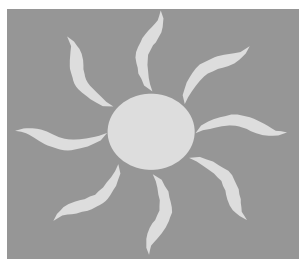


**MINISTRY OF ENVIRONMENT, ENERGY
AND CLIMATE CHANGE**

CLIMATE CHANGE



EMISSIONS INVENTORY

**ANNUAL INVENTORY SUBMISSION OF
GREECE UNDER THE CONVENTION AND THE
KYOTO PROTOCOL FOR GREENHOUSE AND
OTHER GASES FOR THE YEARS 1990-2012**

APRIL 2014

**ANNUAL INVENTORY SUBMISSION
UNDER THE CONVENTION AND
THE KYOTO PROTOCOL
FOR GREENHOUSE AND OTHER GASES
FOR YEARS 1990-2012**

EXECUTIVE SUMMARY

ES.1 Greenhouse gas inventories and climate change

The present report, prepared by Greece (Ministry of Environment, Energy and Climate Change (Climate Team) in co-operation with the National Technical University of Athens, NTUA – School of Chemical Engineering (Inventory Team)), contains estimates of GHG emissions for the period 1990-2012. **It constitutes Greece's submission both under the Convention and the Kyoto Protocol.** The methodologies applied for the estimation of GHG emissions are discussed and the activity data and emission factors used are presented.

International framework and national commitments

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).

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.

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).

Within the framework of the Convention, the Greek government, after taking into consideration both economic and social parameters, agreed that a realistic target for Greece was the restriction of the overall increase of carbon dioxide emissions to $15\% \pm 3\%$ by 2000 compared to 1990 levels. The measures taken in order to achieve this restriction in the CO₂ emissions were described in the 1st Greek National Action Plan for the abatement of CO₂ and other greenhouse gases emissions (MINENV / NTUA 1995).

With respect to the EU target under the Kyoto Protocol (i.e. reduction of emissions at 8% for the period 2008-2012), EU has stated that this will be achieved jointly by EU Member-States under the provisions of Article 4 of the Protocol. The Burden-Sharing agreement between all Member States was finalised during the Environment Council in June 1998 and entered into force with Decision 2002/358/EC concerning the approval, on behalf of the European Community, of the Kyoto Protocol. According to this agreement, Greece is committed to limit its GHG emissions increase for the period 2008 – 2012 to +25% compared to base year emissions (1990 for CO₂, CH₄ and N₂O emissions – 1995 for F - gases). Greece ratified the Protocol in 2002 (Law 3017/2002) and adopted the 2nd National Programme for Climate Change (MINENV, 2002) for achieving the above-mentioned commitment by a decision of the Council of Ministers (DCM5/2003).

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.

Reporting requirements and guidelines under the Convention are defined by relevant decisions of the Conference of the Parties (Decisions 18/CP.8, 13/CP.9, 14/CP.11). In order to ensure transparency, consistency, comparability, completeness and accuracy in national greenhouse gas emissions inventories the use of (a) the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, (b) the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories and (c) the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry was adopted. However, it should be mentioned that Parties are encouraged to

apply country specific methodologies provided that compliance with the above-mentioned references can be proven.

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, Energy and Climate Change, MEECC (former Ministry for the Environment, Physical Planning and Public Works) 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 compliance with relevant requirements defined in international conventions, protocols and agreements. Moreover, the MEECC 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 MEECC has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Irini Nikolaou, Address: Villa Kazouli, Kifisias 241, Athens, Greece, e-mail: i.nikolaou@prv.ypeka.gr, tel.: +30210 8089275, fax: +30210 8089239).

An overview of the organizational structure of the National Inventory System is presented in **Figure 1.1**. The participating entities are:

- The **Ministry of Environment, Energy and Climate Change (MEECC)** 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.
- **Governmental ministries and agencies** through their appointed focal persons, ensure the data provision.

International or national associations, along with individual 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, as follows:

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 IPCC Guidelines, the IPCC Good Practice Guidance and the LULUCF Good Practice Guidance.

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 NTUA) check. The official approval procedure follows for one month period of interactions between the Inventory Team (NTUA) and the Climate Team (MEECC), starting on the 1st of February of the year of submission. During this period, the NTUA 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 MEECC, who supervises the National System, approves the inventory and then the MEECC 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 - 2012 are presented in **Table ES.1** (in kt CO₂ eq).

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 107.2 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 2012, GHG emissions (without *LULUCF*) amounted to 110.98 Mt CO₂ eq showing an increase of 3.56% compared to base year emissions and of 5.77% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the increase would be 5.26 % (from 102.64 Mt CO₂ eq in 1990 to 108.04 Mt CO₂ eq in 2012).

Carbon dioxide emissions accounted for 81.52% of total GHG emissions in 2012 (without *LULUCF*) and increased by approximately 9.01% from 1990. Methane emissions accounted for 8.74% of total GHG emissions in 2012 and decreased by 8.53% from 1990, while nitrous oxide emissions accounted for 6.14% of the total GHG emissions in 2012 and decreased by 33.39% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 3.50% of total GHG emissions in 2012, and 41.68% of the IP sector, have an average increase of 27.29% from 1995 (base year for F-gases).

Table ES.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2001*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
A. GHG emissions per gas (excluding LULUCF)												
CO ₂	82,997.81	82,768.06	84,436.71	83,742.31	85,997.16	86,441.72	88,526.50	93,307.62	98,205.51	97,494.15	102,571.65	104,975.73
CH ₄	10,602.58	10,554.97	10,668.53	10,647.31	10,832.73	10,857.24	11,079.38	10,982.31	11,204.32	11,109.18	11,013.79	10,147.02
N ₂ O	10,224.65	9,927.81	9,785.27	8,953.11	8,776.71	9,070.73	9,291.99	9,086.57	9,050.33	8,964.20	8,640.41	8,463.25
HFC	935.06	1,106.82	908.39	1,606.74	2,144.05	3,290.41	3,817.88	4,097.77	4,579.60	5,365.79	4,243.67	3,849.15
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09	71.16
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06
Total	104,926.55	104,525.00	105,963.36	105,049.80	107,814.49	109,717.66	112,765.57	117,585.67	123,176.58	123,027.51	126,578.61	127,510.38
B. GHG emissions/removals from LULUCF												
CO ₂	-2,313.45	-2,411.42	-2,704.81	-3,019.23	-2,732.12	-3,020.61	-2,622.44	-2,459.70	-2,777.18	-2,992.71	-2,635.59	-2,540.57
CH ₄	27.15	16.86	50.41	40.28	39.45	19.78	15.56	28.52	68.27	6.09	95.97	15.45
N ₂ O	2.76	1.71	5.12	4.10	4.01	2.02	1.59	2.91	6.94	0.63	9.76	1.59
Total	-2,283.54	-2,392.85	-2,649.28	-2,974.86	-2,688.66	-2,998.81	-2,605.28	-2,428.27	-2,701.97	-2,985.98	-2,529.86	-2,523.54
C. GHG Emissions from International Transport												
CO ₂	10,520.55	9,516.76	10,704.75	12,262.74	13,300.82	13,908.07	12,444.84	12,389.76	13,656.18	12,734.85	13,922.58	13,425.06
CH ₄	14.27	12.99	14.75	17.30	18.24	19.30	17.20	17.28	19.48	17.32	20.14	19.86
N ₂ O	270.63	263.44	324.18	358.67	397.46	460.96	381.18	378.80	384.52	359.12	383.66	330.04
Total	10,805.46	9,793.18	11,043.68	12,638.70	13,716.51	14,388.33	12,843.22	12,785.83	14,060.18	13,111.28	14,326.37	13,774.96

Table ES.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2002-2012*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
A. GHG emissions per gas (excluding LULUCF)											
CO ₂	104,714.34	108,788.75	109,112.69	112,894.37	111,383.53	113,848.65	110,005.38	103,712.60	96,758.27	94,250.73	90,472.39
CH ₄	10,148.10	10,155.50	10,175.98	10,201.96	10,245.29	10,088.41	10,056.10	9,788.54	9,891.57	9,775.31	9,698.20
N ₂ O	8,407.14	8,330.61	8,349.32	8,066.77	7,854.21	8,039.57	7,645.28	7,190.60	7,512.85	7,208.40	6,810.34
HFC	4,098.81	3,901.17	3,990.80	4,066.71	2,231.52	2,569.37	2,950.25	3,338.70	3,603.28	3,410.13	3,889.05
PFC	73.57	76.90	73.42	74.32	70.77	80.64	93.53	74.28	105.55	78.34	110.39
SF ₆	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14	5.15	5.11
Total	127,446.22	131,257.18	131,706.68	135,310.59	131,793.69	134,636.55	130,758.06	124,109.98	117,877.65	114,728.07	110,985.47
B. GHG emissions/removals from LULUCF											
CO ₂	-2,874.04	-2,497.87	-2,768.66	-2,701.39	-2,710.59	-1,816.51	-2,979.18	-2,821.57	-2,911.09	-2,965.97	-2,972.55
CH ₄	2.50	3.41	8.56	4.93	9.71	168.26	20.42	21.12	6.14	12.27	25.58
N ₂ O	0.27	0.37	0.89	0.52	1.01	17.10	2.10	2.17	0.65	1.28	2.63
Total	-2,871.27	-2,494.09	-2,759.21	-2,695.94	-2,699.86	-1,631.15	-2,956.65	-2,798.28	-2,904.29	-2,952.42	-2,944.33
C. GHG Emissions from International Transport											
CO ₂	12,279.69	13,220.31	13,399.90	11,532.90	12,736.06	13,006.30	12,897.04	10,982.34	10,822.38	11,165.41	9,793.18
CH ₄	17.85	18.45	18.71	16.71	18.08	18.58	18.20	15.41	15.98	16.39	13.44
N ₂ O	298.33	288.58	281.20	233.62	249.10	239.54	229.63	206.06	213.10	202.62	177.15
Total	12,595.88	13,527.33	13,699.81	11,783.22	13,003.23	13,264.43	13,144.87	11,203.81	11,051.45	11,384.42	9,983.78

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2012 are presented in **Table ES.2**.

- ↳ Emissions from *Energy* in 2012 accounted for 78.61% of total GHG emissions (without LULUCF) and increased by approximately 13.73% 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 - 2012, 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 in all sectors of energy of the years 2008-2012 is attributed among others (i.e. RES, energy efficiency measures, road infrastructure and public transportation improvements, etc) to the economic recession that the country is facing.

The majority of GHG emissions (64.12%) in 2012 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 18.63%, 6.47% and 10.78%, respectively. The rest 0.01% 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 for the years 1990-2008 is transport, showing an average rate of increase of 2.48%. However, for years 2009-2012 a decrease was observed with an average rate of decrease equal to -6.81%. In addition, energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) presented 1.16% and 0.94% average annual rate of increase, respectively. Finally, emissions from manufacturing industries and construction emissions had a mean annual rate of decrease of 1.87%.

- ↳ Emissions from *Industrial Processes* in 2012 accounted for 8.66% of the total emissions (excluding LULUCF) and decreased by 9.42 % compared to 1990 levels. In 2012 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 (20.07%), which followed the intense decrease of 2011 (-36.74% between 2011 and 2010). Emissions from chemical industry have decreased by 23.67% since 2011. Emissions from metal production slightly increased with

regards to 2011 by 1.05%, due to the increased production of aluminium and nickel. As regards to f-gases emissions, have been increased compared to 2011 (14.48%). The general increasing trend during the last years of the time-series depicts the continuous substitution of CFCs in the context of the protocol of Montreal.

- ⇒ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.29% of the total emissions) and has increased by 3.29% compared to 1990 level of emissions.
- ⇒ Emissions from *Agriculture* that accounted for 8.18% of total emissions in 2012 (without *LULUCF*), decreased by approximately 20.44% 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* (4.27% of the total emissions, without *LULUCF*), decreased by approximately 19.58% 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 – 2012. During this period, the *LULUCF* sector offset on average 2.24% (1.21-2.83%) of the total national emissions (without *LULUCF*). The sink capacity of the *LULUCF* sector fluctuates between 1.63 Mt CO₂ eq. and 3.0 Mt CO₂ eq., showing a slightly decreasing 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 1990-2001*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Energy	76,717.09	76,621.20	78,712.84	78,320.91	80,632.58	80,570.02	82,757.47	87,390.13	92,205.06	91,597.16	96,409.10	98,886.61
Industrial processes	10,605.49	10,485.38	9,973.47	10,253.66	10,739.40	12,396.38	13,043.32	13,440.67	14,025.84	14,716.77	13,849.43	13,319.55
Solvents	308.34	315.54	314.37	312.95	307.39	299.82	298.22	300.20	300.40	308.73	306.61	304.28
Agriculture	11,407.60	11,255.04	11,032.04	10,214.24	10,040.20	10,369.59	10,502.01	10,369.38	10,401.76	10,251.62	10,019.45	9,928.16
Waste	5,888.03	5,847.85	5,930.64	5,948.04	6,094.91	6,081.84	6,164.55	6,085.29	6,243.52	6,153.23	5,994.02	5,071.78
Total ¹⁾	104,926.55	104,525.00	105,963.36	105,049.80	107,814.49	109,717.66	112,765.57	117,585.67	123,176.58	123,027.51	126,578.61	127,510.38
LULUCF	-2,283.54	-2,392.85	-2,649.28	-2,974.86	-2,688.66	-2,998.81	-2,605.28	-2,428.27	-2,701.97	-2,985.98	-2,529.86	-2,523.54
Index per sector												
Energy	100.00	99.88	102.60	102.09	105.10	105.02	107.87	113.91	120.19	119.40	125.67	128.90
Industrial processes	100.00	98.87	94.04	96.68	101.26	116.89	122.99	126.73	132.25	138.77	130.59	125.59
Solvents	100.00	102.33	101.95	101.49	99.69	97.24	96.72	97.36	97.42	100.13	99.44	98.68
Agriculture	100.00	98.66	96.71	89.54	88.01	90.90	92.06	90.90	91.18	89.87	87.83	87.03
Waste	100.00	99.32	100.72	101.02	103.51	103.29	104.70	103.35	106.04	104.50	101.80	86.14
Total ²⁾	100.00	99.62	100.99	100.12	102.75	104.57	107.47	112.06	117.39	117.25	120.64	121.52

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 2002-2012*

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Energy	98,802.18	102,696.31	103,010.14	106,172.26	104,893.51	107,452.37	104,198.86	99,717.69	92,488.93	91,668.30	87,249.15
Industrial processes	13,452.19	13,379.60	13,459.15	14,126.12	11,899.96	12,148.40	11,885.40	10,248.68	10,591.29	8,720.81	9,606.76
Solvents	305.13	305.93	306.75	309.29	311.92	313.41	314.13	315.60	316.17	316.41	318.47
Agriculture	9,915.79	9,846.54	9,935.71	9,656.06	9,485.74	9,704.91	9,350.46	9,069.75	9,433.40	9,137.12	9,075.85
Waste	4,970.93	5,028.79	4,994.94	5,046.87	5,202.56	5,017.47	5,009.21	4,758.26	5,047.86	4,885.43	4,735.23
Total ¹⁾	127,446.22	131,257.18	131,706.68	135,310.59	131,793.69	134,636.55	130,758.06	124,109.98	117,877.65	114,728.07	110,985.47
LULUCF	-2,871.27	-2,494.09	-2,759.21	-2,695.94	-2,699.86	-1,631.15	-2,956.65	-2,798.28	-2,904.29	-2,952.42	-2,944.33
Index per sector											
Energy	128.79	133.86	134.27	138.39	136.73	140.06	135.82	129.98	120.56	119.49	113.73
Industrial processes	126.84	126.16	126.91	133.20	112.21	114.55	112.07	96.64	99.87	82.23	90.58
Solvents	98.96	99.22	99.48	100.31	101.16	101.64	101.88	102.36	102.54	102.62	103.29
Agriculture	86.92	86.32	87.10	84.65	83.15	85.07	81.97	79.51	82.69	80.10	79.56
Waste	84.42	85.41	84.83	85.71	88.36	85.21	85.07	80.81	85.73	82.97	80.42
Total ²⁾	121.46	125.09	125.52	128.96	125.61	128.32	124.62	118.28	112.34	109.34	105.77

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

ES.4 Emissions trends for indirect greenhouse gases and sulphur dioxide

The role of carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane organic volatile compounds (NMVOC) is important for climate change as these gases act as precursors of tropospheric ozone. In this way, they contribute to ozone formation and alter the atmospheric lifetimes of other greenhouse gases. For example, CO interacts with the hydroxyl radical (OH), the major atmospheric sink for methane, to form carbon dioxide. Therefore, increased atmospheric concentration of CO limits the number of OH compounds available to destroy methane, thus increasing the atmospheric lifetime of methane.

These gases are generated through a variety of anthropogenic activities. Emissions trends for indirect greenhouse gases and SO₂ are presented in **Table 2.7**, while more information on the emissions of indirect greenhouse gases and SO₂ is provided in Annex V.

- ✎ NO_x emissions decreased by 20.63% from 1990 to 2012. Energy sector accounts for the high majority of emissions (99.07%). The decrease in NO_x emissions from transport after 1998 is attributed to the substitution of old technology vehicles by new catalytic ones (NO_x emissions from this category account for the 39.02% of total NO_x emissions in 2012). Emissions from *Industrial processes* decreased by 53.81% from 1990 due to reductions in the production of nitric acid.
- ✎ The transport sector is the main source of CO emissions. Due to the substitution of old technology vehicles by new and more efficient ones, CO emissions from transport decreased by 70.16% from 1990 to 2012 and as a result total CO emissions in 2012 decreased by 59.69%. Emissions from industrial processes in 2012 increased by 11.41% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2012 emissions from LULUCF accounted for 2.31% of total CO emissions (incl LULUCF), and are by 5.77% lower than emissions of 1990.
- ✎ NMVOC emissions decreased by 43.59% from 1990 to 2012. Emissions from transport (24.34% of total NMVOC emissions in 2012), decreased by 73.44% compared to 1990 levels, while emissions from *Energy* decreased by 54.84% from 1990 to 2012. The significant decrease of NMVOC emissions from *Industrial processes* (approximately 50.20% from 1990 to 2012) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 3.49% compared to 1990 levels.
- ✎ SO₂ emissions decreased by 48.56% from 1990 to 2012. Emissions from energy, which is the main source of SO₂ emissions in Greece (98.38 % of total SO₂ emissions for 2012), decreased with a mean annual rate of decrease of 2.21% for the period 1990 – 2012. The operation of desulphurisation plants at large installations for electricity generation since 1998 resulted in the restriction of the increase 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 88.76% for the period 1990 – 2012. Emissions from *Industrial processes* decreased by 52.32% from 1990 due to decrease of sulphuric acid industrial production.

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PART I: ANNUAL INVENTORY SUBMISSION

1. Introduction

1.1 Background information on greenhouse gas inventories, climate change and supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

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).

National commitments

Within the framework of the Convention, the Greek government, after taking into consideration both economic and social parameters, agreed that a realistic target for Greece was the restriction of the overall increase of carbon dioxide emissions to $15\% \pm 3\%$ by 2000 compared to 1990 levels. The measures taken in order to achieve this restriction in the CO₂ emissions were described in the 1st Greek National Action Plan for the abatement of CO₂ and other greenhouse gases emissions (MINENV / NTUA 1995).

