	Country specific data taking into account that there is a wide variety of manure management systems and that the situation in Greece is not absolute clear.
Rice cultivation	CH ₄	Uncertainty given by NSSG for the rice cultivation data	IPCC Rev. 1996. P. 4.58
Field burning of agr. Residues	CH ₄	Uncertainty given by NSSG for the crop production data	According to Good Practice Guidance. Page 4.82. Table 4.22
Managed solid waste disposal	CH ₄	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	Estimated value according to Good Practice Guidance Page 5.12. Table 5.2
Unmanaged solid waste disposal	CH ₄	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	Estimated value according to Good Practice Guidance. Page 5.12. Table 5.2
Municipal Sludge Disposal on Land	CH ₄	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	Estimated value according to Good Practice Guidance Page 5.12. Table 5.2
Wastewater handling	CH ₄	According to Good Practice Guidance. Page 5.19 Table 5.3 and Page 5.23 Table 5.5	Estimated value according to Good Practice Guidance. Page 5.19 Table 5.3 and Page 5.23 Table 5.5
Waste incineration	CH ₄	According to Good Practice Guidance. Page 5.30	Country Specific
Forest Land remaining Forest Land	CH ₄	The respective EF uncertainty was combined based on uncertainty given by data provider and suggestions by IPCC Guidance	Suggested default value by IPCC Guidance

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Stationary Combustion - all fuels	N ₂ O	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	Although in IPCC GPG is mentioned that EF from Table 2.16 may be expected to limit uncertainties to within an order of magnitude. in order to be conservative we select 300% as uncertainty.
Road transport	N ₂ O	Default IPCC uncertainty is 5%.	IPCC default.
Navigation	N ₂ O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Civil Aviation	N ₂ O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Railway	N ₂ O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	N ₂ O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Nitric Acid	N ₂ O	Plant specific data (IPCC GPG)	N ₂ O may be generated as by product and the Nox abatement may or may not reduce N ₂ O (IPCC GPG).
Manure management	N ₂ O	Country specific data taking into account that there is a wide variety of manure management systems and that the situation in Greece is not absolute clear.	According to Good Practice Guidance. Page 4.43. Table 4.12 and Page 4.44. Table 4.13
Agricultural soils - direct emissions	N ₂ O	Uncertainty given by NSSG for the crop production data	Country specific data.
Agricultural soils - indirect emissions	N ₂ O	Uncertainty given by NSSG for the fertilizers consumption data	According to Good Practice Guidance. Page 4.75
Animal Production	N ₂ O	Country specific data taking into account that there is a wide variety of manure management systems and that the situation in Greece is not absolute clear.	According to Good Practice Guidance. Page 4.43. Table 4.12 and Page 4.44-Table 4.13
Field burning of agr. Residues	N ₂ O	Uncertainty given by NSSG for the crop production data	According to Good Practice Guidance. Page 4.90 Chapter 4A.2.1.6
Wastewater handling	N ₂ O	According to Good Practice Guidance . Page 5.19 Table 5.3 and Page 5.23 Table 5.5	Country specific
Waste incineration	N ₂ O	According to Good Practice Guidance. Page 5.30	According to Good Practice Guidance. Page 5.30
Forest Land remaining Forest Land	N ₂ O	The respective EF uncertainty was combined based on uncertainty given by data provider and suggestions by IPCC Guidance	Suggested default value by IPCC Guidance
Grassland remaining Grassland	N ₂ O	Uncertainty given by data provider.	Uncertainty given by data provider.

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
HFC-23 Emissions from HCFC-22 Manufacture	HFC	IPCC GPG: Tier 1. absolute knowledge of variability of emissions from different industries (1 plant).	IPCC GPG: Tier 1. absolute knowledge of variability of emissions from different industries (1 plant).
Refrigeration and Air Conditioning Equipment	HFC	Assumption on HFCs penetration	Expert judgement , in default range
Foam Blowing	HFC	IPCC GPG	IPCC GPG
Fire Extinguishers	HFC	Absence of data	Default value
Aerosols/MDIs	HFC	Data provided by National Organization of Medicine and at a brand level.	Default values
PFC from Aluminium	PFC	Plant specific data. measurements by plant.	give an overall guidance but are not updated each year."
SF6 from electrical equipment	SF6	Uncertainty of the values provided by PPC regarding the transmission system. CS assessment.	IPCC GPG default for use of SF ₆ .

Table IV.2 *Uncertainty analysis without LULUCF*

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category 2014	Gass	Base year emissions or removals	Year 2014 emissions or removals	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by source/sink category in year 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq.	Gg CO2 eq.	%	%	%	%	%	%	%	%	%
1.A Fuel Combustion Activities												
Liquid	CO2	35,636	33,886	3%	3%	0.0	0.0002	0.0056	0.3233	0.02%	1.37%	0.02%
Solid	CO2	38,912	34,214	3%	3%	0.0	0.0002	0.0326	0.3264	0.10%	1.38%	0.02%
Gas	CO2	102	5,167	3%	2%	0.0	0.0000	0.0483	0.0493	0.10%	0.21%	0.00%
Other fossil fuels	CO2	0	26	3%	3%	0.0	0.0000	0.0002	0.0002	0.00%	0.00%	0.00%
1.A.1 Energy Industry												
Liquid	CH4	7	6	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	16	13	3%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
Solid	CH4	7	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	129	123	3%	300%	3.0	0.0000	0.0000	0.0012	0.00%	0.00%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	2	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.2 Industries and Construction												
Liquid	CH4	5	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