With respect to the EU target under the Kyoto Protocol (i.e. reduction of emissions at 8% for the period 2008-2012), EU has stated that this will be achieved jointly by EU Member-States under the provisions of Article 4 of the Protocol. The Burden-Sharing agreement between all Member States was finalised during the Environment Council in June 1998 and entered into force with Decision 2002/358/EC concerning the approval, on behalf of the European Community, of the Kyoto Protocol. According to this agreement, Greece is committed to limit its GHG emissions increase for the period 2008 – 2012 to +25% compared to base year emissions (1990 for CO₂, CH₄ and N₂O emissions – 1995 for F - gases). Greece ratified the Protocol in 2002 (Law 3017/2002) and adopted the 2nd National Programme for Climate Change (MINENV, 2002) for achieving the above-mentioned commitment by a decision of the Council of Ministers (DCM5/2003).

1.1.2 Background information on greenhouse gas 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.

According to Article 4 of the Convention, Annex I Parties have the obligation to submit national inventories of GHG emissions and removals. At COP2, the annual submission of inventories was decided (Decision 9/CP.2), while the use of the "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories" (henceforth IPCC Guidelines) was adopted with Decision 2/CP.3. In order to enhance the transparency of the GHG inventories submitted and improve comparability across sectors and different countries, the use of Common Reporting Format (CRF) tables for the submission of the emissions/removals estimates per source/sink category was adopted at COP5 (Decision 3/CP.5).

At the 12th session of the Subsidiary Body for Scientific and Technological Advice (SBSTA), the use of the IPCC "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" (henceforth IPCC Good Practice Guidance) for inventories due in 2003 and beyond was decided. The IPCC Good Practice Guidance is considered as an elaboration of the IPCC Guidelines.

New reporting guidelines, together with a structure of the National Inventory Report (NIR) were adopted at COP8 (Decision 18/CP.8) for use in reporting annual inventories due in 2004 and beyond. Overall annual national inventories submissions include the submission of both the Common Reporting Format tables and the National Inventory Report by the 15th of April.

At COP9 the use of the IPCC "Good Practice Guidance for Land Use, Land Use Change and Forestry" (henceforth LULUCF Good Practice Guidance) for inventories due in 2005 and beyond was adopted (Decision 13/CP.9). Moreover, new Common Reporting Format tables for LULUCF, to be used for a trial period covering inventory submissions due in 2005, were adopted with the same decision.

The Conference of the Parties (COP), by its decision 14/CP.11, adopted the tables of the common reporting format and their notes for reporting on land use, land-use change and forestry (LULUCF) sector, to be used for the purpose of submission of the annual inventory due in and after 2007.

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 Council Decision 280/2004/EC concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.

With the present report, which contains estimates of GHG emissions for Greece for the years 1990-2009, and the mandatory supplementary information required for the 2011 submission under the Kyoto Protocol, the above obligations are addressed.

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 10-14) 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 14 chapters and 6 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.

Emissions trends (including other gases) per gas and per sector for the period 1990 – 2008 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 – 8**. In **Chapter 9** an overview of the recalculations made since the 2008 submission and the future improvements planned is presented. The **Chapters 10-14** of part II of this report contain supplementary information required under article 7, paragraph 1. **Chapter 10** 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 11-14** 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**, while **Annex V** provides information with regard to the emissions of oxides of nitrogen, carbon monoxide, non-methane volatile organic compounds and sulphur dioxide per sector. **Annex VI** shows sources of GHGs that are not estimated in the Greek GHG inventory, and the reasons for those sources being omitted.

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, Energy and Climate Change, MEECC (former Ministry for the Environment, Physical Planning and Public Works) 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 MEECC 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 MEECC has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Irini Nikolaou, Address: Villa Kazouli, Kifisias 241, Athens, Greece, e-mail: i.nikolaou@prv.ypeka.gr, tel.: +30210 8089275, fax: +30210 8089239).

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

- The **MEECC** 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.
- **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 MEECC Climate team, the NTUA Inventory team and the designated contact points of the competent Ministries was formalized by circular 918/21-4-08 released by MEECC (former MINENV) 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 new Ministry of Environment, Energy and Climate change retains 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, are transferred to the Ministry of Environment, Energy and Climate Change. The Public Works General Secretariat was transferred to the new Ministry of Infrastructure, Transport and Networks.

Accordingly, there is a restructuring of the roles of the ministries in the national inventory system, as described in section 1.2.2.

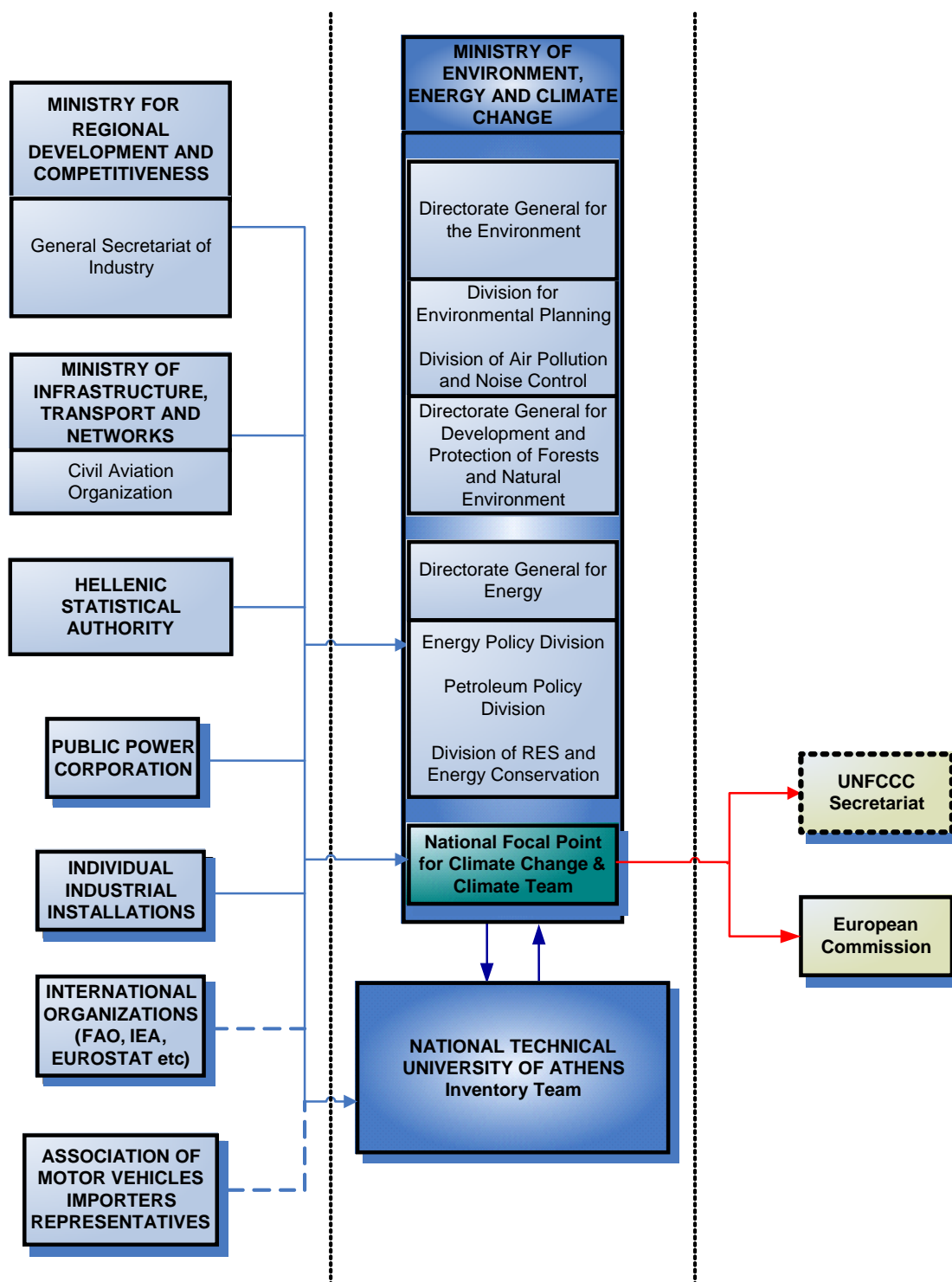


Figure 1.1 *Organizational Structure of the National Inventory System*

1.2.2 Roles and Responsibilities

1.2.2.1 Ministry of Environment, Energy and Climate Change

The Ministry of Environment, Energy and Climate Change, MEECC, 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 consultant (NTUA Inventory Team), who has the technical and scientific responsibility for the inventory planning, preparation and management of all sectors, 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 institute which has the technical responsibility for the inventory planning, preparation and management (currently NTUA) at the beginning of each inventory cycle. The Centralised Inventory File is kept at the premises of the MEECC.
- 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 MEECC 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 NTUA's Inventory Team. MEECC 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 of NTUA and the competent ministries or other agencies involved.

1.2.2.2 National Technical University of Athens (NTUA) - School of Chemical Engineering

The Ministry of Environment, Energy and Climate Change 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. In this framework, NTUA (Inventory Team) has 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 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 Article 3 of the Decision 280/2004/EC of the European Parliament and of the Council.
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 MEECC'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 inventory team at the beginning of the next inventory cycle.
13. Development of QA/QC procedures.
14. Implementing the QA/QC procedures under the supervision of MEECC.
15. Training the representatives of data providing agencies on inventory issues.

The NTUA 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 consultant (NTUA) is responsible for the final decision concerning methodological issues.

NTUA is also responsible in co-operation with MEECC's Climate Team to perform greenhouse gas balance projections in terms of sources and sinks, organized by gas and by sector, according to the national policies and measures adopted.

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

1. Prof. Ioannis Ziomas, Scientific responsible
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Heroon Polytechniou 9, Zografos, 157 80 Athens, Greece.
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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.

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, Energy and Climate Change (Contact Persons: Chatzigianakis Konstantinos, Macheras Ioannis, Panagiotis Drougas) 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 NO_x and SO₂ emissions (Division of Air pollution and Noise control)
 - 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 (Emissions Trading Office)
 - data for f-gases use (Division of Air pollution and Noise control)
 - data for emissions / removals from LULUCF activities (UNFCCC and KP scope) (General Directorate for the Development and Protection of Forests and Natural Environment).

- The Hellenic Statistical Authority (Contact persons: Ioanna Papanagnou 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 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, as elaborated by the IPCC good practice guidance.

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 IPCC Guidelines, the IPCC Good Practice Guidance and the LULUCF Good Practice Guidance.

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 NTUA) check. The official approval procedure follows for one month period of interactions between the Inventory Team (NTUA) and the Climate Team (MEECC), starting on the 1st of February of the year of submission. During this period, the NTUA 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 MEECC, who supervises the National System, approves the inventory and then the MEECC submits the NIR to the European Commission and to the UNFCCC Secretariat.

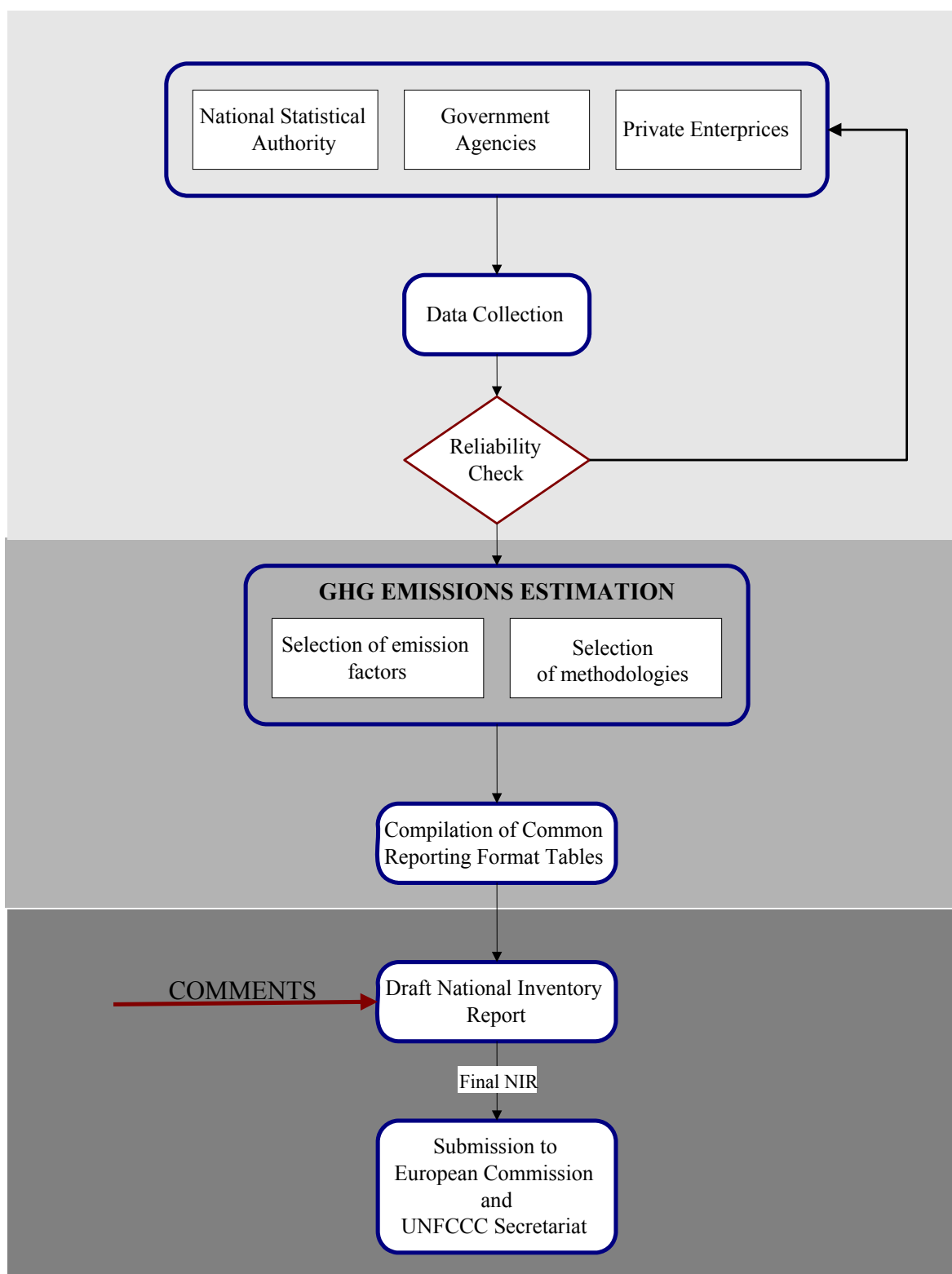


Figure 1.2 *GHG emissions inventory preparation process in Greece*

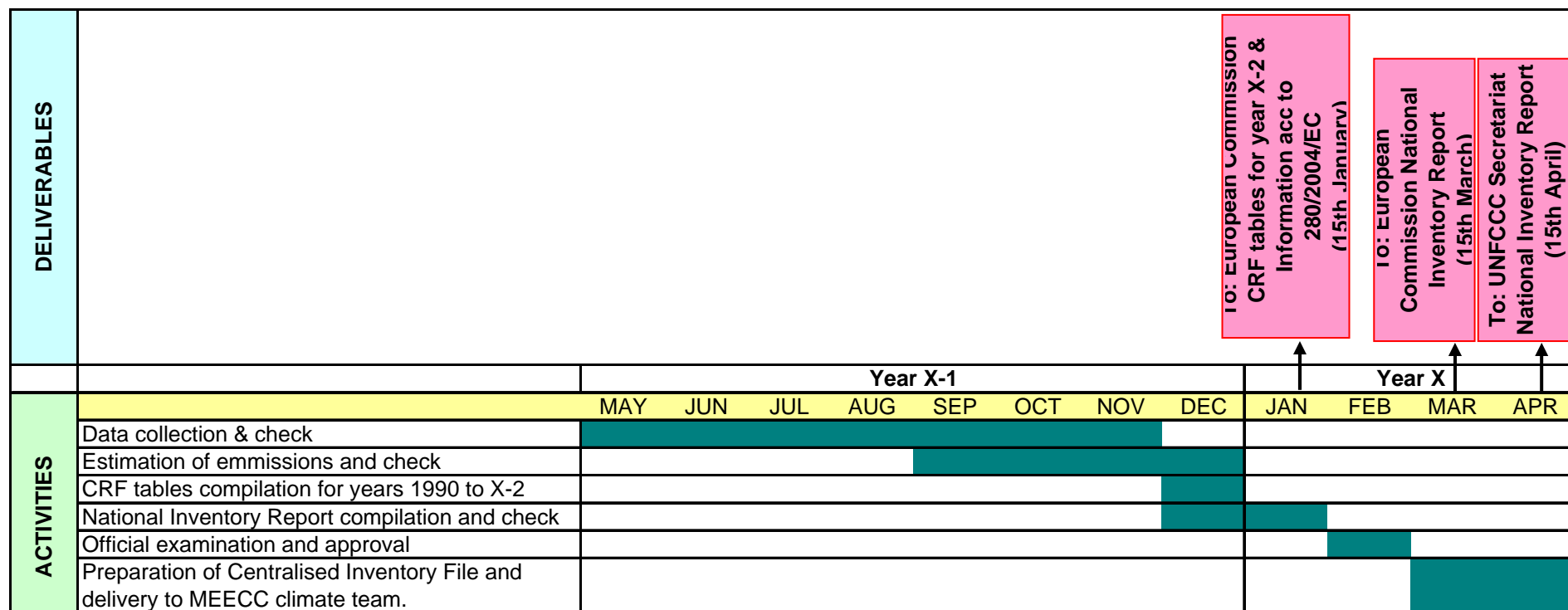


Figure 1.3 *Timetable for the preparation and submission of GHG emissions/removals inventory in Greece*

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 MEECC Climate Team and the NTUA Inventory Team 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 MEECC 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 Inventory Team to the person responsible for keeping the Centralised Inventory File (member of the Climate Team) in MEECC, 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 IPCC Guidelines, the IPCC Good Practice Guidance, the LULUCF Good Practice Guidance and the CORINAIR methodology¹. 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.

¹ Emissions estimates from road transport presented in this inventory derive from the implementation of the COPERT IV model (COmputer Program to calculate Emissions from Road Transport), developed for the Commission of the European Communities in the framework of the CORINAIR methodology.

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	T2	D	T2	D		
2. Manufacturing industries and Construction	T2	CS, PS	T2	D	T2	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	T2	D	T2	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	T2,OTH	CS,D,OTH	T1	D	T1	D		
B. Cropland	T1,T2	CS,D	NA	NA	T1	D		
C. Grassland	T1,T2	CS,D	T1	D	T1	D		
D. Wetlands	T1, T2	CS, D	NA	NA	NA	NA		
E. Settlements	T1,T2	CS, D	NA	NA	NA	NA		
F. Other Land	T1,T2	CS, 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 2005-2012 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, Energy and Climate Change ETS verified reports
1.A2	Manufacturing industry and construction	Fuel consumption	<ul style="list-style-type: none"> Ministry of Environment, Energy and Climate Change 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, Energy and Climate Change
1.B	Fugitive emissions from fuels	Amount of fuels Transmission/distribution pipelines length	<ul style="list-style-type: none"> Ministry of Environment, Energy and Climate Change
2	Industrial processes	Industrial production	<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	Solvents and other products use	Amount of solvents/other products use	<ul style="list-style-type: none"> Hellenic Statistical Authority Ministry of Environment, Energy and Climate Change
4	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
5	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, Energy and Climate Change Hellenic Statistical Authority
6	Waste	Quantities - composition of solid waste generated Recycling Population Industrial production	<ul style="list-style-type: none"> Ministry of Environment, Energy and Climate Change 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)	21
Nitrous oxide (N ₂ O)	310
Hydrofluorocarbons (HFC)	
HFC-23	11700
HFC-32	650
HFC-125	2800
HFC-134a	1300
HFC-143a	3800
HFC-152a	140
HFC-227ea	2900
HFC-236fa	6300
HFC-4310mee	1300
Perfluorocarbons (PFC)	
CF ₄	6500
C ₂ F ₆	9200
C ₄ F ₁₀	7000
C ₆ F ₁₄	7400
Sulphur hexafluoride (SF ₆)	23900

1.5 Brief description of key categories

1.5.1 GHG inventory

The IPCC Good Practice Guidance 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).