Solid	N2O	27	58	3%	300%	3.0	0.0000	0.0003	0.0006	0.09%	0.00%	0.00%
	CH4	1	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	N2O	17	1	3%	300%	3.0	0.0000	0.0001	0.0000	0.04%	0.00%	0.00%
	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Other fossil fuels	N2O	0	4	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	6	5	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	10	7	3%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
1.A.3 Transport												
a. Domestic aviation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	3	8	5%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
b. Road Transportation	CH4	107	78	4%	40%	0.4	0.0000	0.0002	0.0007	0.01%	0.00%	0.00%
	N2O	118	109	5%	50%	0.5	0.0000	0.0000	0.0010	0.00%	0.01%	0.00%
c. Railways	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	23	16	5%	300%	3.0	0.0000	0.0001	0.0002	0.02%	0.00%	0.00%
d. Domestic Navigation	CH4	3	3	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	129	76	5%	300%	3.0	0.0000	0.0005	0.0007	0.14%	0.01%	0.00%
e. Other Transportation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	5	5%	300%	3.0	0.0000	0.0001	0.0001	0.02%	0.00%	0.00%
1.A.4 Other Sectors												
Liquid	CH4	11	2	3%	100%	1.0	0.0000	0.0001	0.0000	0.01%	0.00%	0.00%
	N2O	313	45	3%	300%	3.0	0.0000	0.0025	0.0004	0.74%	0.00%	0.01%
Solid	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	91	105	3%	100%	1.0	0.0000	0.0002	0.0010	0.02%	0.00%	0.00%
	N2O	31	35	3%	300%	3.0	0.0000	0.0001	0.0003	0.02%	0.00%	0.00%
1B Coal Mining	CH4	1,130	1,107	2%	300%	3.0	0.0011	0.0001	0.0106	0.04%	0.03%	0.00%
1.B.2 Oil and	CO2	43	4	5%	300%	3.0	0.0000	0.0004	0.0000	0.11%	0.00%	0.00%

Natural Gas												
	CH4	36	88	5%	300%	3.0	0.0000	0.0005	0.0008	0.15%	0.01%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2 Industrial Processes and Product Use												
2.A.1 Cement Production	CO2	5,762	3,822	2%	2%	0.0	0.0000	0.0167	0.0365	0.03%	0.10%	0.00%
2.A.2 Lime Production	CO2	404	293	5%	6%	0.1	0.0000	0.0009	0.0028	0.01%	0.02%	0.00%
2.A.3 Glass production	CO2	20	17	5%	3%	0.1	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
2.A.4 Other process uses of carbonates	CO2	590	363	10%	5%	0.1	0.0000	0.0020	0.0035	0.01%	0.05%	0.00%
2.B.1 Ammonia Production	CO2	652	241	3%	6%	0.1	0.0000	0.0037	0.0023	0.02%	0.01%	0.00%
2.B.2 Nitric acid production	N2O	1,066	27	2%	3%	0.0	0.0000	0.0096	0.0003	0.03%	0.00%	0.00%
2.B.8 Petrochemical and Carbon Black Production	CO2	29	0	5%	5%	0.1	0.0000	0.0003	0.0000	0.00%	0.00%	0.00%
	CH4	1	0	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.B.10 Other-Hydrogen production	CO2	0	328	3%	3%	0.0	0.0000	0.0031	0.0031	0.01%	0.01%	0.00%
2.B.9 Flurochemical production	HFC	1,183	0	50%	50%	0.7	0.0000	0.0109	0.0000	0.55%	0.00%	0.00%
2.C.1 Iron and Steel Production	CO2	105	70	5%	5%	0.1	0.0000	0.0003	0.0007	0.00%	0.00%	0.00%
	CH4	0	0	5%	4%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.2 Ferroalloys	CO2	622	701	7%	7%	0.1	0.0000	0.0009	0.0067	0.01%	0.07%	0.00%
2.C.3 Aluminium Production	CO2	225	277	2%	2%	0.0	0.0000	0.0006	0.0026	0.00%	0.01%	0.00%
2.C.3 Aluminium Production	PFCs	190	80	3%	6%	0.1	0.0000	0.0010	0.0008	0.01%	0.00%	0.00%