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 IPCC Good Practice Guidance, adopting the categorization of sources that is presented in table 7.1 of the IPCC Good Practice Guidance.

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 2012 are presented in **Table 1.4**.

Twelve key source categories are found in the energy sector and eight in the IP sector in 2012 (without *LULUCF*).

Table 1.4 *Key categories for the Greek inventory system without LULUCF for 2012*

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 transport	CO ₂	Level, Trend
Transport – Navigation	CO ₂	Level, Trend
Coal mining and handling	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors - Liquid fuels	N ₂ O	Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Lime Production	CO ₂	Trend
Limestone & Dolomite Use	CO ₂	Trend
Ferroalloys	CO ₂	Level
Nitric acid production	N ₂ O	Trend
Ammonia production	CO ₂	Trend
Other chemicals	CO ₂	Trend
Ozone depleting substances substitutes	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 – Animal production	N ₂ O	Level
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

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 2012 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* thirteen categories from the Energy Sector and eight from the IP Sector have been identified as key.

Table 1.5 *Key categories for the Greek inventory system with LULUCF for 2012*

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 transport	CO ₂	Level, Trend
Transport – Navigation	CO ₂	Level, Trend
Transport – Civil Aviation	CO ₂	Level
Coal mining and handling	CH ₄	Level, Trend
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors - Liquid fuels	N ₂ O	Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Lime Production	CO ₂	Trend
Limestone & Dolomite Use	CO ₂	Trend
Ferroalloys	CO ₂	Level
Nitric acid production	N ₂ O	Trend
Ammonia production	CO ₂	Trend
Other chemicals	CO ₂	Trend
Ozone depleting substances substitutes	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 – Animal production	N ₂ O	Level
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

The results of the analysis for the previous years are presented in Table 7 of each year's CRF excel file. 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 GPG LULUCF, 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 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 5.B.2.1, 5.C.2.1, 5.D.2.1, 5.E.2.1 and 5.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 5.B.2, 5.C.2, 5.D.2, 5.E.2 and 5.F.2 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

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 National Technical University of Athens is responsible in close co-operation with the Ministry of Environment, Energy and Climate Change. 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 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 within the NTUA), of the QA/QC procedures included in the plan for:

- ↳ data collection and processing,
- ↳ applying methods consistent with IPCC Good Practice Guidance and LULUCF Good Practice Guidance for calculating / recalculating emissions or removals,
- ↳ 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 IPCC Good Practice Guidance, (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.

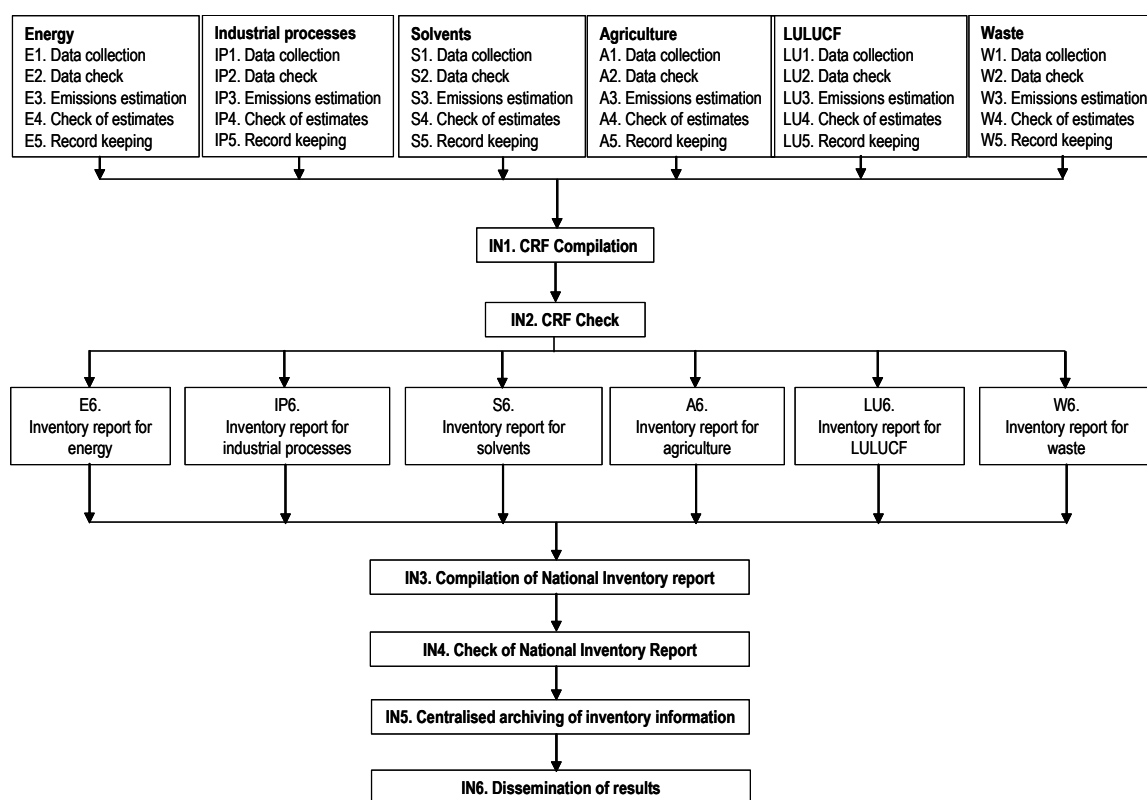


Figure 1.4 Flow chart activities concerning the GHG emissions inventory

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 MEECC and the NTUA staff members. 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 MEECC/NTUA 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

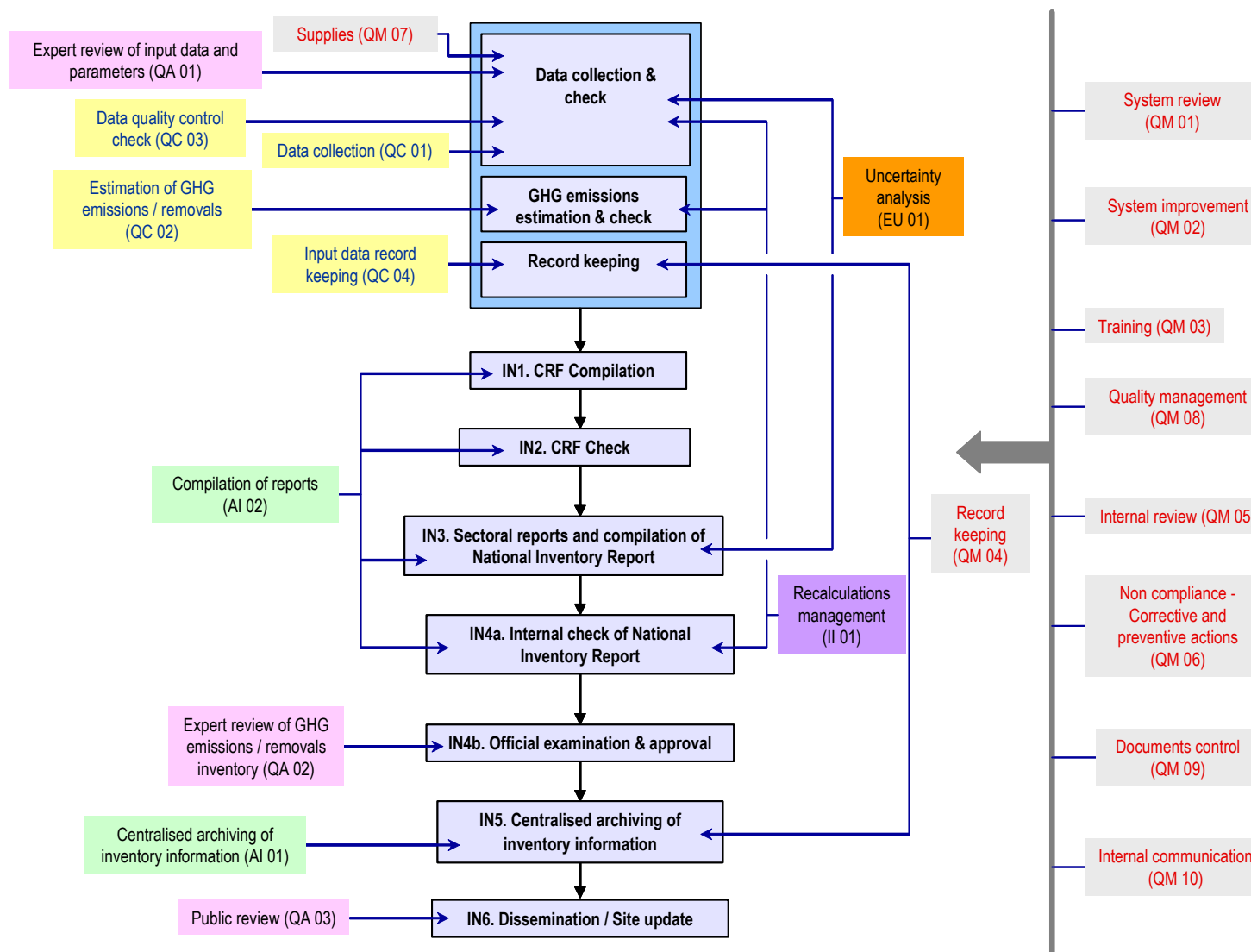


Figure 1.5 *QA/QC processes and procedures and inventory related activities*

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, therefore, the only possible way to collect such information was by communicating directly to the respective plants.

In the recent years, the organisation of the new inventory system accommodates this kind of situation, enabling the operation of new procedures of confidential data exchange between the inventory team and the Hellenic Statistics Authority (El.Stat). More specifically, the cooperation established under the new system contributed to the confidentiality waiver that was decided by the relevant committee of the Service in 2008. The newly 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.

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. More details on this will be provided in paragraph 4.12.

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 IPCC Good Practice Guidance and the LULUCF Good Practice Guidance, 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 1.9 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 2012, were estimated at:

2.5% for CO₂ emissions

46.1% for CH₄ emissions

96.5% for N₂O emissions and

170.1% for the F-gases emissions.

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

Source categories	Gas	Uncertainty (%)
Stationary combustion – Solid fuels	CO ₂	4.2
Stationary combustion – Liquid fuels		4.2
Stationary combustion – Gaseous fuels		3.6
Stationary combustion – Other fuels		4.2
Mobile combustion – Road transport		7.1
Mobile combustion – Navigation		7.1
Mobile combustion – Aviation		7.1
Mobile combustion – Railway		7.1
Pipeline transport		7.1
Fugitive – Oil and Natural gas		300.0
Cement production		2.8
Lime production		7.8
Limestone & Dolomite Use		11.2
Soda Ash Production and Use		11.2
Glass Production		5.8
Ammonia Production		6.7
Other Chemicals (Hydrogen Production)		4.2
Iron & steel production		7.1
Ferroalloys		9.9
Aluminium Production		5.8
Solvent and other product use		300.0
Waste incineration		100.1
Total CO₂		2.5
Fuel combustion	CH ₄	100.0
Mobile combustion – Road transport		40.2
Mobile combustion – Navigation		100.1
Mobile combustion – Aviation		100.1
Mobile combustion – Railway		100.1
Pipeline transport		100.1
Fugitive – Oil and Natural gas		300.0
Fugitive – Coal mining and handling		300.0
Other Chemicals (Organic chemicals production)		7.1
Iron and Steel Production		6.4
Enteric fermentation		30.4
Manure management		50.2
Rice cultivation		40.0
Field burning of agricultural residues		28.3
MSW (Managed solid waste disposal on land)		44.7
MSW (Unmanaged solid waste disposal on land)		74.7
Industrial waste (Managed Waste Disposal on Land)		44.7
Industrial waste (Unmanaged Waste Disposal on Land)		74.7

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

Source categories	Gas	Uncertainty (%)
Construction and Demolition Waste (Managed Waste Disposal on Land)	CH₄	44.7
Construction and Demolition Waste (Unmanaged Waste Disposal on Land)		74.7
Municipal Sludge Disposal on Land		44.7
Wastewater handling		104.4
Waste incineration		100.1
Total CH₄		42.2
Fuel combustion	N₂O	300.0
Mobile combustion – Road transport		50.2
Mobile combustion – Navigation		300.0
Mobile combustion – Aviation		300.0
Mobile combustion – Railway		300.0
Pipeline transport		300.0
Oil and Natural gas		300.0
Nitric acid production		20.1
Solvent and other product use		300.0
Manure management		111.8
Agricultural soils – Animal production		111.8
Agricultural soil – Direct emissions		400.5
Agricultural soil – Indirect emissions		53.9
Field burning of agricultural residues		28.3
Wastewater handling		11.2
Waste incineration		100.1
Total N₂O		94.1
HFC-23 emissions from production of HCFC-22	F-gases	70.7
HFC from Refrigeration and Air Conditioning Equipment		180.3
HFC from Foam Blowing		64.0
HFC from Fire Extinguishers		60.8
HFC from Aerosols/MDIs		15.8
PFC from Aluminium production		6.7
SF ₆ from electrical equipment		53.9
Total F-gases		167.6
Total uncertainty (%)		8.03

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 9.65% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 10.03%. 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 1.10**. The uncertainty estimates for GHG emissions per gas, with LULUCF, in 2012, were estimated at (the detailed calculations are presented in Annex IV):

- ✎ 2.8% for CO₂ emissions,
- ✎ 46.0% for CH₄ emissions,
- ✎ 96.5% for N₂O emissions and
- ✎ 170.1% for the F-gases emissions.

Total uncertainty is 9.94%, while the uncertainty that carried over into the GHG emissions trend is 10.24%.

Table 1.9 *Uncertainty analysis for the LULUCF sector*

Source / Sink categories	Gas	Uncertainty (%)
Forest Land remaining Forest Land	CO ₂	34
Conversion to Forest Land	CO ₂	113
Cropland remaining Cropland	CO ₂	54
Conversion to Cropland	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
Forest Land remaining Forest Land	CH ₄	71
Grassland remaining Grassland	CH ₄	71
Forest Land remaining Forest Land	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’, 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	112.8
Deforestation	CO ₂	51.0
Forest Management	CO ₂	34.0
Forest Management	CH ₄	70.9
Forest Management	N ₂ O	70.9

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 1990-2012 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.
- ✎ NO_x emissions from *glass production* are not estimated due to lack of emission factors in the IPCC guidelines.
- ✎ *Potential emissions* of F-gases have not been estimated, due to the lack of data. The initial plan of Greece was to collect data concerning imports and exports of F-gases (in bulk) by the Hellenic Statistic authority. Nevertheless since these compounds were not reported per f-gas type but aggregately to the ElStat, the estimation of potential emissions was not possible. Moreover in line to the implementation of the improvement plan of 2012 the inventory team has been into close collaboration with National Association of Refrigeration Importing & Trading Companies and a form sent annually to all their members asking for the quantities of F-gases imported, exported and sold per blend and year. Since the respond of the companies for 2011 and 2012 was 50%, the inventory team couldn't use these data for the estimation of potential emissions. For the implementation of EC Regulation No 842/2006 a Common Ministerial Decision 18694 has been published in Greece on the 11th of April 2012. The above mention regulation defined among others the data collection procedures regarding the enterprises that produce, import, export, recover, recycle and trade F-gases on annual basis until every 31th of March of each year. The inventory team was planning to use the information that shall be gathered in the framework of the Common Ministerial Decision 18694. The inventory team was planning to use the information that will be collected in the framework of the Common Ministerial Decision 18694. With reference to this regulation the importers and exporters of f-gases communicate to the Commission and to the Competent Greek Authority (namely the Ministry of Environment, Energy and Climate Change) the above mentioned information. Considering the scheduled dates for gathering the data, this improvement was planned for the 2014 submission. The Inventory Team is in communication with the respective Directory and has already viewed some of the reports; however, the filing of the reports is in a rather non-consistent manner (hardcopies, missing information etc.). Additionally, the data are not complete since not all the companies responded. Thus, no safe conclusions can be drawn and the respective information has not proven useful so far. The inventory team is trying to resolve this issue by communicating with each of the company

separately trying to encourage all the members to respond and complete the required data. In addition, an excel sheet has been resending to them. It should be mention that any available data will be examined by the inventory team if they are adequate according to the IPCC GPG, and how this information could be introduced in the next submissions.

Annex VI provides in detail the sources of GHGs that are not estimated in the Greek GHG inventory, and the reasons for those sources being omitted.

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 - 2012 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 107.2 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 2012, GHG emissions (without *LULUCF*) amounted to 110.98 Mt CO₂ eq showing an increase of 3.56% compared to base year emissions and of 5.77% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the increase would be 5.26 % (from 102.64 Mt CO₂ eq in 1990 to 108.04 Mt CO₂ eq in 2012).

Carbon dioxide emissions accounted for 81.52% of total GHG emissions in 2012 (without *LULUCF*) and increased by approximately 9.01% from 1990. Methane emissions accounted for 8.74% of total GHG emissions in 2012 and decreased by 8.53% from 1990, while nitrous oxide emissions accounted for 6.14% of the total GHG emissions in 2012 and decreased by 33.39% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 3.50% of total GHG emissions in 2012, and 41.68% of the IP sector, have an average increase of 27.29% from 1995 (base year for F-gases).