2.C.4. Magnesium production	SF6	0	0	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.5 Lead production	CO2	14	10	2%	20%	0.2	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
2.C.6 Zinc production	CO2	46	66	2%	20%	0.2	0.0000	0.0002	0.0006	0.00%	0.00%	0.00%
2.D.1 Lubricant Use	CO2	78	28	5%	5%	0.1	0.0000	0.0004	0.0003	0.00%	0.00%	0.00%
2.D.2 Paraffin Wax Use	CO2	2	1	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.4 Other product manufacture and use	CO2	102	85	5%	5%	0.1	0.0000	0.0001	0.0008	0.00%	0.01%	0.00%
2.F.1 Refrigeration and Air-Conditioning Equipment	HFC	0	5,480	100%	150%	1.8	0.0095	0.0523	0.0523	7.84%	7.39%	1.16%
	PFC	0	55	100%	150%	1.8	0.0000	0.0005	0.0005	0.08%	0.07%	0.00%
2.F.2 Foam Blowing	HFC	0	190	40%	50%	0.6	0.0000	0.0018	0.0018	0.09%	0.10%	0.00%
2.F.3 Fire Extinguishers	HFC	0	43	60%	10%	0.6	0.0000	0.0004	0.0004	0.00%	0.03%	0.00%
2.F.4 Aerosols	HFC	0	46	15%	5%	0.2	0.0000	0.0004	0.0004	0.00%	0.01%	0.00%
2.G.1 Electrical Equipment	SF6	3	5	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.3 N2O from Product Uses	N2O	133	142	5%	5%	0.1	0.0000	0.0001	0.0014	0.00%	0.01%	0.00%
3 Agriculture												
3.A Enteric Fermentation	CH4	4,017	4,041	5%	50%	0.5	0.0004	0.0015	0.0385	0.07%	0.27%	0.00%
3.B Manure Management	CH4	884	822	5%	30%	0.3	0.0000	0.0003	0.0078	0.01%	0.06%	0.00%
3.B Manure Management	N2O	305	325	5%	100%	1.0	0.0000	0.0003	0.0031	0.03%	0.02%	0.00%
3.C Rice Cultivation	CH4	82	140	2%	40%	0.4	0.0000	0.0006	0.0013	0.02%	0.00%	0.00%
3.D Direct N2O Emissions	N2O	3,554	2,460	20%	200%	2.0	0.0024	0.0093	0.0235	1.87%	0.66%	0.04%

from Agricultural Soils												
3.D Indirect N ₂ O Emissions from Managed Soils	N ₂ O	1,238	875	20%	50%	0.5	0.0000	0.0031	0.0083	0.15%	0.24%	0.00%
3.F Field burning of agricultural residues	CH ₄	34	42	20%	20%	0.3	0.0000	0.0001	0.0004	0.00%	0.01%	0.00%
	N ₂ O	10	13	20%	20%	0.3	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
3.H Urea application	CO ₂	60	26	20%	50%	0.5	0.0000	0.0003	0.0002	0.02%	0.01%	0.00%
5 Waste												
5.A.1 Managed waste disposal sites	CH ₄	81	1,497	30%	30%	0.4	0.0000	0.0135	0.0143	0.41%	0.61%	0.01%
5.A.1 Unmanaged waste disposal sites	CH ₄	2,163	1,686	30%	30%	0.4	0.0000	0.0039	0.0161	0.12%	0.68%	0.00%
5.B.1 Biological treatment of solid waste-Composting	CH ₄	0	20	30%	100%	1.0	0.0000	0.0002	0.0002	0.02%	0.01%	0.00%
	N ₂ O	0	18	30%	100%	1.0	0.0000	0.0002	0.0002	0.02%	0.01%	0.00%
5. Incineration and open burning of waste	CO ₂	0	3	50%	40%	0.6	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH ₄	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N ₂ O	0	1	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.D.1 Domestic Wastewater Treatment and Discharge	CH ₄	2,959	522	30%	30%	0.4	0.0000	0.0223	0.0050	0.67%	0.21%	0.00%
	N ₂ O	274	317	30%	30%	0.4	0.0000	0.0005	0.0030	0.02%	0.13%	0.00%
5.D.2 Industrial Wastewater Treatment and Discharge	CH ₄	1,017	1,016	30%	30%	0.4	0.0000	0.0003	0.0097	0.01%	0.41%	0.00%
	N ₂ O	5	6	100%	30%	1.0	0.0000	0.0000	0.0001	0.00%	0.01%	0.00%

Total	104,827.11	101,403.31	0.0139	0.0127
		Percentage uncertainty in total inventory	11.8%	Trend uncertainty 11.3%

Table IV.3 *Uncertainty analysis with LULUCF*

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Source category 2014	Gas	Base year emissions or removals	Year 2014 emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by source/sink category in year 2013	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Gg CO2 eq.	Gg CO2 eq.	%	%	%	%	%	%	%	%	%
1.A Fuel Combustion Activities												
Liquid	CO2	35,636	33,886	3%	3%	0.0	0.0002	0.0022	0.3304	0.01%	1.40%	0.02%
Solid	CO2	38,912	34,214	3%	3%	0.0	0.0002	0.0295	0.3336	0.09%	1.42%	0.02%
Gas	CO2	102	5,167	3%	2%	0.0	0.0000	0.0494	0.0504	0.10%	0.21%	0.00%
Other fossil fuels	CO2	0	26	3%	3%	0.0	0.0000	0.0003	0.0003	0.00%	0.00%	0.00%
1.A.1 Energy Industry												
Liquid	CH4	7	6	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	16	13	3%	300%	3.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
Solid	CH4	7	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	129	123	3%	300%	3.0	0.0000	0.0000	0.0012	0.00%	0.01%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	2	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.2 Industries and Construction												
Liquid	CH4	5	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	27	58	3%	300%	3.0	0.0000	0.0003	0.0006	0.09%	0.00%	0.00%
Solid	CH4	1	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