Table 2.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2001*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
A. GHG emissions per gas (excluding LULUCF)												
CO ₂	82,997.81	82,768.06	84,436.71	83,742.31	85,997.16	86,441.72	88,526.50	93,307.62	98,205.51	97,494.15	102,571.65	104,975.73
CH ₄	10,602.58	10,554.97	10,668.53	10,647.31	10,832.73	10,857.24	11,079.38	10,982.31	11,204.32	11,109.18	11,013.79	10,147.02
N ₂ O	10,224.65	9,927.81	9,785.27	8,953.11	8,776.71	9,070.73	9,291.99	9,086.57	9,050.33	8,964.20	8,640.41	8,463.25
HFC	935.06	1,106.82	908.39	1,606.74	2,144.05	3,290.41	3,817.88	4,097.77	4,579.60	5,365.79	4,243.67	3,849.15
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09	71.16
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06
Total	104,926.55	104,525.00	105,963.36	105,049.80	107,814.49	109,717.66	112,765.57	117,585.67	123,176.58	123,027.51	126,578.61	127,510.38
B. GHG emissions/removals from LULUCF												
CO ₂	-2,313.45	-2,411.42	-2,704.81	-3,019.23	-2,732.12	-3,020.61	-2,622.44	-2,459.70	-2,777.18	-2,992.71	-2,635.59	-2,540.57
CH ₄	27.15	16.86	50.41	40.28	39.45	19.78	15.56	28.52	68.27	6.09	95.97	15.45
N ₂ O	2.76	1.71	5.12	4.10	4.01	2.02	1.59	2.91	6.94	0.63	9.76	1.59
Total	-2,283.54	-2,392.85	-2,649.28	-2,974.86	-2,688.66	-2,998.81	-2,605.28	-2,428.27	-2,701.97	-2,985.98	-2,529.86	-2,523.54
C. GHG Emissions from International Transport												
CO ₂	10,520.55	9,516.76	10,704.75	12,262.74	13,300.82	13,908.07	12,444.84	12,389.76	13,656.18	12,734.85	13,922.58	13,425.06
CH ₄	14.27	12.99	14.75	17.30	18.24	19.30	17.20	17.28	19.48	17.32	20.14	19.86
N ₂ O	270.63	263.44	324.18	358.67	397.46	460.96	381.18	378.80	384.52	359.12	383.66	330.04
Total	10,805.46	9,793.18	11,043.68	12,638.70	13,716.51	14,388.33	12,843.22	12,785.83	14,060.18	13,111.28	14,326.37	13,774.96

Table 2.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2002-2012*

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
A. GHG emissions per gas (excluding LULUCF)											
CO ₂	104,714.34	108,788.75	109,112.69	112,894.37	111,383.53	113,848.65	110,005.38	103,712.60	96,758.27	94,250.73	90,472.39
CH ₄	10,148.10	10,155.50	10,175.98	10,201.96	10,245.29	10,088.41	10,056.10	9,788.54	9,891.57	9,775.31	9,698.20
N ₂ O	8,407.14	8,330.61	8,349.32	8,066.77	7,854.21	8,039.57	7,645.28	7,190.60	7,512.85	7,208.40	6,810.34
HFC	4,098.81	3,901.17	3,990.80	4,066.71	2,231.52	2,569.37	2,950.25	3,338.70	3,603.28	3,410.13	3,889.05
PFC	73.57	76.90	73.42	74.32	70.77	80.64	93.53	74.28	105.55	78.34	110.39
SF ₆	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14	5.15	5.11
Total	127,446.22	131,257.18	131,706.68	135,310.59	131,793.69	134,636.55	130,758.06	124,109.98	117,877.65	114,728.07	110,985.47
B. GHG emissions/removals from LULUCF											
CO ₂	-2,874.04	-2,497.87	-2,768.66	-2,701.39	-2,710.59	-1,816.51	-2,979.18	-2,821.57	-2,911.09	-2,965.97	-2,972.55
CH ₄	2.50	3.41	8.56	4.93	9.71	168.26	20.42	21.12	6.14	12.27	25.58
N ₂ O	0.27	0.37	0.89	0.52	1.01	17.10	2.10	2.17	0.65	1.28	2.63
Total	-2,871.27	-2,494.09	-2,759.21	-2,695.94	-2,699.86	-1,631.15	-2,956.65	-2,798.28	-2,904.29	-2,952.42	-2,944.33
C. GHG Emissions from International Transport											
CO ₂	12,279.69	13,220.31	13,399.90	11,532.90	12,736.06	13,006.30	12,897.04	10,982.34	10,822.38	11,165.41	9,793.18
CH ₄	17.85	18.45	18.71	16.71	18.08	18.58	18.20	15.41	15.98	16.39	13.44
N ₂ O	298.33	288.58	281.20	233.62	249.10	239.54	229.63	206.06	213.10	202.62	177.15
Total	12,595.88	13,527.33	13,699.81	11,783.22	13,003.23	13,264.43	13,144.87	11,203.81	11,051.45	11,384.42	9,983.78

2.2 Description and interpretation of emission trends by category

GHG emissions trends by sector for the period 1990 - 2012 are presented in **Table 2.2**.

- ↳ Emissions from *Energy* in 2012 (**Figure 2.1**) accounted for 78.61% of total GHG emissions (without LULUCF) and increased by approximately 13.73% 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 - 2012, 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 in all sectors of energy of the years 2008-2012 is attributed among others (i.e. RES, energy efficiency measures, road infrastructure and public transportation improvements, etc) to the economic recession that the country is facing.

The majority of GHG emissions (64.12%) in 2012 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 18.63%, 6.47% and 10.78%, respectively. The rest 0.01% 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 for the years 1990-2008 is transport, showing an average rate of increase of 2.48%. However, for years 2009-2012 a decrease was observed with an average rate of decrease equal to -6.81%. In addition, energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) presented 1.16% and 0.94% average annual rate of increase, respectively. Finally, emissions from manufacturing industries and construction emissions had a mean annual rate of decrease of 1.87%.

- ↳ Emissions from *Industrial Processes* in 2012 accounted for 8.66% of the total emissions (excluding LULUCF) and decreased by 9.42 % compared to 1990 levels. In 2012 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 (20.07%), which followed the intense decrease of 2011 (-36.74% between 2011 and 2010). Emissions from chemical industry have decreased by 23.67% since 2011. Emissions from metal production slightly increased with

regards to 2011 by 1.05%, due to the increased production of aluminium and nickel. As regards to f-gases emissions, have been increased compared to 2011 (14.48%). The general increasing trend during the last years of the time-series depicts the continuous substitution of CFCs in the context of the protocol of Montreal.

- ⇒ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.29% of the total emissions) and has increased by 3.29% compared to 1990 level of emissions.
- ⇒ Emissions from *Agriculture* that accounted for 8.18% of total emissions in 2012 (without *LULUCF*), decreased by approximately 20.44% 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* (4.27% of the total emissions, without *LULUCF*), decreased by approximately 19.58% 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 – 2012. During this period, the *LULUCF* sector offset on average 2.24% (1.21-2.83%) of the total national emissions (without *LULUCF*). The sink capacity of the *LULUCF* sector fluctuates between 1.63 Mt CO₂ eq. and 3.0 Mt CO₂ eq.. 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.

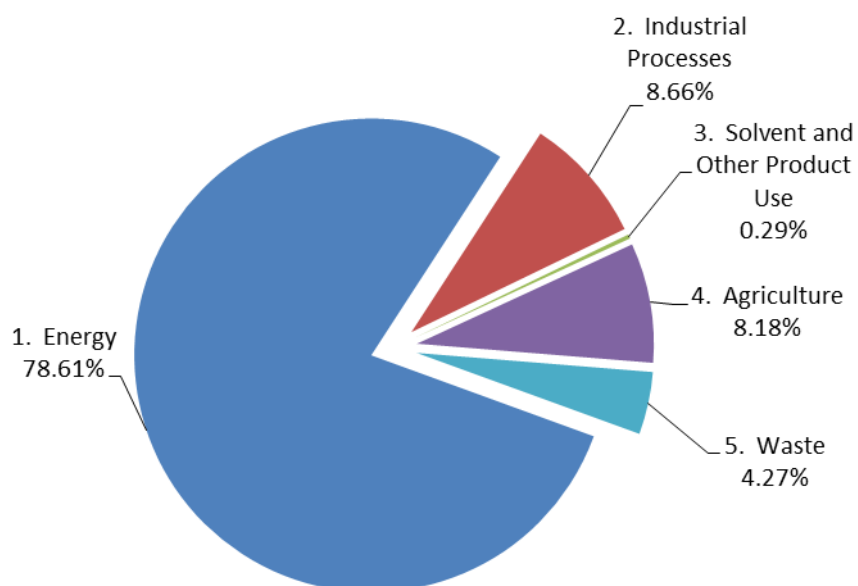


Figure 2.1 *Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2012*

Table 2.2a *Total GHG emissions (in kt CO₂ eq) by sector for the period 1990-2001*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Energy	76,717.09	76,621.20	78,712.84	78,320.91	80,632.58	80,570.02	82,757.47	87,390.13	92,205.06	91,597.16	96,409.10	98,886.61
Industrial processes	10,605.49	10,485.38	9,973.47	10,253.66	10,739.40	12,396.38	13,043.32	13,440.67	14,025.84	14,716.77	13,849.43	13,319.55
Solvents	308.34	315.54	314.37	312.95	307.39	299.82	298.22	300.20	300.40	308.73	306.61	304.28
Agriculture	11,407.60	11,255.04	11,032.04	10,214.24	10,040.20	10,369.59	10,502.01	10,369.38	10,401.76	10,251.62	10,019.45	9,928.16
Waste	5,888.03	5,847.85	5,930.64	5,948.04	6,094.91	6,081.84	6,164.55	6,085.29	6,243.52	6,153.23	5,994.02	5,071.78
Total ¹⁾	104,926.55	104,525.00	105,963.36	105,049.80	107,814.49	109,717.66	112,765.57	117,585.67	123,176.58	123,027.51	126,578.61	127,510.38
LULUCF	-2,283.54	-2,392.85	-2,649.28	-2,974.86	-2,688.66	-2,998.81	-2,605.28	-2,428.27	-2,701.97	-2,985.98	-2,529.86	-2,523.54
Index per sector												
Energy	100.00	99.88	102.60	102.09	105.10	105.02	107.87	113.91	120.19	119.40	125.67	128.90
Industrial processes	100.00	98.87	94.04	96.68	101.26	116.89	122.99	126.73	132.25	138.77	130.59	125.59
Solvents	100.00	102.33	101.95	101.49	99.69	97.24	96.72	97.36	97.42	100.13	99.44	98.68
Agriculture	100.00	98.66	96.71	89.54	88.01	90.90	92.06	90.90	91.18	89.87	87.83	87.03
Waste	100.00	99.32	100.72	101.02	103.51	103.29	104.70	103.35	106.04	104.50	101.80	86.14
Total ²⁾	100.00	99.62	100.99	100.12	102.75	104.57	107.47	112.06	117.39	117.25	120.64	121.52

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 2002-2012*

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Energy	98,802.18	102,696.31	103,010.14	106,172.26	104,893.51	107,452.37	104,198.86	99,717.69	92,488.93	91,668.30	87,249.15
Industrial processes	13,452.19	13,379.60	13,459.15	14,126.12	11,899.96	12,148.40	11,885.40	10,248.68	10,591.29	8,720.81	9,606.76
Solvents	305.13	305.93	306.75	309.29	311.92	313.41	314.13	315.60	316.17	316.41	318.47
Agriculture	9,915.79	9,846.54	9,935.71	9,656.06	9,485.74	9,704.91	9,350.46	9,069.75	9,433.40	9,137.12	9,075.85
Waste	4,970.93	5,028.79	4,994.94	5,046.87	5,202.56	5,017.47	5,009.21	4,758.26	5,047.86	4,885.43	4,735.23
Total ¹⁾	127,446.22	131,257.18	131,706.68	135,310.59	131,793.69	134,636.55	130,758.06	124,109.98	117,877.65	114,728.07	110,985.47
LULUCF	-2,871.27	-2,494.09	-2,759.21	-2,695.94	-2,699.86	-1,631.15	-2,956.65	-2,798.28	-2,904.29	-2,952.42	-2,944.33
Index per sector											
Energy	128.79	133.86	134.27	138.39	136.73	140.06	135.82	129.98	120.56	119.49	113.73
Industrial processes	126.84	126.16	126.91	133.20	112.21	114.55	112.07	96.64	99.87	82.23	90.58
Solvents	98.96	99.22	99.48	100.31	101.16	101.64	101.88	102.36	102.54	102.62	103.29
Agriculture	86.92	86.32	87.10	84.65	83.15	85.07	81.97	79.51	82.69	80.10	79.56
Waste	84.42	85.41	84.83	85.71	88.36	85.21	85.07	80.81	85.73	82.97	80.42
Total ²⁾	121.46	125.09	125.52	128.96	125.61	128.32	124.62	118.28	112.34	109.34	105.77

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 2012 by source category is presented in **Table 2.3**. Total CO₂ emissions increased from 82.99 Mt in 1990 to 90.47 Mt in 2012 (without LULUCF). The increase of 9.01% from 1990 to 2012 is mainly attributed to the increased electricity production as well as to the increased energy consumption in the residential sector. The decrease in 2012 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 74.43 Mt in 1990 to 85.01 Mt in 2012, presenting a total increase of 14.21% from 1990 to 2012. Carbon dioxide emissions from *Industrial processes* in 2012 decreased by 36.92% compared to 1990 levels and from *Solvents and other products use* decreased by 4.12% compared to 1990 levels. Finally, emissions from *Waste* in 2009 show a continuous increase from 1990. (**Figure 2.2**).

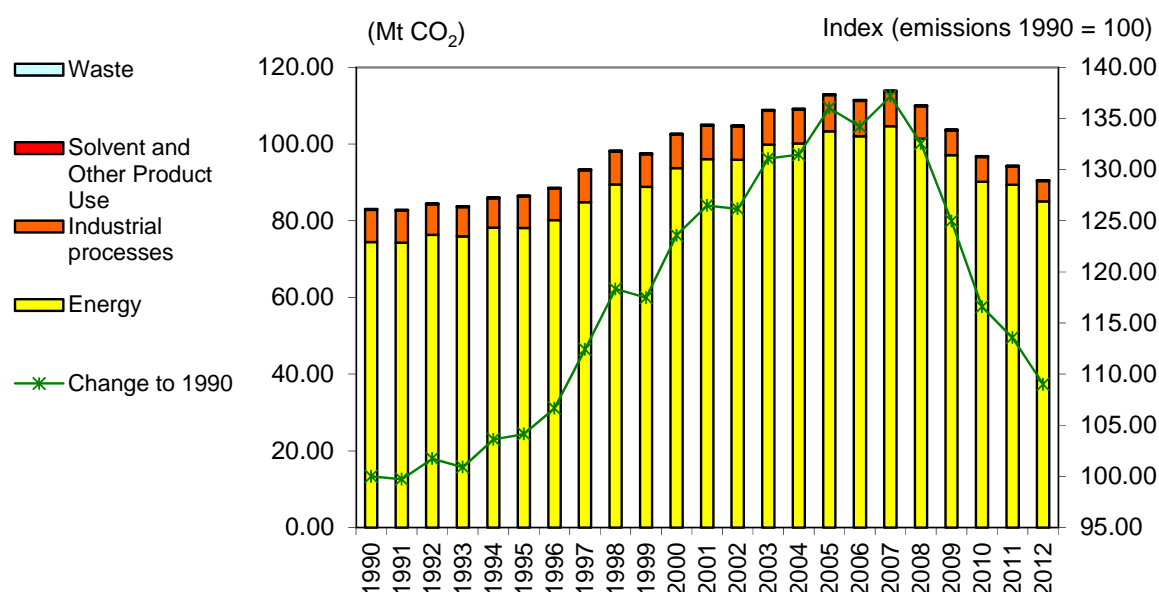


Figure 2.2 CO₂ emissions by sector (in Mt) for the years 1990 – 2012 (without LULUCF)

Table 2.3a *CO₂ emissions / removals by sector for the period 1990-2001 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total (with LULUCF)	80,684.36	80,356.64	81,731.90	80,723.08	83,265.04	83,421.11	85,904.06	90,847.92	95,428.33	94,501.44	99,936.06	102,435.16
Total (without LULUCF)	82,997.81	82,768.06	84,436.71	83,742.31	85,997.16	86,441.72	88,526.50	93,307.62	98,205.51	97,494.15	102,571.65	104,975.73
1. Energy	74,433.65	74,295.99	76,319.96	75,934.17	78,185.79	78,117.73	80,202.52	84,804.75	89,469.36	88,830.67	93,688.97	96,074.01
A. Fuel combustion	74,363.43	74,225.10	76,261.75	75,886.85	78,140.57	78,079.01	80,158.92	84,765.61	89,442.18	88,829.23	93,664.81	96,056.96
1. Energy industries	42,992.74	41,850.29	44,131.81	44,030.08	46,006.63	44,769.81	43,948.69	47,385.19	49,904.80	50,199.06	54,629.23	55,149.40
2. Man. Industry and Construction	9,162.50	9,084.27	8,828.86	8,527.17	8,452.07	9,215.80	9,769.38	9,974.00	10,030.91	8,979.19	9,721.62	9,894.81
3. Transport	14,082.28	14,869.39	15,241.58	15,410.89	15,703.71	16,041.92	16,487.86	17,188.45	18,941.24	19,259.70	18,317.10	19,168.63
4. Other sectors	8,125.91	8,421.16	8,059.51	7,918.71	7,978.16	8,051.48	9,952.98	10,217.96	10,565.23	10,391.28	10,996.86	11,844.13
B. Fugitive emissions	70.23	70.90	58.20	47.33	45.22	38.73	43.60	39.15	27.18	1.44	24.15	17.04
2. Industrial processes	8,394.22	8,296.07	7,943.70	7,637.79	7,647.93	8,169.12	8,171.60	8,349.57	8,583.54	8,503.30	8,725.13	8,746.83
A. Mineral products	6,801.86	6,721.93	6,798.81	6,751.24	6,721.12	7,206.15	7,195.06	7,275.70	7,316.11	7,295.65	7,502.89	7,560.19
B. Chemical production	652.04	620.50	218.32	140.72	NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	83.17	350.99	344.81	275.90	135.77
C. Metal production	940.32	953.64	926.57	745.84	926.82	962.97	976.54	990.70	916.44	862.83	946.34	1,050.87
3. Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33	154.67
5. LULUCF	-2,313.45	-2,411.42	-2,704.81	-3,019.23	-2,732.12	-3,020.61	-2,622.44	-2,459.70	-2,777.18	-2,992.71	-2,635.59	-2,540.57
6. 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
International transport ¹⁾	10,520.55	9,516.76	10,704.75	12,262.74	13,300.82	13,908.07	12,444.84	12,389.76	13,656.18	12,734.85	13,922.58	13,425.06
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
Marine	8,081.56	7,413.61	8,510.55	9,927.28	10,529.05	11,308.94	9,955.58	9,982.08	11,129.21	9,897.12	11,433.23	11,111.58

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

Table 2.3b *CO₂ emissions / removals by sector for the period 2002-2012 (in kt)*

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total (with LULUCF)	101,840.31	106,290.88	106,344.03	110,192.98	108,672.94	112,032.14	107,026.20	100,891.03	93,847.18	91,284.77	87,499.84
Total (without LULUCF)	104,714.34	108,788.75	109,112.69	112,894.37	111,383.53	113,848.65	110,005.38	103,712.60	96,758.27	94,250.73	90,472.39
1. Energy	95,907.49	99,811.38	100,113.26	103,302.39	102,075.38	104,636.76	101,429.74	97,085.03	90,145.93	89,334.68	85,011.50
A. Fuel combustion	95,889.64	99,799.75	100,101.79	103,292.93	102,066.27	104,629.80	101,424.41	97,077.51	90,135.33	89,325.51	85,002.75
1. Energy industries	54,572.12	55,809.09	57,129.73	57,939.93	55,765.64	59,232.38	58,019.05	54,480.47	52,036.60	53,838.38	54,507.26
2. Man. industry and Construction	9,444.31	9,133.51	8,491.51	10,170.76	10,383.78	10,102.46	9,346.07	7,411.93	6,717.41	5,271.14	5,496.40
3. Transport	19,487.05	20,572.51	20,992.99	21,052.36	21,890.75	22,637.22	21,675.77	24,571.95	21,862.23	19,474.10	15,838.48
4. Other sectors	12,386.16	14,284.64	13,487.56	14,129.89	14,026.09	12,657.74	12,383.52	10,613.15	9,519.10	10,741.89	9,160.61
B. Fugitive emissions	17.85	11.62	11.47	9.46	9.11	6.96	5.33	7.52	10.60	9.17	8.75
2. Industrial processes	8,651.25	8,821.03	8,842.51	9,432.35	9,146.10	9,048.41	8,411.27	6,462.60	6,447.55	4,751.31	5,294.94
A. Mineral products	7,323.46	7,361.38	7,369.43	7,932.34	7,640.65	7,475.99	6,962.97	5,324.52	4,925.08	3,115.64	3,740.92
B. Chemical production	165.68	286.61	304.52	296.92	313.93	317.94	338.06	453.25	662.97	584.38	502.02
C. Metal production	1,162.10	1,173.04	1,168.56	1,203.09	1,191.52	1,254.48	1,110.24	684.83	859.50	1,051.28	1,051.99
3. Solvents	155.12	155.50	155.87	157.70	159.64	160.34	160.68	161.38	161.64	161.75	162.72
5. LULUCF	-2,874.04	-2,497.87	-2,768.66	-2,701.39	-2,710.59	-1,816.51	-2,979.18	-2,821.57	-2,911.09	-2,965.97	-2,972.55
6. Waste	0.48	0.85	1.05	1.93	2.41	3.13	3.68	3.60	3.14	2.99	3.23
International transport ¹⁾	12,279.69	13,220.31	13,399.90	11,532.90	12,736.06	13,006.30	12,897.04	10,982.34	10,822.38	11,165.41	9,793.18
Aviation	2,313.55	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
Marine	9,966.15	10,208.93	10,304.32	9,156.02	9,885.10	10,092.53	9,867.12	8,376.25	8,737.45	8,897.11	7,279.15

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

2.3.2 Methane

The trend of methane emissions from 1990 to 2012 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 and LULUCF Sectors, while in 2012 emissions are slightly lower than 2011.

Waste represents the largest anthropogenic source of methane emissions in Greece accounting for 44.65% of total methane emissions in 2012 (without *LULUCF*). Methane emissions from Waste decreased by 22.07% since 1990 and are mainly attributed to Solid Waste Disposal on Land and Wastewater Handling.

Methane emissions from *Agriculture* in 2012 increased by 0.61% compared to 1990 levels. Methane emissions from *Agriculture*, with enteric fermentation being the main source category in the sector, in 2012 accounted for 37.86% 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 17.49% of the total methane emissions. Finally, the contribution of CH₄ emissions from *Iron and Steel Production* can be considered negligible (0.003%).

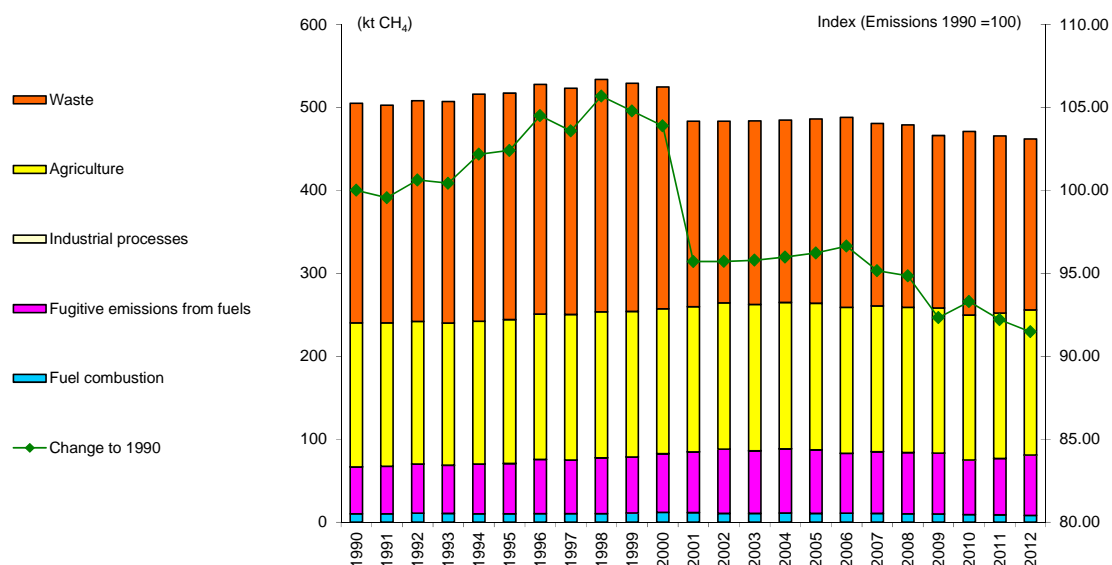


Figure 2.3 *CH₄ emissions by sector (in kt) for the period 1990 – 2012 (without LULUCF)*

Table 2.4a *CH₄ emissions by source category for the period 1990–2001 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total (with LULUCF)	506.18	503.42	510.43	508.93	517.72	517.95	528.33	524.33	536.79	529.30	529.04	483.93
Total (without LULUCF)	504.88	502.62	508.03	507.01	515.84	517.01	527.59	522.97	533.54	529.01	524.47	483.19
1. Energy	66.49	67.24	69.90	68.57	69.85	70.68	75.48	74.73	77.58	78.45	82.47	84.71
A. Fuel combustion	9.97	10.06	10.84	10.47	10.08	10.09	10.25	10.15	10.26	10.97	11.72	11.44
1. Energy industries	0.60	0.61	0.62	0.63	0.64	0.65	0.65	0.67	0.70	0.71	0.79	0.78
2. Manufacturing industry and Construction	0.43	0.43	0.43	0.42	0.40	0.42	0.44	0.45	0.44	0.42	0.48	0.47
3. Transport	4.94	5.01	4.97	5.04	5.06	5.12	5.15	5.25	5.44	5.61	5.67	5.82
4. Other sectors	4.00	4.01	4.81	4.39	3.98	3.90	4.01	3.78	3.68	4.23	4.79	4.37
B. Fugitive emissions from fuels	56.52	57.18	59.07	58.10	59.77	60.59	65.23	64.58	67.33	67.48	70.75	73.27
1. Solid fuels	52.16	52.96	55.33	55.09	56.96	57.95	60.08	59.14	61.19	62.36	64.21	66.68
2. Oil and natural gas	4.36	4.23	3.74	3.01	2.82	2.64	5.15	5.44	6.14	5.12	6.54	6.60
2. Industrial processes	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.01
4. Agriculture	173.77	172.88	171.91	171.47	172.35	173.47	175.38	175.58	175.95	175.48	174.71	174.82
A. Enteric fermentation	149.03	148.04	147.31	145.82	145.88	146.66	148.05	148.12	149.12	149.27	149.27	149.20
B. Manure management	20.16	20.09	20.19	20.20	20.20	20.15	20.20	20.21	20.24	20.22	20.07	19.98
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
F. Field burning of agricultural residues	1.29	1.81	1.47	1.41	1.53	1.44	1.41	1.43	1.34	1.32	1.39	1.42
5. LULUCF	1.29	0.80	2.40	1.92	1.88	0.94	0.74	1.36	3.25	0.29	4.57	0.74
6. Waste	264.59	262.46	266.18	266.94	273.60	272.82	276.69	272.62	279.97	275.06	267.27	223.64
A. Solid waste disposal on land	105.99	109.28	112.81	116.53	120.48	124.73	129.16	133.86	138.73	143.74	149.59	133.70
B. Wastewater handling	158.61	153.18	153.37	150.41	153.12	148.10	147.53	138.63	141.11	131.19	117.55	89.94
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⁾	0.68	0.62	0.70	0.82	0.87	0.92	0.82	0.82	0.93	0.82	0.96	0.95
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
Marine	0.67	0.61	0.69	0.81	0.86	0.91	0.81	0.81	0.92	0.81	0.95	0.93

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

Table 2.4b *CH₄ emissions by source category for the period 2002-2012 (in kt)*

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total (with LULUCF)	483.36	483.76	484.98	486.04	488.33	488.41	479.83	467.13	471.32	466.08	463.04
Total (without LULUCF)	483.24	483.60	484.57	485.81	487.87	480.40	478.86	466.12	471.03	465.49	461.82
1. Energy	87.87	86.00	88.37	87.05	82.95	84.85	84.01	83.21	74.79	76.86	80.76
A. Fuel combustion	10.48	10.50	10.98	10.41	10.70	10.43	10.03	9.64	9.03	8.88	8.02
1. Energy industries	0.78	0.80	0.80	0.83	0.84	0.90	0.89	0.79	0.73	0.74	0.74
2. Manufacturing industry and Construction	0.48	0.41	0.42	0.49	0.46	0.45	0.49	0.42	0.42	0.42	0.32
3. Transport	5.78	5.75	5.80	5.62	5.52	5.29	4.99	4.78	4.33	3.74	2.87
4. Other sectors	3.45	3.52	3.97	3.46	3.87	3.79	3.66	3.65	3.56	3.98	4.09
B. Fugitive emissions from fuels	77.39	75.51	77.38	76.64	72.26	74.42	73.98	73.57	65.76	67.97	72.74
1. Solid fuels	70.82	68.64	70.39	69.74	64.84	66.80	66.05	65.22	56.80	58.96	63.27
2. Oil and natural gas	6.57	6.87	6.99	6.90	7.42	7.62	7.93	8.35	8.96	9.02	9.47
2. Industrial processes	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.01
4. Agriculture	176.33	176.26	176.37	176.66	176.02	175.74	174.86	174.80	174.82	175.12	174.84
A. Enteric fermentation	150.61	150.64	150.51	150.70	150.40	149.90	148.94	148.55	148.65	148.96	148.71
B. Manure management	19.85	19.84	19.89	19.91	19.84	19.55	19.37	19.17	19.11	19.06	19.00
C. Rice cultivation	4.48	4.52	4.55	4.62	4.46	5.00	5.00	5.60	5.60	5.60	5.60
F. Field burning of agricultural residues	1.38	1.27	1.42	1.43	1.32	1.28	1.54	1.48	1.45	1.50	1.53
5. LULUCF	0.12	0.16	0.41	0.23	0.46	8.01	0.97	1.01	0.29	0.58	1.22
6. Waste	219.03	221.31	219.81	222.07	228.87	219.79	219.97	208.09	221.40	213.49	206.20
A. Solid waste disposal on land	139.51	148.59	151.59	160.75	167.19	164.98	169.43	159.43	168.01	159.95	152.58
B. Wastewater handling	79.52	72.72	68.22	61.26	61.36	54.46	50.17	48.56	52.86	52.88	52.82
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
International Transport ¹⁾	0.85	0.88	0.89	0.80	0.86	0.88	0.87	0.73	0.76	0.78	0.64
Aviation	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Marine	0.84	0.87	0.88	0.78	0.85	0.87	0.85	0.72	0.75	0.77	0.63

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 2012 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 (79.35% approximately of the total nitrous oxide emissions in 2012, without *LULUCF*). Emissions from this sector decreased by 30.34% 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 7.95% of total nitrous oxide emissions in 2012) decreased by 38.94% from 1990. Emissions from the *Energy* sector tend to decrease mainly due to the penetration of natural gas in electricity production.

Production of nitric acid is the major source of N_2O emissions from *Industrial processes* and accounts for 4.51% of total N_2O emissions in 2012. Nitrous oxide emissions from this source decreased by 72.31% from 1990, due to the reduction of nitric acid production in Greece. However, it should be mentioned that the high decrease between 2008 and 2009, which was attributed to the economic recession, is counterbalanced by 12.59% increase of emissions between 2009-2011, compared to 2008, followed by a -35.43% decrease between 2011-2012.

N_2O emissions from *Waste* in 2012 (5.90% of total emissions without *LULUCF*) increased by 21.24% compared to 1990 levels.

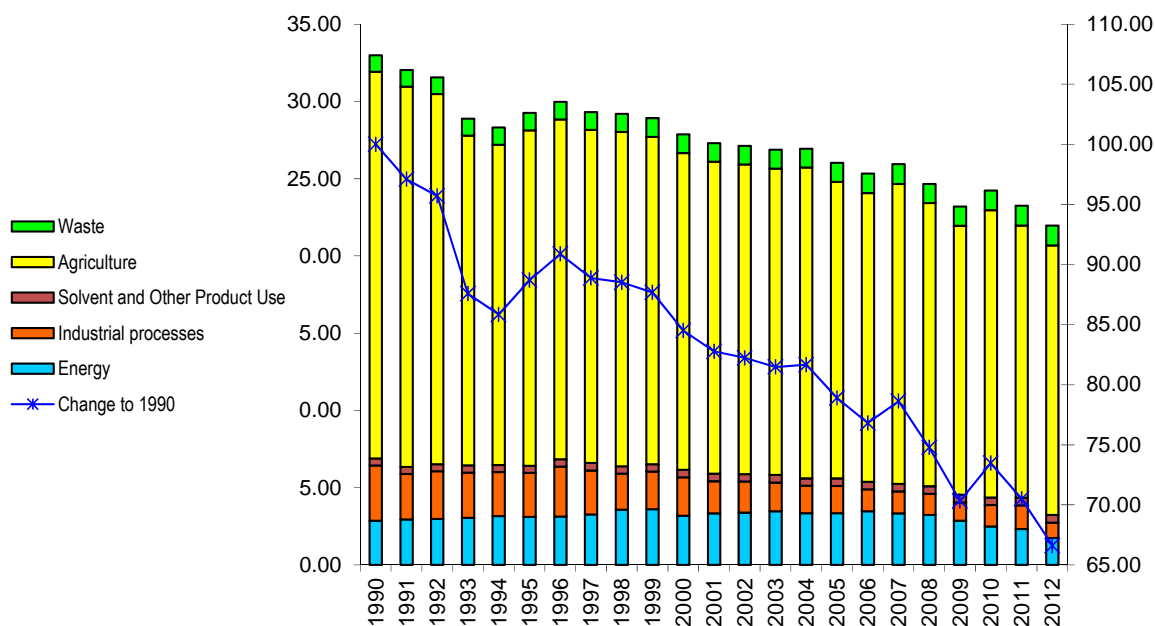


Figure 2.4 N_2O emissions by sector (in kt) for the period 1990 – 2012 (without LULUCF)

Table 2.5a *N₂O emissions by source category for the period 1990-2001 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total (with LULUCF)	32.99	32.03	31.58	28.89	28.32	29.27	29.98	29.32	29.22	28.92	27.90	27.31
Total (without LULUCF)	32.98	32.03	31.57	28.88	28.31	29.26	29.97	29.31	29.19	28.92	27.87	27.30
1. Energy	2.86	2.95	2.98	3.05	3.16	3.12	3.13	3.28	3.57	3.61	3.19	3.33
A. Fuel combustion	2.86	2.94	2.98	3.05	3.16	3.12	3.13	3.28	3.57	3.61	3.19	3.33
1. Energy industries	0.50	0.48	0.51	0.51	0.53	0.51	0.50	0.54	0.57	0.56	0.60	0.61
2. Man. industry and Construction	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.18	0.16	0.17	0.17
3. Transport	0.99	1.04	1.12	1.22	1.31	1.35	1.33	1.44	1.70	1.75	1.26	1.39
4. Other sectors	1.23	1.27	1.21	1.17	1.17	1.10	1.13	1.12	1.12	1.13	1.15	1.16
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
2. Industrial processes	3.58	2.95	3.08	2.93	2.85	2.83	3.24	2.84	2.34	2.43	2.49	2.09
3. Solvent and Other Product Use	0.45	0.45	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48
4. Agriculture	25.03	24.60	23.94	21.33	20.71	21.70	22.00	21.56	21.63	21.18	20.49	20.18
B. Manure management	1.74	1.73	1.73	1.73	1.72	1.74	1.76	1.77	1.81	1.82	1.81	1.80
D. Agricultural soils	23.25	22.82	22.17	19.57	18.95	19.92	20.20	19.75	19.79	19.33	18.64	18.34
F. Field burning of agr. residues	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04
5. LULUCF	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.03	0.01
6. Waste	1.07	1.08	1.10	1.10	1.13	1.14	1.14	1.16	1.17	1.22	1.23	1.21
International transport ¹⁾	0.87	0.85	1.05	1.16	1.28	1.49	1.23	1.22	1.24	1.16	1.24	1.06
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
Marine	0.80	0.78	0.98	1.08	1.19	1.40	1.15	1.15	1.16	1.07	1.16	0.99

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

Table 2.5b *N₂O emissions by source category for the period 2002-2012 (in kt)*

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total (with LULUCF)	27.12	26.87	26.94	26.02	25.34	25.99	24.67	23.20	24.24	23.26	21.98
Total (without LULUCF)	27.12	26.87	26.93	26.02	25.34	25.93	24.66	23.20	24.24	23.25	21.97
1. Energy	3.39	3.48	3.36	3.36	3.47	3.33	3.24	2.86	2.49	2.32	1.75
A. Fuel combustion	3.39	3.48	3.36	3.36	3.47	3.33	3.24	2.86	2.49	2.32	1.75
1. Energy industries	0.60	0.61	0.63	0.63	0.59	0.62	0.61	0.59	0.55	0.56	0.57
2. Man. industry and Construction	0.16	0.15	0.14	0.15	0.15	0.15	0.15	0.13	0.12	0.11	0.10
3. Transport	1.38	1.37	1.41	1.39	1.48	1.44	1.40	1.26	1.03	0.81	0.64
4. Other sectors	1.24	1.35	1.18	1.19	1.24	1.12	1.08	0.88	0.79	0.85	0.44
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
2. Industrial processes	2.01	1.86	1.77	1.76	1.43	1.42	1.36	1.19	1.38	1.53	0.99
3. Solvent and Other Product Use	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.50
4. Agriculture	20.04	19.82	20.10	19.18	18.68	19.40	18.32	17.42	18.59	17.61	17.43
B. Manure management	1.84	1.86	1.90	1.94	1.94	1.92	1.90	1.89	1.90	1.91	1.92
D. Agricultural soils	18.17	17.93	18.17	17.21	16.70	17.45	16.38	15.49	16.65	15.66	15.48
F. Field burning of agr. residues	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04
5. LULUCF	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0.01	0.00	0.00	0.01
6. Waste	1.20	1.23	1.22	1.23	1.27	1.29	1.25	1.24	1.28	1.29	1.30
International transport ¹⁾	0.96	0.93	0.91	0.75	0.80	0.77	0.74	0.66	0.69	0.65	0.57
Aviation	0.07	0.10	0.10	0.08	0.09	0.09	0.10	0.08	0.07	0.07	0.08
Marine	0.89	0.84	0.81	0.68	0.71	0.68	0.64	0.58	0.62	0.58	0.49

1) 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:

- ↳ 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 2008-2012 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.
- ↳ 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
- ↳ 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. 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 and consequently consumption also affected. During 2009-2012 emissions experience a strong decline which is attributed to the corresponding decrease of aerosols being sold.
- ↳ 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. Following the implementation of 2012 Inventory Improvement Plan, the inventory team continuous to gather data concerning the imports of foam products containing f-gases (4.14.2)
- ↳ 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.

- ✎ 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 1990-2012 (in kt CO₂ eq)*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
HFC	935.06	1,106.82	908.39	1,606.74	2,144.05	3,290.38	3,817.85	4,097.74	4,579.56	5,361.67	4,237.89	3,835.87
HFC-23	935.06	1,106.82	908.39	1,606.64	2,143.91	3,253.07	3,746.34	3,965.47	4,371.38	5,043.57	3,768.07	3,219.93
HFC-32						0.03	0.21	0.70	1.29	2.21	4.61	8.54
HFC-125						4.88	9.69	19.28	31.09	48.40	78.46	108.34
HFC-134a				0.09	0.15	24.85	47.66	86.64	135.69	206.49	296.31	393.93
HFC-152a												1.80
HFC-143a						7.58	13.98	25.68	40.14	61.03	90.47	108.81
HFC-227ea										4.09	5.75	7.79
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09	71.16
SF₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06
Total	1,101.51	1,274.16	1,072.86	1,707.07	2,207.87	3,347.96	3,867.70	4,209.17	4,716.41	5,459.98	4,352.76	3,924.38

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
HFC	4,043.00	3,843.14	3,934.42	3,976.24	2,058.33	2,421.82	2,765.04	3,196.39	3,465.17	3,291.82	3,777.24
HFC-23	3,243.30	2,730.93	2,623.66	2,234.52	87.25	125.84	136.43	155.61	176.19	118.25	150.75
HFC-32	14.12	24.80	35.68	46.24	60.27	74.62	90.69	108.26	129.88	155.57	197.83
HFC-125	154.34	242.35	302.11	395.27	485.02	582.68	692.59	824.42	979.95	1,054.21	1,318.03
HFC-134a	504.02	644.88	757.09	1,041.82	1,202.03	1,347.36	1,542.86	1,697.72	1,697.66	1,547.25	1,591.48
HFC-152a	32.68	43.79	37.43	39.96	49.50	43.91	42.92	37.36	32.91	30.33	29.80
HFC-143a	140.26	201.37	217.06	286.53	320.97	362.91	409.33	476.33	545.08	461.85	562.83
HFC-227ea	10.09	13.07	17.77	22.38	26.49	32.04	35.44	38.99	41.61	42.68	38.33
PFC	73.57	76.90	73.42	74.32	70.78	80.64	93.53	74.28	105.55	78.34	110.39
SF₆	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14	5.15	5.11
Total	4,176.63	3,982.32	4,068.70	4,147.48	2,310.67	2,659.93	3,051.31	3,418.24	3,714.97	3,493.63	4,004.55

2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO₂

The role of carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane organic volatile compounds (NMVOC) is important for climate change as these gases act as precursors of tropospheric ozone. In this way, they contribute to ozone formation and alter the atmospheric lifetimes of other greenhouse gases. For example, CO interacts with the hydroxyl radical (OH), the major atmospheric sink for methane, to form carbon dioxide. Therefore, increased atmospheric concentration of CO limits the number of OH compounds available to destroy methane, thus increasing the atmospheric lifetime of methane.