Gas	N2O	17	1	3%	300%	3.0	0.0000	0.0001	0.0000	0.04%	0.00%	0.00%
	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Other fossil fuels	N2O	0	4	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	6	5	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	10	7	3%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
1.A.3 Transport									0.0000			0.00%
a. Domestic aviation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	3	8	5%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
b. Road Transportation	CH4	107	78	4%	40%	0.4	0.0000	0.0002	0.0008	0.01%	0.00%	0.00%
	N2O	118	109	5%	50%	0.5	0.0000	0.0000	0.0011	0.00%	0.01%	0.00%
c. Railways	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	23	16	5%	300%	3.0	0.0000	0.0001	0.0002	0.02%	0.00%	0.00%
d. Domestic Navigation	CH4	3	3	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	129	76	5%	300%	3.0	0.0000	0.0005	0.0007	0.14%	0.01%	0.00%
e. Other Transportation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	5	5%	300%	3.0	0.0000	0.0001	0.0001	0.02%	0.00%	0.00%
1.A.4 Other Sectors									0.0000			0.00%
Liquid	CH4	11	2	3%	100%	1.0	0.0000	0.0001	0.0000	0.01%	0.00%	0.00%
	N2O	313	45	3%	300%	3.0	0.0000	0.0025	0.0004	0.75%	0.00%	0.01%
Solid	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	91	105	3%	100%	1.0	0.0000	0.0002	0.0010	0.02%	0.00%	0.00%
	N2O	31	35	3%	300%	3.0	0.0000	0.0001	0.0003	0.02%	0.00%	0.00%
1B Coal Mining	CH4	1,130	1,107	2%	300%	3.0	0.0011	0.0002	0.0108	0.07%	0.03%	0.00%
1.B.2 Oil and Natural Gas	CO2	43	4	5%	300%	3.0	0.0000	0.0004	0.0000	0.11%	0.00%	0.00%
	CH4	36	88	5%	300%	3.0	0.0000	0.0005	0.0009	0.16%	0.01%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2 Industrial Processes and Product Use									0.0000			0.00%
2.A.1 Cement Production	CO2	5,762	3,822	2%	2%	0.0	0.0000	0.0165	0.0373	0.03%	0.11%	0.00%
2.A.2 Lime Production	CO2	404	293	5%	6%	0.1	0.0000	0.0009	0.0029	0.01%	0.02%	0.00%

2.A.3 Glass production	CO2	20	17	5%	3%	0.1	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
2.A.4 Other process uses of carbonates	CO2	590	363	10%	5%	0.1	0.0000	0.0020	0.0035	0.01%	0.05%	0.00%
2.B.1 Ammonia Production	CO2	652	241	3%	6%	0.1	0.0000	0.0037	0.0024	0.02%	0.01%	0.00%
2.B.2 Nitric acid production	N2O	1,066	27	2%	3%	0.0	0.0000	0.0097	0.0003	0.03%	0.00%	0.00%
2.B.8 Petrochemical and Carbon Black Production	CO2	29	0	5%	5%	0.1	0.0000	0.0003	0.0000	0.00%	0.00%	0.00%
	CH4	1	0	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.B.10 Other-Hydrogen production	CO2	0	328	3%	3%	0.0	0.0000	0.0032	0.0032	0.01%	0.01%	0.00%
2.B.9 Fluorochemical production	HFC	1,183	0	50%	50%	0.7	0.0000	0.0110	0.0000	0.55%	0.00%	0.00%
2.C.1 Iron and Steel Production	CO2	105	70	5%	5%	0.1	0.0000	0.0003	0.0007	0.00%	0.00%	0.00%
	CH4	0	0	5%	4%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.2 Ferroalloys	CO2	622	701	7%	7%	0.1	0.0000	0.0010	0.0068	0.01%	0.07%	0.00%
2.C.3 Aluminium Production	CO2	225	277	2%	2%	0.0	0.0000	0.0006	0.0027	0.00%	0.01%	0.00%
2.C.3 Aluminium Production	PFCs	190	80	3%	6%	0.1	0.0000	0.0010	0.0008	0.01%	0.00%	0.00%
2.C.4. Magnesium production	SF6	0	0	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.5 Lead production	CO2	14	10	2%	20%	0.2	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
2.C.6 Zinc production	CO2	46	66	2%	20%	0.2	0.0000	0.0002	0.0006	0.00%	0.00%	0.00%
2.D.1 Lubricant Use	CO2	78	28	5%	5%	0.1	0.0000	0.0005	0.0003	0.00%	0.00%	0.00%
2.D.2 Paraffin Wax Use	CO2	2	1	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.4 Other product manufacture and use	CO2	102	85	5%	5%	0.1	0.0000	0.0001	0.0008	0.00%	0.01%	0.00%
2.F.1 Refrigeration and Air-Conditioning Equipment	HFC	0	5,480	100%	150%	1.8	0.0101	0.0534	0.0534	8.02%	7.56%	1.21%
	PFC	0	55	100%	150%	1.8	0.0000	0.0005	0.0005	0.08%	0.08%	0.00%
2.F.2 Foam Blowing	HFC	0	190	40%	50%	0.6	0.0000	0.0019	0.0019	0.09%	0.10%	0.00%
2.F.3 Fire Extinguishers	HFC	0	43	60%	10%	0.6	0.0000	0.0004	0.0004	0.00%	0.04%	0.00%
2.F.4 Aerosols	HFC	0	46	15%	5%	0.2	0.0000	0.0004	0.0004	0.00%	0.01%	0.00%
2.G.1 Electrical Equipment	SF6	3	5	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.3 N2O from Product Uses	N2O	133	142	5%	5%	0.1	0.0000	0.0001	0.0014	0.00%	0.01%	0.00%
3 Agriculture									0.0000			0.00%
3.A Enteric Fermentation	CH4	4,017	4,041	5%	50%	0.5	0.0004	0.0019	0.0394	0.10%	0.28%	0.00%