These gases are generated through a variety of anthropogenic activities. Emissions trends for indirect greenhouse gases and SO₂ are presented in **Table 2.7**, while more information on the emissions of indirect greenhouse gases and SO₂ is provided in Annex V.

- ✎ NO_x emissions decreased by 20.63% from 1990 to 2012. Energy sector accounts for the high majority of emissions (99.07%). The decrease in NO_x emissions from transport after 1998 is attributed to the substitution of old technology vehicles by new catalytic ones (NO_x emissions from this category account for the 39.02% of total NO_x emissions in 2012). Emissions from *Industrial processes* decreased by 53.81% from 1990 due to reductions in the production of nitric acid.
- ✎ The transport sector is the main source of CO emissions. Due to the substitution of old technology vehicles by new and more efficient ones, CO emissions from transport decreased by 70.16% from 1990 to 2012 and as a result total CO emissions in 2012 decreased by 59.69%. Emissions from industrial processes in 2012 increased by 11.41% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2012 emissions from *LULUCF* accounted for 2.31% of total CO emissions (incl *LULUCF*), and are by 5.77% lower than emissions of 1990.
- ✎ NMVOC emissions decreased by 43.59% from 1990 to 2012. Emissions from transport (24.34% of total NMVOC emissions in 2012), decreased by 73.44% compared to 1990 levels, while emissions from *Energy* decreased by 54.84% from 1990 to 2012. The significant decrease of NMVOC emissions from *Industrial processes* (approximately 50.20% from 1990 to 2012) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 3.49% compared to 1990 levels.
- ✎ SO₂ emissions decreased by 48.56% from 1990 to 2012. Emissions from energy, which is the main source of SO₂ emissions in Greece (98.38 % of total SO₂ emissions for 2012), decreased with a mean annual rate of decrease of 2.21% for the period 1990 – 2012. The operation of desulphurisation plants at large installations for electricity generation since 1998 resulted in the restriction of the increase 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

88.76% for the period 1990 – 2012. Emissions from *Industrial processes* decreased by 52.32% from 1990 due to decrease of sulphuric acid industrial production.

Table 2.7a Emissions trends for indirect greenhouse gases and SO₂ (in kt) for the period 1990-2001

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NO_x	326.21	335.88	342.70	340.22	348.81	329.07	333.01	346.65	369.81	367.59	360.35	382.27
1. Energy	323.24	332.84	339.71	337.27	345.90	326.49	330.38	343.95	366.74	365.17	356.87	379.88
Transport	180.55	182.71	184.05	184.93	188.20	179.04	176.25	184.33	203.80	204.90	183.33	195.32
Other energy sectors	142.69	150.14	155.66	152.33	157.70	147.45	154.13	159.61	162.94	160.27	173.54	184.56
2. Industrial processes	1.48	1.25	1.08	1.21	1.07	1.08	1.17	1.07	1.06	1.16	1.10	0.91
4. Agriculture	1.17	1.58	1.32	1.27	1.36	1.27	1.28	1.30	1.20	1.19	1.25	1.29
5. LULUCF	0.32	0.20	0.60	0.48	0.47	0.23	0.18	0.34	0.81	0.07	1.14	0.18
CO	1142.92	1124.19	1094.10	1085.38	1062.82	961.43	954.02	957.14	975.05	955.79	961.23	918.02
1. Energy	1084.66	1059.10	1022.10	1019.56	996.04	905.46	900.64	897.49	898.90	904.66	870.46	859.87
Transport	877.57	848.63	799.60	804.89	787.08	700.14	693.68	690.57	692.46	689.51	640.31	637.71
Other energy sectors	207.09	210.47	222.49	214.67	208.96	205.31	206.96	206.92	206.44	215.15	230.15	222.16
2. Industrial processes	19.89	20.14	20.14	19.50	18.12	17.47	17.24	17.79	19.58	20.97	21.57	21.80
4. Agriculture	27.06	37.93	30.86	29.54	32.23	30.26	29.65	29.97	28.13	27.62	29.21	29.91
5. LULUCF	11.31	7.02	21.00	16.78	16.44	8.24	6.49	11.88	28.45	2.54	39.99	6.44
NM_{VOC}	269.19	271.33	268.71	267.90	266.20	259.64	260.17	261.74	267.17	270.02	265.76	262.94
1. Energy	187.07	185.51	182.45	181.43	180.34	171.05	171.46	172.08	173.17	172.69	163.41	161.09
Transport	139.17	137.53	132.81	133.53	131.53	120.75	120.09	120.06	120.66	120.27	107.07	105.72
Other energy sectors	47.90	47.98	49.64	47.90	48.81	50.31	51.37	52.02	52.51	52.42	56.34	55.37
2. Industrial processes	25.48	27.54	28.81	30.32	31.56	36.94	37.65	38.24	42.64	43.58	49.14	49.51
3. Solvents	56.65	58.27	57.45	56.16	54.31	51.64	51.05	51.43	51.36	53.75	53.20	52.35
SO₂	476.05	517.01	533.96	530.67	521.92	539.96	530.07	528.89	536.41	555.15	495.94	503.93
1. Energy	467.50	508.94	526.72	523.89	514.77	532.00	522.07	520.64	528.15	546.75	488.36	496.48
Transport	38.70	38.70	41.00	38.23	42.75	32.08	30.64	37.74	52.57	56.44	21.32	28.69
Other energy sectors	428.79	470.24	485.71	485.66	472.02	499.92	491.43	482.90	475.59	490.31	467.04	467.79
2. Industrial processes	8.56	8.07	7.25	6.79	7.15	7.96	8.00	8.25	8.26	8.40	7.58	7.46

Table 2.7b Emissions trends for indirect greenhouse gases and SO₂ (in kt) for the period 2002-2012

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NO_x	383.23	393.36	398.98	416.60	412.84	416.07	392.44	379.77	319.52	296.18	258.91
1. Energy	380.82	391.03	396.53	414.23	410.56	411.90	389.79	377.38	317.23	293.69	256.50
<i>Transport</i>	189.81	189.43	194.55	187.87	193.29	188.70	179.65	191.42	148.27	129.76	101.02
<i>Other energy sectors</i>	191.01	201.60	201.98	226.36	217.27	223.20	210.14	185.97	168.96	163.93	155.48
2. Industrial processes	1.13	1.10	1.05	0.98	0.94	0.97	0.96	0.79	0.85	0.94	0.68
4. Agriculture	1.25	1.19	1.31	1.33	1.23	1.21	1.45	1.36	1.36	1.40	1.43
5. LULUCF	0.03	0.04	0.10	0.06	0.11	1.99	0.24	0.25	0.07	0.15	0.30
CO	856.30	811.87	810.65	721.59	740.08	750.76	630.00	599.79	527.67	497.00	460.74
1. Energy	803.39	760.70	753.76	665.52	684.31	629.27	565.02	540.77	474.96	437.05	395.84
<i>Transport</i>	598.59	577.62	565.29	499.73	517.59	453.72	404.18	383.77	324.99	293.81	261.85
<i>Other energy sectors</i>	204.80	183.08	188.47	165.79	166.72	175.55	160.84	157.00	149.96	143.24	133.99
2. Industrial processes	22.95	23.06	23.52	23.93	24.08	24.44	24.05	19.14	19.69	23.26	22.16
4. Agriculture	28.91	26.69	29.80	30.09	27.64	26.94	32.43	31.08	30.47	31.57	32.08
5. LULUCF	1.04	1.42	3.57	2.05	4.05	70.11	8.51	8.80	2.56	5.11	10.66
NM_{VOC}	258.11	245.66	245.92	221.34	231.13	220.06	228.10	212.42	184.84	158.65	151.85
1. Energy	154.21	148.92	143.52	134.49	134.07	129.26	119.31	114.62	98.44	89.84	84.49
<i>Transport</i>	99.23	94.19	90.21	79.59	77.15	70.40	61.95	60.04	47.82	41.72	36.96
<i>Other energy sectors</i>	54.98	54.73	53.31	54.90	56.92	58.86	57.36	54.58	50.62	48.12	47.53
2. Industrial processes	51.42	44.13	49.67	33.79	43.38	36.90	54.78	43.57	32.08	14.45	12.69
3. Solvents	52.49	52.61	52.73	53.05	53.68	53.90	54.01	54.24	54.32	54.36	54.67
SO₂	515.16	553.48	547.80	540.69	533.23	537.94	445.16	425.55	265.41	262.16	244.90
1. Energy	507.58	545.83	540.05	531.59	526.56	531.20	438.78	420.66	260.27	257.94	240.82
<i>Transport</i>	25.06	26.67	31.66	27.77	30.41	27.43	23.31	46.74	34.12	35.11	25.36
<i>Other energy sectors</i>	482.52	519.16	508.39	503.81	496.15	503.77	415.47	373.92	226.15	222.82	215.46
2. Industrial processes	7.59	7.65	7.75	9.10	6.67	6.74	6.38	4.90	5.14	4.23	4.08

2.5 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 5,12 ha and land areas under forest management were 1,229,45 ha. In 2012 net removals from ARD activities were 44.91 kt CO₂ eq and from Forest Management activities 1,834.41 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", the description and interpretation of emission / removal trends for the associated UNFCCC categories can be found in Chapter 7.

The Kyoto Protocol activity of Deforestation encompasses the UNFCCC subcategories 5.B.2.1, 5.C.2.1, 5.D.2.1, 5.E.2.1 and 5.F.2.1 (Forest land converted to other land uses). In figure 2.5 emissions from these subcategories during the period 1990-2012 are summed up in order to illustrate the effect of deforestation.

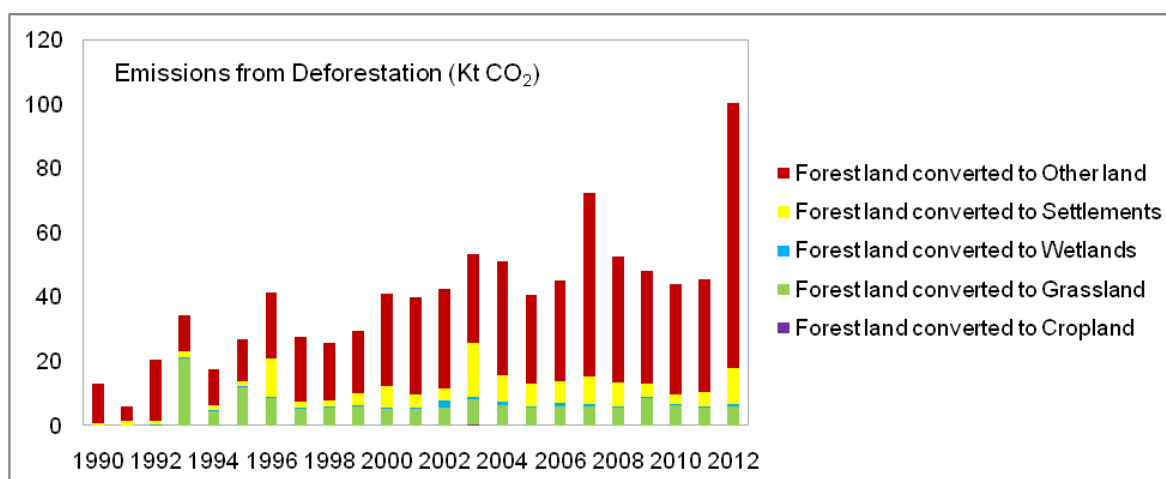


Figure 2.5 *CO₂ emissions (in kt) from deforestation for the period 1990 – 2012*

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 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 combustion², 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 2012 amounted to approximately 1046 PJ. The consumption of solid fuels and oil products accounts for 78.9% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar, wind energy and geothermal) are 2.8% and 4.3% respectively. Finally, the share of natural gas in gross inland consumption is 13.5% while the rest 0.5 % of gross inland consumption is covered by electricity (net imports – exports). In 2012, gross inland consumption increased by approximately 18.4% compared to 1990, presenting a 0.8% 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 2012 a decrease in gross inland consumption is observed, presenting a about 4.6% average annual rate of decrease, while in 2011 a marginal decrease compared to 2010 is observed.

² Emissions from off-road machinery should be reported under Stationary combustion according to the IPCC Guidelines

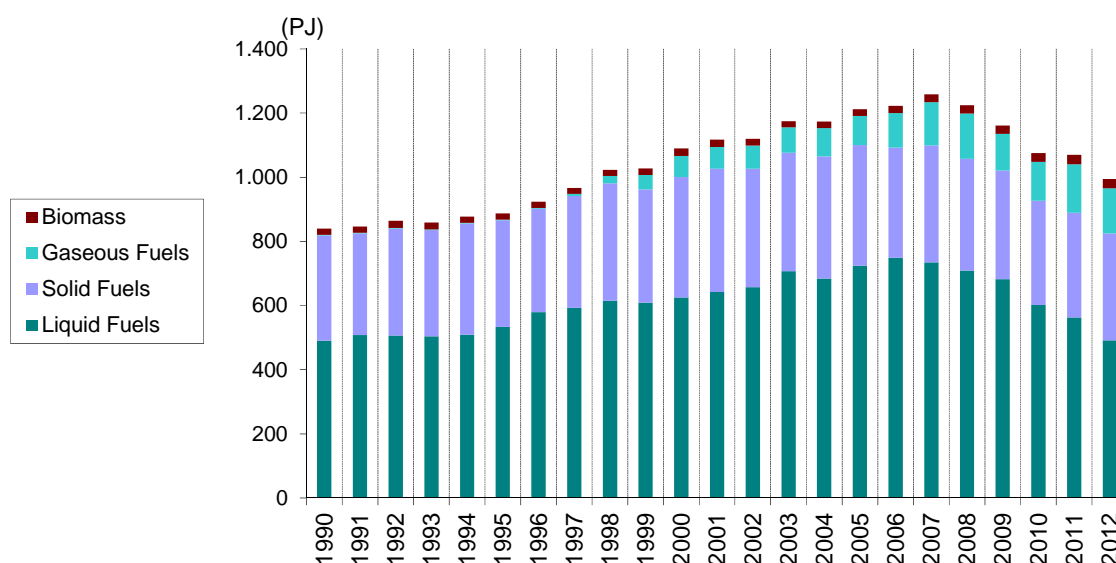


Figure 3.1 Gross inland consumption (in PJ) by energy type for the period 1990 - 2012

GHG emissions from *Energy* in 2012 increased by 13.7% compared to 1990 (**Figure 3.2**), while the average annual rate of increase for the period 1990 – 2012 was 0.6%. The highest increase on an annual basis (compared to the previous year) was recorded in 1997 (emissions increased by 5.8%), due to the significant increase in electricity demand as a result of particular weather conditions (very high summer temperatures).

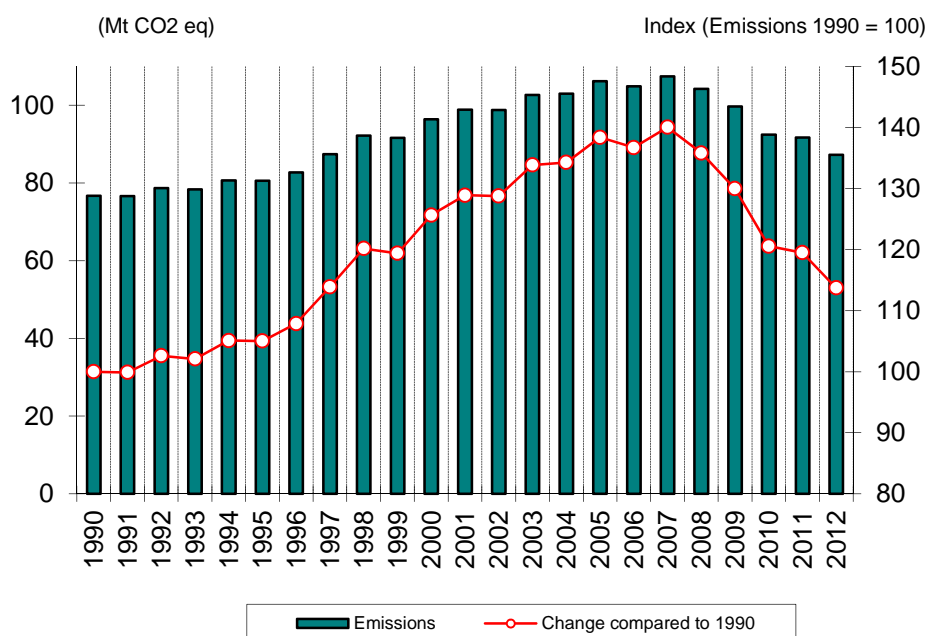


Figure 3.2 Total GHG emissions from Energy (in Mt CO₂ eq) for the period 1990 – 2012

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 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 16.3% in 2012 compared to 2008, mainly due to the economic recession, but also due to measures as increase of RES and NG share of the energy mixture, 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 (62.7%) in 2012 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 18.5%, 6.3% and 10.8% respectively. The rest 1.7% 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 energy industries, showing an increase of 26.7%, followed by transport and other sectors (i.e. residential, tertiary and agriculture sectors) with a 11.1% and 9.2% increase compared to 1990, respectively. Emissions from manufacturing industries and construction emissions had decreased by around 40% compared to 1990. Finally, fugitive emissions from fuels increased by 36.4% for the period 1990 – 2012.

Table 3.1 *GHG emissions from Energy by source category and gas for the period 1990 – 2012*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO2 emissions (in Mt)																							
A. Fuel Combustion																							
1. Energy Industries	42,99	41,85	44,13	44,03	46,01	44,77	43,95	47,39	49,90	50,20	54,63	55,15	54,57	55,81	57,13	57,94	55,77	59,23	58,02	54,48	52,04	53,84	54,51
2. Industry	9,16	9,08	8,83	8,53	8,45	9,22	9,77	9,97	10,03	8,98	9,72	9,89	9,44	9,13	8,49	10,17	10,38	10,10	9,35	7,41	6,72	5,27	5,50
3. Transport	14,08	14,87	15,24	15,41	15,70	16,04	16,49	17,19	18,94	19,26	18,32	19,17	19,49	20,57	20,99	21,05	21,89	22,64	21,68	24,57	21,86	19,47	15,84
4. Other Sectors	8,13	8,42	8,06	7,92	7,98	8,05	9,95	10,22	10,57	10,39	11,00	11,84	12,39	14,28	13,49	14,13	14,03	12,66	12,38	10,61	9,52	10,74	9,16
B. Fugitive Emissions from Fuels																							
1. 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
2. Oil and Natural Gas	0,07	0,07	0,06	0,05	0,05	0,04	0,04	0,04	0,03	0,00	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
CH4 emissions (in kt)																							
A. Fuel Combustion																							
1. Energy Industries	0,60	0,61	0,62	0,63	0,64	0,65	0,65	0,67	0,70	0,71	0,79	0,78	0,78	0,80	0,80	0,83	0,84	0,90	0,89	0,79	0,73	0,74	0,74
2. Industry	0,43	0,43	0,43	0,42	0,40	0,42	0,44	0,45	0,44	0,42	0,48	0,47	0,48	0,41	0,42	0,49	0,46	0,45	0,49	0,42	0,42	0,42	0,32
3. Transport	4,94	5,01	4,97	5,04	5,06	5,12	5,15	5,25	5,44	5,61	5,67	5,82	5,78	5,75	5,80	5,62	5,52	5,29	4,99	4,78	4,33	3,74	2,87
4. Other Sectors	4,00	4,01	4,81	4,39	3,98	3,90	4,01	3,78	3,68	4,23	4,79	4,37	3,45	3,52	3,97	3,46	3,87	3,79	3,66	3,65	3,56	3,98	4,09
B. Fugitive Emissions from Fuels																							
1. Solid Fuels	52,16	52,96	55,33	55,09	56,96	57,95	60,08	59,14	61,19	62,36	64,21	66,68	70,82	68,64	70,39	69,74	64,84	66,80	67,80	68,80	69,80	70,80	71,80
2. Oil and Natural Gas	4,36	4,23	3,74	3,01	2,82	2,64	5,15	5,44	6,14	5,12	6,54	6,60	6,57	6,87	6,99	6,90	7,42	7,62	7,93	8,35	8,96	9,02	9,47
N2O emissions																							
A. Fuel Combustion (in kt)																							
1. Energy Industries	0,50	0,48	0,51	0,51	0,53	0,51	0,50	0,54	0,57	0,56	0,60	0,61	0,60	0,61	0,63	0,63	0,59	0,62	0,61	0,59	0,55	0,56	0,57
2. Industry	0,14	0,15	0,15	0,15	0,15	0,16	0,16	0,17	0,18	0,16	0,17	0,17	0,16	0,15	0,14	0,15	0,15	0,15	0,15	0,13	0,12	0,11	0,10
3. Transport	0,99	1,04	1,12	1,22	1,31	1,35	1,33	1,44	1,70	1,75	1,26	1,39	1,38	1,37	1,41	1,39	1,48	1,44	1,40	1,26	1,03	0,81	0,64
4. Other Sectors	1,23	1,27	1,21	1,17	1,17	1,10	1,13	1,12	1,12	1,13	1,15	1,16	1,24	1,35	1,18	1,19	1,24	1,12	1,08	0,88	0,79	0,85	0,44
B. Fugitive Emissions from Fuels (in t)																							
1. 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
2. Oil and Natural Gas	0,64	0,64	0,53	0,43	0,41	0,35	0,40	0,36	0,24	0,01	0,22	0,15	0,15	0,11	0,11	0,09	0,08	0,06	0,05	0,07	0,10	0,08	0,08

NA: Not Applicable, NO: Not Occurring

3.1.2 Methodology

The calculation of GHG emissions from fuel combustion activities is based on the IPCC Guidelines, the IPCC Good Practice Guidance and the CORINAIR methodology, while fugitive emissions from fuels are estimated according to the methodologies suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

The methodology applied for the calculation of emissions by source category for 2012 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	T2	D	T2	D
1A1b	Petroleum refining	T2	PS	T2	D	T2	D
1A1c	Solid fuel manufacturing and other energy industries	T2	PS	T2	D	T2	D
1A2	Manufacturing industries and Construction	T2	CS, PS	T2	D	T2	D
1A3	Transport						
1A3a	Aviation	T2	D	T2	D	T2	D
1A3b	Road transport	T1	D, CS	M, T1	M, D	M, T1	M, D
1A3c	Railways	T1	D	CR	CR	CR	CR
1A3d	Navigation	T1	CS	T1, CR	D, CR	T1, CR	D, CR
1A3e	Pipeline transport	T1	D	CR	CR	CR	CR
1A4	Other sectors						
1A4a	Commercial / Institutional	T2	CS, D	T2	D	T2	D
1A4b	Residential	T2	CS, D	T2	D	T2	D
1A4c	Agriculture / Forestry / Fisheries	T2	D	T2	D	T2	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	T2a	D	T2a	D	T2a	D
	Marine	T1	CS	CR	CR	CR	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.

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 2012 (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
Coal mining and handling	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors - Liquid fuels	N ₂ O	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 IPCC Guidelines, 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 – 2012*

Year	Reference approach	Sectoral approach	Deviation %
1990	75940	74363	2.12
1991	75817	74225	2.14
1992	77447	76262	1.55
1993	77456	75887	2.07
1994	79794	78141	2.12
1995	80220	78079	2.74
1996	81057	80159	1.12
1997	85174	84766	0.48
1998	89446	89442	0.00
1999	88841	88829	0.01
2000	93522	93665	-0.15
2001	96645	96057	0.61
2002	96552	95890	0.69
2003	99246	99800	-0.56
2004	99766	100102	-0.33
2005	103940	103293	0.63
2006	100951	102066	-1.09
2007	101627	104630	-2.87
2008	100191	101424	-1.22
2009	97716	97078	0.66
2010	90124	90135	-0.01
2011	89941	89326	0.69
2012	85268	85003	0.31

As shown in the table above, the estimated deviation (which ranges from –2.87% to 2.74%) is within the threshold defined by the IPCC Guidelines, with the exception of the deviation estimated for the years 1995 and 2007. 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 – 2012 (%)*

Year	Liquid fuels	Solid fuels	Gaseous fuels
1990	2.45	-0.08	0.00
1991	2.82	-0.50	-0.63
1992	2.68	0.95	-0.84
1993	2.53	0.86	-0.88
1994	2.80	0.96	-0.09
1995	1.59	3.59	0.00
1996	1.30	0.85	0.00
1997	-0.02	0.63	1.05
1998	-1.09	0.62	0.15
1999	-0.58	0.38	0.07
2000	-0.13	-0.84	0.78
2001	0.82	-0.08	1.42
2002	0.84	0.25	0.03
2003	-0.53	-0.81	0.07
2004	0.35	-1.37	0.03
2005	1.59	-0.63	0.62
2006	-1.96	-0.75	0.46
2007	-6.86	0.36	-0.56
2008	-1.97	-1.82	-0.93
2009	0.65	-0.31	1.82
2010	-0.32	-1.69	1.34
2011	0.63	0.08	0.33
2012	-0.69	-0.18	0.28

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, the corresponding EUROCONTROL 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, new country specific carbon content was applied. As a consequence, recalculations of the whole time series were carried out.

GHG emissions from international bunkers (*Table 3.8a,b,c*) decreased by about 10% since 1990 for marine bunkers and increased by 4% for international aviation.

Table 3.7 *Allocation of LTOs to domestic and international aviation for the period 1990-2012*

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
2012	95044	104735

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 2010-2012*

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

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 industrial processes, 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 in 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.
- ↳ No data regarding non-energy use in the iron and steel industry are reported in the national energy balance and, as a result, CO₂ emissions from the use of fuels as reduction agents, 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.

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 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Naphtha	2.7	3.2	2.3	2.3	1.5	3.2	3.9	2.2	0.6	1.0	2.1	1.7	0.9	2.7	4.5	3.7	6.0	3.3	1.3	3.1	5.0	1.7	2.9
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	1.5	1.1	1.5	1.4	1.3	0.9	1.2
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	14.5	12.2	18.8	15.0	10.8	4.6	4.0
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
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
Coal / lignite (non ferrous)	4.8	5.0	5.7	6.7	6.7	6.7	8.1	6.4	6.1	4.3	6.0	5.5	5.7	6.1	5.9	5.7	5.7	6.1	6.0	3.1	4.8	6.1	6.9
Petcoke	1.8	2.1	2.2	1.7	1.6	1.5	1.5	1.5	1.5	1.8	1.8	1.9	3.5	1.9	1.9	1.9	1.9	2.2	1.6	1.4	2.2	1.6	1.9
Other petroleum products ³	2.5	0.5	1.3	0.7	1.3	1.0	0.9	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	6.2	13.1	6.6

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

Carbon dioxide emissions from non-energy fuel use, as well as the amount of carbon stored in the final products are presented in **Table 3.11**.

³ paraffin waxes and other oil products

Table 3.11 *CO₂ emissions (in kt) from non-energy use and total amount of carbon stored (in kt) for the period 1990 - 2012*

Year	Carbon stored (kt)	CO ₂ emissions (kt)
1990	616.16	334.57
1991	609.24	203.65
1992	544.56	219.75
1993	542.98	193.22
1994	497.95	201.12
1995	547.52	205.95
1996	597.39	204.42
1997	558.76	192.22
1998	623.18	133.86
1999	588.82	128.03
2000	697.09	228.88
2001	662.52	284.82
2002	720.88	269.97
2003	727.66	418.57
2004	779.25	400.17
2005	651.04	399.23
2006	735.22	341.94
2007	655.73	241.38
2008	769.61	214.57
2009	657.26	311.46
2010	723.78	365.87
2011	618.87	545.29
2012	565.40	339.63

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 – 2012 (*Figure 3.3*).

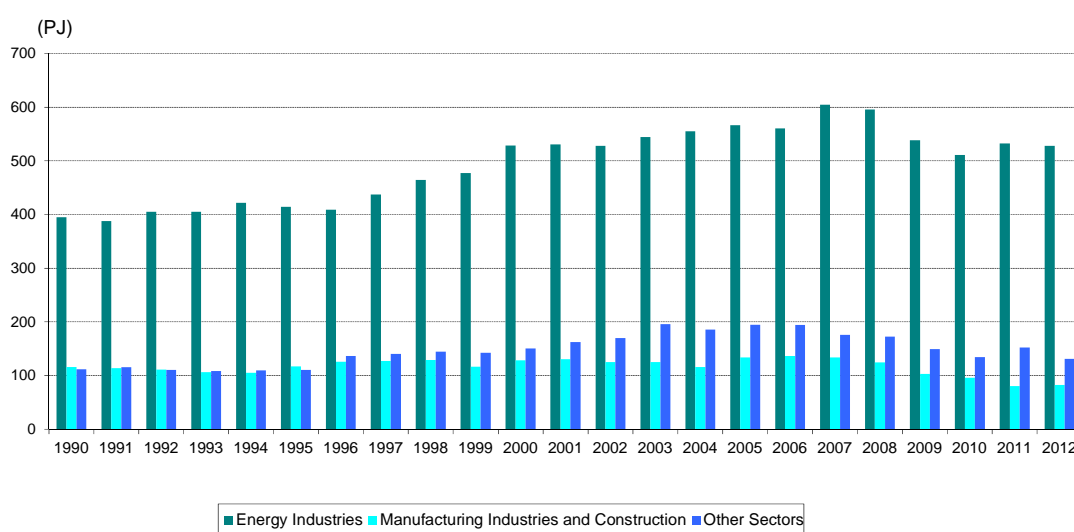


Figure 3.3 Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2012

The consumption of fossil fuels in 2012 increased by approximately 19.3% compared to 1990, with an average annual rate of increase of 0.9% for the period 1990 – 2012. In years 2008-2010 and 2012 the consumption of fossil fuels had a decreasing trend with annual rates of -2.4%, -11.4%, -6.3% and -3.1%, respectively, while in 2011 an annual increasing rate of 3.3%.

- Fuel consumption in energy industries accounts for 65% (average value for the period 1990 – 2012) of fuel consumption in stationary combustion. The average annual rate of increase for the period 1990 – 2012 is estimated at 1.4%, resulting in an increase of 33.8% in 2012 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 – 2012 the fuel consumption in energy industries had a decreasing trend with an average annual rate of 2.6% (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 2012 decreased by 28.6% compared to 1990 levels.
- ↪ Fossil fuels consumption in Other sectors increased by 17.7% from 1990 to 2012.

GHG emissions from stationary combustion follow the trend of fossil fuels consumption, presenting however a lower annual rate of increase. Therefore, GHG emissions in 2012 (69.6 Mt CO₂ eq) increased by 14.2% compared to 1990 (61.0 Mt CO₂ eq), with an average annual rate of increase estimated at 0.7% for the period 1990 – 2012 (**Figure 3.4**). The years 2008-2012, a decreasing trend of emissions is observed with average annual rate of 3.3%. This decreasing trend is attributed to the penetration of natural gas and RES technologies to the energy mix, but also, especially for the years 2009 and 2010, to the economic recession that the country is facing. In 2011 an annual increase of 2.3% is observed compared to 2010.

It is noted that emissions from stationary combustion account for around 60% of total national emissions (without *LULUCF*) for the period 1990 – 2012, while **nine key categories** are included in this sector (**CO₂ emissions from solid, liquid and gaseous fuels combustion of Energy industries and Manufacturing industries, CO₂ emissions from liquid and gaseous fuels combustion from Other sectors and N₂O emissions from liquid fuels combustion from Other sectors**).

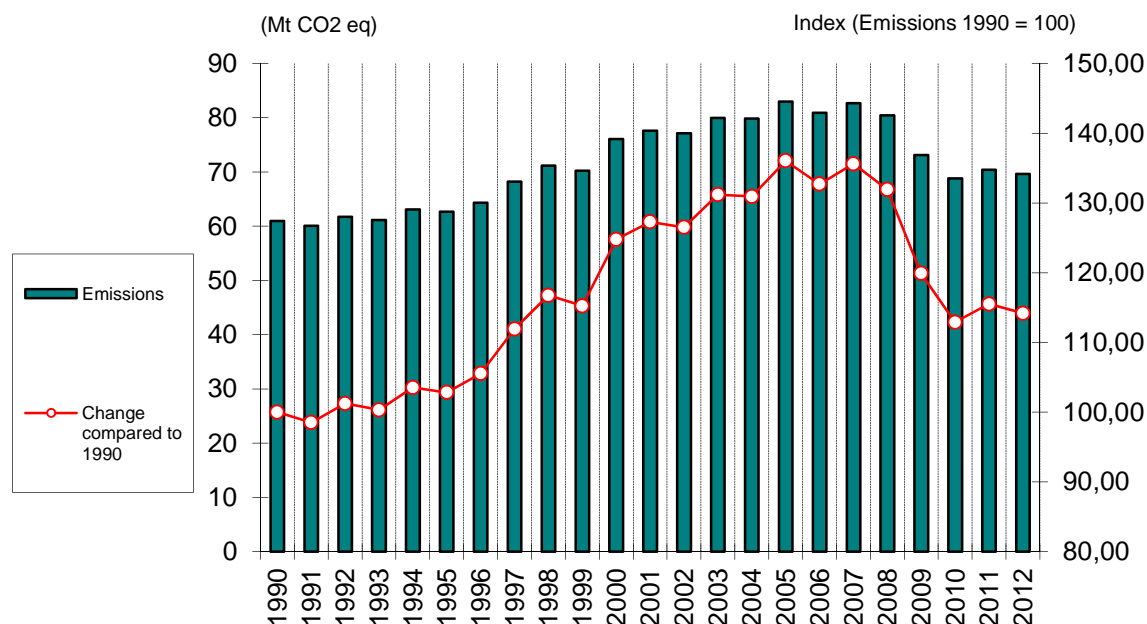


Figure 3.4 *GHG emissions (in Mt CO₂ eq) from stationary combustion for the period 1990 – 2012*

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 2012. Overall, CO₂ emissions in 2012 increased by 14.7% compared to 1990 levels with an average annual rate of increase estimated at 0.7%. N₂O emissions in 2012 account for 0.5% of emissions from stationary combustion, decreasing with an average annual rate of 2% during the period 1990 – 2012. CH₄ emissions account for the rest 0.2% of total emissions of the sector and decreased by 2.4% from 1990 to 2012.

Table 3.12 *GHG emissions per gas and source category from stationary combustion for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GHG emissions per gas																							
CO ₂ (in Mt)	60.28	59.36	61.02	60.48	62.44	62.04	63.67	67.58	70.50	69.57	75.35	76.89	76.40	79.23	79.11	82.24	80.18	81.99	79.75	72.51	68.27	69.85	69.16
CH ₄ (in kt)	5.03	5.05	5.86	5.43	5.02	4.97	5.10	4.91	4.82	5.36	6.05	5.62	4.70	4.74	5.18	4.78	5.17	5.14	5.04	4.86	4.70	5.14	5.15
N ₂ O (in kt)	1.87	1.90	1.87	1.83	1.85	1.77	1.79	1.84	1.87	1.86	1.93	1.94	2.00	2.11	1.95	1.97	1.99	1.89	1.84	1.59	1.46	1.51	1.10
GHG emissions per source category (in Mt CO ₂ eq)																							
Energy																							
industries	43.16	42.01	44.30	44.20	46.18	44.94	44.12	47.57	50.10	50.39	54.83	55.36	54.77	56.02	57.34	58.15	55.97	59.44	58.23	54.68	52.22	54.03	54.70
Industry	9.22	9.14	8.88	8.58	8.51	9.27	9.83	10.04	10.09	9.04	9.78	9.96	9.50	9.19	8.54	10.23	10.44	10.16	9.40	7.46	6.76	5.31	5.53
Other sectors	8.59	8.90	8.54	8.37	8.42	8.47	10.39	10.64	10.99	10.83	11.46	12.30	12.84	14.78	13.94	14.57	14.49	13.08	12.80	10.96	9.84	11.09	9.38
TOTAL (Mt CO₂ eq)	60.97	60.05	61.72	61.16	63.12	62.69	64.33	68.25	71.18	70.26	76.07	77.61	77.12	79.98	79.82	82.95	80.90	82.69	80.43	73.10	68.82	70.43	69.62

Energy industries constitute the major contributor (79% in 2012) in the overall GHG emissions from stationary combustion, followed by manufacturing industry and construction from 1990 to 1995 and by other sectors since 1996. Emissions from other sectors increase with a mean annual rate of 0.8% for the period 1990 – 2012. However, they have a decreasing trend the last years, which is attributed to the increasing share of natural gas in the other sectors' fuel mix and the economic recession (for the years 2009-2012).

3.2.4.2 Methodological issues

The calculation of GHG emissions from stationary combustion was based on the Revised 1996 IPCC Guidelines and the IPCC Good Practice Guidance. 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 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 IPCC Guidelines constitute an important source of information regarding carbon content, fraction of carbon oxidised and therefore the calculated EF by fuel type (IPCC 1997, Tables 1-1 and 1-6). However, as indicated in Table 3.13 for the cases of refinery gas, LPG, petcoke, steamcoal, lignite, domestic and imported natural gas plant and/or country specific data have been processed for the calculation of the respective EFs. PS EFs for diesel and HFO are also used (source EU ETS reports).
- ✎ Information on the net calorific value (NCV) per fuel is mainly provided by the national energy balance, compiled by the Ministry of Environment, Energy and Climate Change (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. HFO's and diesel's NCV were obtained from greek refineries' statistics and EU ETS reports.