3.B Manure Management	CH4	884	822	5%	30%	0.3	0.0000	0.0002	0.0080	0.01%	0.06%	0.00%
3.B Manure Management	N2O	305	325	5%	100%	1.0	0.0000	0.0003	0.0032	0.03%	0.02%	0.00%
3.C Rice Cultivation	CH4	82	140	2%	40%	0.4	0.0000	0.0006	0.0014	0.02%	0.00%	0.00%
3.D Direct N2O Emissions from Agricultural Soils	N2O	3,554	2,460	20%	200%	2.0	0.0025	0.0092	0.0240	1.84%	0.68%	0.04%
3.D Indirect N2O Emissions from Managed Soils	N2O	1,238	875	20%	50%	0.5	0.0000	0.0030	0.0085	0.15%	0.24%	0.00%
3.F Field burning of agricultural residues	CH4	34	42	20%	20%	0.3	0.0000	0.0001	0.0004	0.00%	0.01%	0.00%
	N2O	10	13	20%	20%	0.3	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
3.H Urea application	CO2	60	26	20%	50%	0.5	0.0000	0.0003	0.0003	0.02%	0.01%	0.00%
4 LAND USE, LAND-USE CHANGE AND FORESTRY										0.0000		0.00%
4.A.1 Forest Land remaining Forest Land	CO2	-1,139	-2,143	5%	33%	0.3	0.0001	0.0103	0.0209	0.34%	0.15%	0.00%
	CH4	47	1	11%	70%	0.7	0.0000	0.0004	0.0000	0.03%	0.00%	0.00%
	N2O	4	0	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.A.2 Conversion to Forest Land	CO2	0	-124	5%	113%	1.1	0.0000	0.0012	0.0012	0.14%	0.01%	0.00%
	CH4	0	0	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.B.1 Cropland remaining Cropland	CO2	-908	-317	12%	52%	0.5	0.0000	0.0054	0.0031	0.28%	0.05%	0.00%
4.B.2 Conversion to Cropland	CO2	0	1	10%	50%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.C.1 Grassland remaining Grassland	CO2	0	0	10%	50%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	16	8	10%	70%	0.7	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
	N2O	1	1	10%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.C.2 Conversion to Grassland	CO2	0	-851	10%	50%	0.5	0.0000	0.0083	0.0083	0.41%	0.12%	0.00%
4.D.2 Land converted to Wetlands	CO2	0	0	10%	50%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.E.2 Conversion to Settlements	CO2	6	11	10%	50%	0.5	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
4.F.2 Conversion to Other Land	CO2	20	82	10%	50%	0.5	0.0000	0.0006	0.0008	0.03%	0.01%	0.00%

4.G Harvested Wood Products	CO2	-325	93	10%	50%	0.5	0.0000	0.0039	0.0009	0.20%	0.01%	0.00%
5 Waste									0.0000			0.00%
5.A.1 Managed waste disposal sites	CH4	81	1,497	30%	30%	0.4	0.0000	0.0138	0.0146	0.42%	0.62%	0.01%
5.A.1 Unmanaged waste disposal sites	CH4	2,163	1,686	30%	30%	0.4	0.0001	0.0038	0.0164	0.11%	0.70%	0.00%
5.B.1 Biological treatment of solid waste-Composting	CH4	0	20	30%	100%	1.0	0.0000	0.0002	0.0002	0.02%	0.01%	0.00%
	N2O	0	18	30%	100%	1.0	0.0000	0.0002	0.0002	0.02%	0.01%	0.00%
5. Incineration and open burning of waste	CO2	0	3	50%	40%	0.6	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	1	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.D.1 Domestic Wastewater Treatment and Discharge	CH4	2,959	522	30%	30%	0.4	0.0000	0.0225	0.0051	0.68%	0.22%	0.01%
	N2O	274	317	30%	30%	0.4	0.0000	0.0005	0.0031	0.02%	0.13%	0.00%
5.D.2 Industrial Wastewater Treatment and Discharge	CH4	1,017	1,016	30%	30%	0.4	0.0000	0.0004	0.0099	0.01%	0.42%	0.00%
	N2O	5	6	100%	30%	1.0	0.0000	0.0000	0.0001	0.00%	0.01%	0.00%
Total		102,548.33	98,166.64				0.0150					0.0133
Percentage uncertainty in total inventory							12.2%	Trend uncertainty				11.5%

Legend

A: IPCC Source category 2002

B: Gas

C: Base year emissions 1990

D: Year t emissions 2001

E: Activity data uncertainty

F: Emission factor uncertainty

G: Combined uncertainty

H: Combined uncertainty as % of total national emissions in year t

I: Type A sensitivity

J: Type B sensitivity

K: Uncertainty in trend in national emissions introduced by emission factor uncertainty

L: Uncertainty in trend in national emissions introduced by activity data uncertainty

M: Uncertainty introduced into the trend in total national emissions

Annex V: Indirect greenhouse gases and SO₂

Nitrogen oxides

Emissions of nitrogen oxides in 2014 decreased by 24.72% compared to 1990 levels, with an average annual rate of decrease estimated at 0.99% for the period 1990 - 2014. Emissions of NO_x derive by 99.02% from the energy sector and especially from transport, which is responsible for the 46.81% of total NO_x emissions. In Table V.1 NO_x emissions by source category for the period 1990 – 2014 are presented.

Carbon monoxide

Emissions of carbon monoxide in 2014 decreased by 59.51% approximately compared to 1990 levels, with an average annual rate of decrease estimated at 2.38% for the period 1990 – 2014. CO emissions derive by 86.91% from the energy sector and especially from transport, which is responsible for the 57.37% of total CO emissions. In Table V.2 CO emissions by source category for the period 1990 – 2014 are presented.

Non-methane volatile organic compounds

NMVOC emissions decreased by 47.36% in 2014 compared to 1990, with an average annual rate of decrease estimated at 1.90%. NMVOC emissions derive by 56.60% from the energy sector and especially from transport, which is responsible for the 34.79% of total NMVOC emissions. In Table V.3 NMVOC emissions by source category for the period 1990 – 2014 are presented.

Sulphur dioxide

Sulphur dioxide emissions in 2014 decreased by 71.09% compared to 1990 levels, with an average annual rate of decrease estimated at 2.84% for the period 1990 - 2014. SO₂ emissions derive by 96.68% from the energy sector and mainly from the energy industries, which are responsible for the 71.37% of total SO₂ emissions. In Table V.4 SO₂ emissions by source category for the period 1990 – 2014 are presented.

The operation of desulphurisation plants at large power plants since 1998 and the increasing share of RES technologies for electricity production resulted in the reduction of SO₂ emissions from electricity generation. Reductions with respect to the sulphur content of liquid fossil fuels and the introduction of natural gas in the Greek energy system resulted in a reduction of SO₂ emissions from manufacturing industry, transport and residential sectors. Specifically, a reduction of SO₂ emissions from manufacturing industry of 89.51% was observed for the period 1990 – 2014. Emissions from Industrial processes decreased by 45.00% in 2014 compared to 1990, due to the decrease of sulphuric acid industrial production.

Table V.1 *NOx emissions (in kt) by source category. for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL	328.9	338.7	345.7	342.6	352.0	332.2	337.0	350.8	374.2	371.0	365.0	386.5	387.2	397.5	403.2	418.8	416.9	420.3	396.4	383.5	323.9	302.4	242.7	248.8	247.6
Energy	325.7	335.5	342.5	339.4	348.9	329.4	334.3	347.9	370.7	368.5	361.0	384.0	384.7	395.1	400.6	416.3	414.5	415.5	393.6	380.9	321.5	299.8	240.1	246.4	245.2
Fuel combustion	322.3	332.4	339.3	336.7	345.5	325.9	330.0	343.5	366.3	364.7	356.4	379.5	380.3	390.5	396.1	411.9	409.9	410.9	389.3	376.8	316.9	295.8	235.2	241.6	240.2
<i>Energy industries</i>	73.5	79.9	88.9	86.5	92.2	82.0	85.1	90.4	94.9	94.5	104.7	114.7	117.2	125.2	132.4	146.3	139.1	149.7	140.0	129.6	119.5	119.3	107.5	98.3	97.1
<i>Industry</i>	22.5	21.5	21.1	21.3	21.0	23.6	25.5	25.6	24.2	21.9	24.5	24.6	24.6	22.3	22.6	30.8	28.8	28.8	27.2	21.7	18.8	14.0	16.3	17.4	17.9
<i>Transport</i>	180.5	182.7	184.0	184.9	188.2	179.0	176.2	184.3	203.8	204.9	183.3	195.3	189.8	189.4	194.5	187.9	193.3	188.7	179.6	191.4	148.3	129.8	101.0	117.5	115.9
<i>Other sectors</i>	45.7	48.3	45.1	43.9	44.1	41.2	43.1	43.2	43.4	43.4	43.8	44.8	48.7	53.6	46.5	46.9	48.7	43.7	42.4	34.1	30.3	32.7	10.4	8.5	9.3
Fugitive emissions	3.5	3.1	3.2	2.7	3.4	3.6	4.3	4.4	4.4	3.9	4.7	4.6	4.4	4.6	4.5	4.5	4.5	4.6	4.3	4.1	4.7	4.0	4.9	4.8	5.0
Industrial processes	1.5	1.3	1.1	1.2	1.1	1.1	1.2	1.1	1.1	1.2	1.1	0.9	1.1	1.1	1.0	1.0	0.9	1.0	1.0	0.8	0.9	0.9	0.7	0.7	0.7
Nitric acid production	0.8	0.7	0.6	0.8	0.8	0.7	0.8	0.6	0.5	0.6	0.6	0.5	0.6	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3
Ammonia production	0.3	0.3	0.2	0.1	NO	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Iron and Steel Production	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.1	0.1
Aluminium production	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2
Paper and pulp	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Agriculture	1.3	1.7	1.4	1.4	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.4	1.3	1.3	1.6	1.5	1.5	1.5	1.5	1.6	1.6
Field burning of agricultural residues	1.3	1.7	1.4	1.4	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.4	1.3	1.3	1.4	1.4	1.3	1.3	1.6	1.5	1.5	1.5	1.5	1.6	1.6
LULUCF	0.5	0.2	0.7	0.6	0.6	0.3	0.2	0.4	1.2	0.1	1.6	0.2	0.0	0.0	0.1	0.1	0.2	2.5	0.3	0.3	0.1	0.2	0.4	0.2	0.1
Forest Land	0.3	0.1	0.3	0.4	0.3	0.2	0.1	0.2	0.8	0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.1	1.2	0.2	0.2	0.1	0.0	0.1	0.0	0.0
Remaining Forest Land																									

Table V.2 *CO emissions (in kt) by source category. for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL	1150.5	1129.1	1101.8	1093.4	1070.4	967.4	958.4	964.2	990.5	959.4	979.4	922.8	859.6	815.3	814.5	726.9	746.9	772.5	636.5	606.3	532.7	500.7	559.1	464.6	465.8
Energy	1085.7	1060.0	1023.1	1020.3	997.1	906.5	902.0	898.9	900.3	905.8	871.9	861.4	804.8	762.1	755.2	668.3	687.8	630.5	566.3	541.9	476.5	438.3	490.1	402.3	404.8
Fuel combustion	1084.4	1058.9	1021.9	1019.3	995.8	905.1	900.4	897.3	898.7	904.4	870.2	859.6	803.1	760.4	753.5	666.7	686.1	628.8	564.7	540.4	474.8	436.8	488.3	400.5	403.0
<i>Energy industries</i>	36.4	34.8	36.8	37.0	38.8	37.2	36.2	39.7	42.3	42.5	46.0	46.8	46.2	47.0	48.7	48.8	45.5	49.0	47.0	45.6	43.6	45.2	45.5	40.8	37.4
<i>Industry</i>	9.7	9.5	9.4	9.4	9.1	9.7	10.1	10.2	10.0	9.7	10.9	11.4	11.3	9.4	9.4	15.8	12.3	12.3	11.3	11.0	11.3	9.9	7.9	4.9	5.7
<i>Transport</i>	877.6	848.6	799.6	804.9	787.1	700.1	693.7	690.6	692.5	689.5	640.3	637.7	598.6	577.6	565.3	499.7	517.6	453.7	404.2	383.8	325.0	293.8	261.8	245.3	267.2
<i>Other sectors</i>	160.8	165.9	176.0	168.1	160.8	158.1	160.4	156.7	153.9	162.7	173.0	163.7	147.0	126.4	130.2	102.4	110.7	113.8	102.2	100.0	94.8	87.9	173.1	109.6	92.6
Fugitive emissions	1.3	1.2	1.2	1.0	1.3	1.3	1.6	1.6	1.7	1.4	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.5	1.7	1.5	1.8	1.8	1.9
Industrial processes	19.9	20.1	20.1	19.5	18.1	17.5	17.2	17.8	19.6	21.0	21.6	21.8	22.9	23.1	23.5	23.9	24.1	24.4	24.0	19.1	19.7	23.3	22.1	22.4	22.7
Ammonia production	0.0	0.0	0.0	0.0	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron and Steel Production	1.7	1.7	1.6	1.7	1.4	1.6	1.4	1.7	1.9	1.6	1.9	2.2	3.1	2.9	3.3	3.9	4.1	4.3	4.2	3.4	3.1	3.3	2.1	1.8	1.7
Asphalt roofing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aluminium production	18.0	18.3	18.4	17.7	16.6	15.7	15.7	15.9	17.5	19.2	19.5	19.4	19.7	20.0	20.0	19.8	19.8	19.9	19.7	15.6	16.4	19.8	19.9	20.4	20.8
Paper and pulp	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
Agriculture	28.8	40.2	32.7	31.4	34.2	32.0	31.5	31.9	29.8	29.3	31.0	31.8	30.7	28.5	31.8	32.1	29.5	28.7	34.6	33.1	32.5	33.7	34.2	34.5	35.1
Field burning of agricultural residues	28.8	40.2	32.7	31.4	34.2	32.0	31.5	31.9	29.8	29.3	31.0	31.8	30.7	28.5	31.8	32.1	29.5	28.7	34.6	33.1	32.5	33.7	34.2	34.5	35.1
LULUCF	16.2	8.7	25.9	22.2	21.1	11.4	7.6	15.6	40.8	3.3	54.9	7.9	1.2	1.6	4.0	2.5	5.5	88.8	11.6	12.2	4.1	5.5	12.6	5.4	3.2
Forest Land	10.7	4.1	11.8	12.3	10.8	7.1	2.9	8.5	26.7	1.7	32.9	3.5	0.3	0.5	1.3	1.1	3.3	43.4	6.8	7.4	3.1	1.3	5.0	0.4	0.2
Remaining Forest Land																									

Table V.3 *NMVOC emissions (in kt) by source category. for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL	237.7	238.4	233.7	232.1	228.6	215.8	215.5	216.7	218.0	220.4	208.7	207.3	198.4	194.0	191.1	178.5	177.9	171.8	161.7	155.0	141.7	131.1	124.8	125.9	125.1
Energy	175.4	174.3	170.3	169.8	168.1	157.7	157.7	158.4	159.0	159.0	148.3	146.4	138.9	133.3	128.8	118.1	116.7	110.6	101.5	96.8	82.6	75.1	70.3	70.7	70.8
Fuel combustion	164.7	163.9	159.6	159.4	157.0	145.7	145.6	145.6	145.8	146.2	134.8	132.8	125.0	118.9	114.6	102.6	101.0	94.3	85.6	81.2	67.6	61.7	57.3	58.6	59.1
<i>Energy industries</i>	5.1	5.2	5.2	5.1	5.4	5.3	5.3	5.7	5.6	5.8	6.1	6.3	5.9	6.2	6.4	6.7	6.5	6.7	6.7	6.1	5.4	5.4	5.5	5.1	4.9
<i>Industry</i>	4.9	4.9	4.9	4.8	4.7	4.9	5.2	5.2	5.1	4.9	5.6	5.4	5.5	4.7	4.6	4.5	4.5	4.7	5.4	4.5	4.5	4.6	3.3	2.0	2.6
<i>Transport</i>	139.2	137.5	132.8	133.5	131.5	120.7	120.1	120.1	120.7	120.3	107.1	105.7	99.2	94.2	90.2	79.6	77.2	70.4	61.9	60.0	47.8	41.7	37.0	42.7	43.5
<i>Other sectors</i>	15.6	16.2	16.8	16.0	15.4	14.9	15.0	14.7	14.5	15.2	16.0	15.4	14.3	13.8	13.4	11.8	12.9	12.6	11.5	10.5	9.8	10.0	11.5	8.8	8.1
Fugitive emissions	10.7	10.4	10.6	10.4	11.1	11.9	12.2	12.8	13.2	12.8	13.4	13.5	13.9	14.4	14.2	15.5	15.7	16.3	15.8	15.7	15.1	13.4	13.0	12.1	11.8
Industrial processes	62.4	64.1	63.4	62.3	60.5	58.1	57.7	58.3	59.1	61.5	60.4	60.9	59.4	60.7	62.3	60.4	61.2	61.2	60.2	58.1	59.1	56.0	54.5	55.2	54.3
Asphalt roofing	0.8	0.9	1.0	1.0	1.0	1.2	1.2	1.3	1.4	1.4	1.7	1.7	1.8	1.5	1.7	1.1	1.5	1.2	1.9	1.5	1.1	0.5	0.3	0.4	0.6
Road paving with asphalt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia production	0.0	0.0	0.0	0.0	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petrochemical and Carbon Black Production	0.9	0.9	0.9	1.1	1.1	1.1	1.2	1.4	1.4	1.1	1.0	0.9	0.9	0.9	1.1	1.0	0.9	0.6	NO	NO	NO	NO	NO	NO	
Iron and Steel Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solvent use	13.3	13.4	13.6	13.7	13.9	14.0	14.0	14.2	14.2	14.3	14.4	14.4	14.4	14.3	14.3	14.4	14.4	14.5	14.5	14.5	14.5	14.5	14.5	14.4	14.2
Domestic solvent use	27.7	27.9	28.3	28.5	28.8	29.0	29.2	29.4	29.6	29.7	29.8	29.9	30.0	29.7	29.8	29.9	30.0	30.1	30.2	30.2	30.2	30.0	30.0	29.9	29.5
Paper and pulp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Food and beverages industry	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.6	0.6	0.7	0.7	0.6	0.8	0.8	0.8	1.0	0.9

Table V.4 *SO₂ emissions (in kt) by source category. for the period 1990 – 2014*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL	477.7	517.4	533.9	528.0	523.6	541.3	535.2	533.5	539.3	556.4	498.7	507.7	517.2	555.6	551.7	541.5	533.5	537.1	444.0	423.0	247.6	190.1	150.9	140.8	138.1
Energy	469.4	509.5	526.8	521.4	516.7	533.5	527.4	525.5	531.3	548.3	491.4	500.6	509.9	548.2	544.2	534.1	527.0	530.5	437.8	418.3	242.7	186.1	147.0	136.4	133.5
Fuel combustion	460.4	501.6	518.5	514.5	508.0	524.3	516.3	514.2	519.8	538.3	479.4	488.7	498.4	536.4	532.6	522.5	515.3	518.6	426.7	407.6	230.7	175.8	134.3	124.1	120.7
Energy industries	299.1	340.9	361.6	373.2	381.9	407.3	386.7	379.5	378.5	405.3	370.6	372.2	383.5	421.7	414.2	414.4	402.0	406.4	365.9	333.7	202.4	147.7	108.3	102.8	98.6
Industry	94.3	91.2	89.7	78.5	65.7	70.7	79.6	79.5	70.7	59.0	68.6	67.4	69.3	64.2	63.4	56.9	58.5	62.5	18.8	11.8	11.9	11.3	10.6	9.3	9.9
Transport	38.7	38.7	41.0	38.2	42.7	32.1	30.6	37.7	52.6	56.4	21.3	28.7	25.1	26.7	31.7	27.8	30.4	27.4	23.3	46.7	11.3	11.2	8.4	9.3	9.4
Other sectors	28.4	30.7	26.2	24.6	17.6	14.2	19.4	17.5	18.1	17.5	18.8	20.4	20.6	23.7	23.3	23.4	24.4	22.3	18.7	15.4	5.2	5.6	7.0	2.7	2.8
Fugitive emissions	8.9	8.0	8.3	6.9	8.7	9.2	11.1	11.3	11.5	10.0	12.0	11.8	11.4	11.9	11.6	11.5	11.7	11.9	11.1	10.6	12.0	10.2	12.7	12.3	12.8
Industrial processes	8.3	7.9	7.1	6.6	7.0	7.8	7.8	8.0	8.0	8.1	7.3	7.2	7.3	7.4	7.5	7.4	6.5	6.5	6.2	4.7	5.0	4.1	3.8	4.4	4.6
Cement production	3.2	3.2	3.2	3.3	3.3	3.5	3.5	3.5	3.5	3.5	3.6	3.6	3.5	3.5	3.5	3.7	3.7	3.6	3.4	2.6	2.4	1.4	1.8	2.1	2.2
Ammonia production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulphuric acid production	3.6	3.2	2.3	2.1	2.4	2.9	2.9	3.1	3.1	3.2	2.1	2.0	2.2	2.2	2.3	2.0	1.2	1.2	1.1	0.9	1.2	1.1	0.5	0.6	0.8
Iron and Steel production	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ferroalloys Production	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.3	0.3	0.3
Aluminium production	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	1.0	1.0	1.0	1.0
Pulp and paper	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