- ↳ 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 (2012)*

Fuel type	Net calorific value (TJ/kt)	Carbon content. CC (tC/TJ)	Oxidation factor. OF (%)	EF (tCO ₂ /TJ)
Liquid fuels				
Refinery gas	45.08 ⁴	15.62	99.0	56.69
LPG	47.31	17.2	99.0	62.44 ⁵ , 62.77 ⁶
Gasoline	44.80	18.9	99.0	68.61
Kerosene	44.75	19.6	99.0	71.15
Diesel oil	43.00	20.2	99.0	73.33
Heavy fuel oil	40.19	21.1	99.0	76.59
Naphtha	45.01	20.0	99.0	72.60
Petroleum coke	32.33 ⁷ , 32.37 ⁸	27.8 ⁷ , 26.0 ⁸	98.0	99.84 ⁷ , 93.49 ⁸
Other oil products	40.19	20.0	99.0	72.60
Solid fuels				
Steam coal	25.03 ⁹	26.8	98.0	96.31 ⁹
Lignite				
Electricity generation	5.337	35.37	98.0	127.084
Other sectors	8.501	27.6	98.0	99.18
Oven and gas coke	29.31	29.5	98.0	106.00
BKB / Patent fuel	14.20	25.8	98.0	92.71
Gaseous fuels				
Natural gas – Domestic		15.96 - 16.23 ¹⁰	99.5	56.73 ¹¹
Natural gas – Imports		15.16 ¹² , 15.08 ¹³	99.5	55.32 ¹² , 55.00 ¹³

⁴ 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.

⁵ For use in sectors other than refineries.

⁶ Only for petroleum refining category. It comprises emissions from LPG used as feedstock for hydrogen production. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

⁷ Mean value. Petcoke consumed in refineries. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

⁸ 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.

⁹ Derived from PS data of verified EU ETS emission reports.

¹⁰ Depends on the reservoir that the gas is extracted.

¹¹ 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.

¹² Mean value based on chemical composition data of NG provided by DESFA (Hellenic Gas Transmission System Operator S.A.).

¹³ Mean value for electricity production based on PS data derived from verified EU ETS emission reports.

Gas works gas		15.3	99.5	55.82
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- ⇒ 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 (2011):
1. the South Kavala reservoir, which has a NCV of 11313 kcal/Nm³ and a carbon content of 15.96 tC/TJ.
 2. the Prinos reservoir, which has a NCV of 12192 kcal/Nm³ and a carbon content of 16.23 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**.

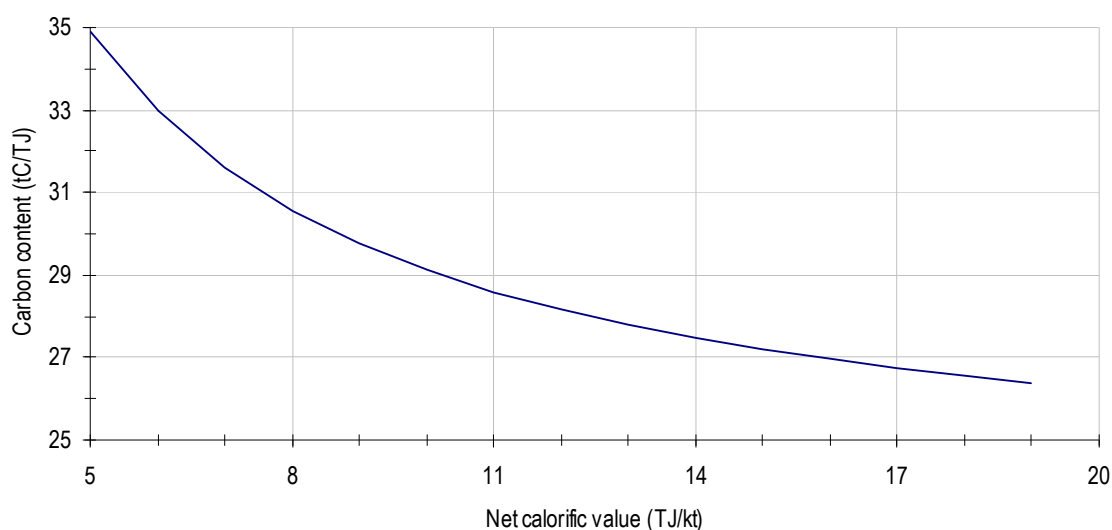
Table 3.14 *Net calorific value of lignite by sector (in TJ / kt) for the period 1990 - 2012*

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

- ⇒ 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 2006-2012 plant specific values for CC were used, based on verified EU-ETS reports, ranging from 33.95 to 35.37 tC/TJ. These

values lies out of the range suggested by the IPCC Guidelines and the IPCC Good Practice Guidance. However, given that the net calorific value of the Greek lignite is one of 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 that 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 2005-2012, 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 2 methodology with IPCC defaults emission factors was applied. For the application of the tier 2 methodology, the disaggregation of energy consumption into different activities / technologies is required. CH₄ and N₂O emissions are estimated on the basis of the following equation:

$$E_g = \sum_{f,t} FC_{f,t} \cdot NCV_f \cdot EF_{g,f,t}$$

where, g is an index referring to a greenhouse gas, E_g is emissions of gas- g , f is an index referring to the fuel consumed, t is an index referring to an activity / technology, $FC_{f,t}$ is the consumption of fuel- f in activity- t , NCV_f is the net calorific value of fuel- f and $EF_{g,f,t}$ is the emission factor for gas- g in activity- t using fuel- f .

ETS data of years 2005-2010 were used for the disaggregation of energy consumption into different activities / technologies. Average emission factors per fuel and source category / activity were estimated by combining ETS data and IPCC default emission factors per technology / activity and fuel. Emissions were calculated by multiplying the fuel consumption obtained from national energy balance per activity by the average emission factors of the respective source activity and fuel, which has been estimated as above-mentioned.

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% and increases at an average annual rate of 3% in 2011 and 2012. Gross electricity production in 2012 (61.0 TWh) was approximately 74% higher compared to 1990 levels (**Figure 3.6**).

Electricity generation from the use of fossil fuels is approximately 81.4% of electricity production in 2012. 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 8.4% and 21.9% respectively. The rest of electricity production, i.e. around 16.6%, 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 – 2012 are presented in **Table 3.15**.

GHG emissions from electricity generation in 2012 increased by 25.4% compared to 1990 levels at an average annual rate of 1.1 % for the period 1990 – 2012. 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.

CO₂ emissions in 2012 accounted for 99.7% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 82.5% of total emissions in 2012. However, due to the penetration of natural gas and RES technologies, total emissions per electricity produced by fossil fuels has a decreasing trend.

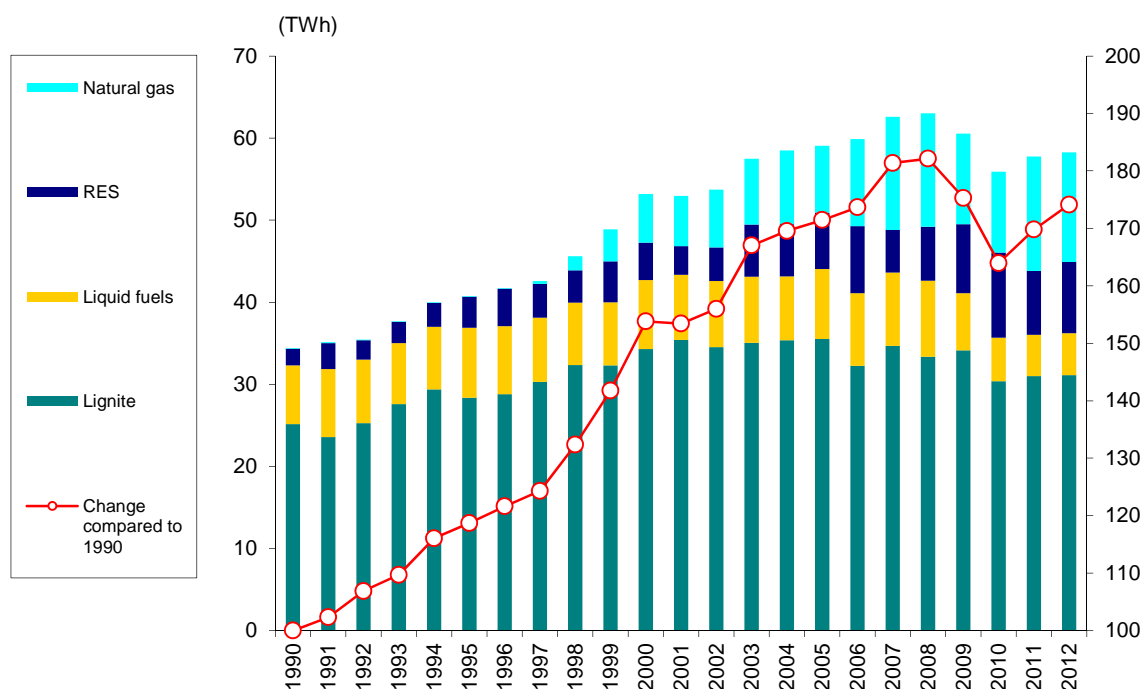


Figure 3.6 Electricity production (in TWh) by energy type for the period 1990 – 2012

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 2012, compared to 1990 levels, is estimated at 54%, with an average annual rate of increase estimated at 2.1% for the period 1990 – 2012. 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 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO₂ emissions (in Mt)																							
Liquid fuels	5.37	5.80	5.71	5.85	5.73	6.19	6.10	5.91	5.74	5.95	6.37	5.92	5.82	6.38	5.70	6.27	6.42	6.57	6.95	5.33	3.99	3.78	3.81
Solid fuels	35.21	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
Gaseous fuels	NO	NO	NO	NO	NO	NO	NO	0.10	0.78	1.96	2.87	2.84	3.03	3.37	3.66	3.55	4.24	5.66	5.72	4.17	4.64	5.97	5.10
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
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
Gaseous fuels	NO	NO	NO	NO	NO	NO	NO	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
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
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
Gaseous fuels	NO	NO	NO	NO	NO	NO	NO	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
TOTAL (Mt CO₂ eq)	40.74	39.54	41.92	41.84	43.64	42.38	41.31	44.70	47.18	47.81	51.64	52.13	51.44	52.84	53.99	54.43	51.57	55.00	54.08	50.87	48.49	50.63	51.08

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 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂ (kt)	2308	2350	2283	2262	2433	2459	2694	2744	2821	2558	3072	3117	3222	3075	3225	3620	4287	4337	4047	3714	3669	3333	3560
CH ₄ (kt)	0.10	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.11	0.13	0.14	0.14	0.14	0.14	0.15	0.18	0.18	0.17	0.16	0.16	0.15	0.16
N ₂ O (kt)	0.02	0.02	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	0.04	0.04	0.03	0.03	0.03	0.03	0.03
TOTAL (kt CO₂ eq)	2317	2359	2292	2270	2442	2468	2704	2754	2832	2568	3084	3128	3234	3087	3237	3633	4302	4352	4061	3727	3683	3345	3573

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 - 2012) 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 2012 decreased by approximately 55.5% 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 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Emissions (in kt CO ₂ eq)																							
CO ₂	102.03	108.48	94.15	89.50	103.14	98.59	103.88	110.38	83.63	6.19	104.04	98.86	104.30	90.29	108.96	90.71	96.50	93.08	88.87	85.97	48.91	46.00	45.40
CH ₄	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.00	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
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	0.06	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.02
TOTAL	102.12	108.57	94.23	89.58	103.23	98.68	103.97	110.48	83.71	6.19	104.13	98.94	104.39	90.37	109.06	90.79	96.58	93.17	88.95	86.05	48.95	46.04	45.44

3.2.4.3.2 Recalculations

No recalculations were performed.

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 - 2012 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 – 2012 (**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 - 2012. 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 - 2012 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 - 2012. 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 - 2012 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 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 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 - 2012.

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 2012 decreased by 40% compared to 1990.

3.2.4.4.2 Recalculations

1.A.2c Chemicals / Solid fuels / 1990 and 1991

The associated emissions with the non-energy use of lignite for ammonia production (in one installation for 1990 and 1991) were reallocated to the industrial processes sector, as from this submission (2014 submission).

Table 3.18 *GHG emissions (in kt CO₂ eq) from manufacturing industries and construction for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Iron and Steel																							
CO ₂	475.14	428.33	425.83	376.75	366.44	352.45	259.78	283.57	270.09	270.09	316.22	284.19	308.93	322.49	303.32	228.83	184.85	173.32	199.03	189.43	159.61	148.48	197.06
CH ₄	0.4	0.36	0.36	0.32	0.31	0.3	0.22	0.24	0.2	0.2	0.22	0.19	0.2	0.21	0.2	0.13	0.08	0.07	0.08	0.08	0.07	0.06	0.10
N ₂ O	1.19	1.06	1.06	0.94	0.92	0.89	0.66	0.7	0.57	0.57	0.6	0.49	0.51	0.53	0.52	0.29	0.13	0.13	0.15	0.13	0.11	0.09	0.51
Non ferrous metals																							
CO ₂	607.68	693.6	692.91	678.52	653.71	665.66	685.55	677.23	767.86	884.45	926.99	919.28	966.11	1002.69	968.57	808.74	823.89	817.47	740.55	533.77	503.57	462.21	529.30
CH ₄	0.44	0.51	0.51	0.5	0.48	0.49	0.51	0.5	0.57	0.64	0.66	0.66	0.68	0.7	0.67	0.55	0.57	0.57	0.5	0.33	0.3	0.28	0.19
N ₂ O	2.14	2.45	2.45	2.4	2.32	2.36	2.47	2.45	2.81	3.34	3.56	3.51	3.7	3.89	3.76	3.38	3.22	3.17	3.05	2.81	2.64	2.32	3.07
Chemicals																							
CO ₂	749.50	461.64	418.74	435.5	446.72	459.91	689.04	750.39	926.85	505.74	638.85	632.88	653.54	776.21	876.48	916.57	872.96	863.25	841.01	839.64	929.67	1195.66	748.07
CH ₄	0.31	0.18	0.17	0.14	0.14	0.15	0.34	0.4	0.53	0.27	0.29	0.27	0.27	0.25	0.35	0.36	0.39	0.38	0.33	0.29	0.29	0.32	0.17
N ₂ O	2.42	2.38	2.4	2.9	3.13	3.07	3.1	3.65	4.46	3.61	3.55	3.52	3.4	3.54	3.76	4.07	3.81	3.65	3.51	3.97	4.09	4.32	2.65
Paper, pulp and print																							
CO ₂	301.47	288.51	281.4	265.9	250.81	211	289.37	340.3	305.8	314.58	373.79	344.1	354.17	364.5	252.27	229.31	268.83	255.59	239.91	197.38	178.73	150.98	118.37
CH ₄	0.22	0.22	0.21	0.19	0.17	0.16	0.21	0.23	0.19	0.25	0.25	0.21	0.21	0.21	0.16	0.14	0.16	0.15	0.14	0.1	0.09	0.08	0.06
N ₂ O	0.44	0.42	0.4	0.38	0.37	0.32	1.02	1.24	1.47	2.23	1.94	1.91	1.84	1.85	1.18	1.1	1.38	1.28	1.3	1.25	1.14	0.90	0.73
Food processing – Beverages – Tobacco																							
CO ₂	902.31	925.19	939.89	960.05	920.05	936.47	1005.83	973.47	1059.77	963.38	1086.77	992.76	1038.2	1090.53	875.18	790.12	846.88	704.82	651.74	587.96	498.67	400.78	506.49
CH ₄	0.64	0.66	0.67	0.68	0.64	0.62	4.9	4.89	4.94	4.9	5.91	5.73	6.15	5.27	5.37	6.06	5.51	5.54	6.58	6.06	5.93	6.01	4.54
N ₂ O	1.41	1.39	1.41	1.44	1.4	1.37	10.71	11.19	11.6	12.13	14.34	13.99	14.71	13.21	13.18	14.97	13.79	13.19	15.32	14.66	13.91	13.40	11.94
Other industries																							
CO ₂	6126.41	6287	6070.1	5810.45	5814.33	6590.29	6839.81	6949.05	6700.54	5994.82	6411.02	6696.86	6109.8	5596.25	5290.17	7241.17	7397.91	7262.3	6683.43	5093.57	4447.36	2913.04	3397.10
CH ₄	6.93	7.09	7.09	6.92	6.71	7	3.15	3.17	2.84	2.54	2.73	2.76	2.5	2.05	2.08	3.07	2.88	2.76	2.62	2.04	2.04	2.00	1.71
N ₂ O	36.03	37.98	37.87	37.81	38.36	41.7	32.95	33.65	33.85	28.11	29.12	29.89	26.4	23.56	22.29	22.1	23.72	26.03	23.16	17.36	15.52	11.68	11.31
TOTAL	9215.08	9138.97	8883.45	8581.79	8507.02	9274.23	9829.63	10036.32	10094.93	9038.02	9784.65	9957.96	9504.89	9188.77	8544.72	10226.77	10439.43	10159.4	9402.78	7460.98	6763.56	5312.60	5533.38

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 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 2012 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. A decreasing trend of the last years is attributed to the penetration of natural gas to the fuel mixture and economic recession (years 2009-2010).

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 – 2012.

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 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 recalculations were performed.

Table 3.19 *GHG emissions (in kt) from the residential sector for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂	4671	4681	4586	4553	4581	4803	6512	6813	7145	6989	7575	8153	8446	10036	9601	9861	9536	8591	8383	7404	6678	7903	6947
CH ₄	3.83	3.83	4.64	4.22	3.81	3.74	3.84	3.62	3.51	4.06	4.60	4.19	3.25	3.24	3.67	3.11	3.53	3.44	3.35	3.31	3.23	3.49	3.53
N ₂ O	0.14	0.14	0.16	0.15	0.14	0.14	0.15	0.15	0.15	0.16	0.18	0.17	0.15	0.16	0.17	0.16	0.16	0.15	0.15	0.14	0.13	0.15	0.14

Table 3.20 *GHG emissions (in kt) from the commercial / institutional sector for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂	527	671	626	596	614	659	799	772	787	761	777	1011	1029	1130	1220	1535	1596	1498	1494	1230	1140	1076	1341
CH ₄	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.06	0.06	0.05	0.05	0.04	0.04	0.03	0.04
N ₂ O	0.00	0.01	0.01	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

Table 3.21 *GHG emissions (in kt) from agriculture for the period 1990 - 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂	2927	3069	2847	2770	2783	2589	2642	2632	2633	2642	2644	2680	2911	3119	2666	2734	2894	2568	2506	1980	1701	1763	872
CH ₄	0.15	0.16	0.15	0.14	0.14	0.13	0.14	0.13	0.13	0.14	0.16	0.14	0.15	0.24	0.25	0.30	0.29	0.30	0.26	0.30	0.29	0.46	0.52
N ₂ O	1.09	1.13	1.05	1.02	1.03	0.95	0.97	0.97	0.97	0.97	0.97	0.98	1.08	1.18	1.00	1.02	1.07	0.95	0.93	0.73	0.65	0.70	0.29

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, Energy and Climate Change (MEECC).

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 MEECC 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

Only the recalculations described in paragraph 3.2.4.4.2 were performed in the stationary combustion sectors in the 2014 submission.

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 2012 increased by approximately 46% compared to 1990 emissions (from 14.54 Mt CO₂ eq in 1990 to 21.18 Mt CO₂ eq in 2010) whereas the most important increase of 71% occurred in 2009. The average annual rate of emissions increase from transport for the period 1990 – 2012 was approximately 2%, however, in 2008, an approximately 5% decrease of total emissions was observed compared to 2007 emissions. A more intense decrease (>10%) occurred in 2010 compared to 2009 emissions as a result of the economic recession.

In 2012, the majority of GHG emissions derived from road transport, the contribution of which increased from 82% in 1990 to approximately 87% 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 11% in 2012. Additionally, the contribution of internal aviation ranges from almost 1.7% to 3.5% for the period 1990-2012, with the smaller contribution in 2012, while the contribution of railways decreased from 1.6% in 1990 to less than 0.3% in 2012. The contribution of other transport (pipeline transportation) is negligible.

Finally, the aggregated contribution of transport in total National GHG emissions is 18.4%.

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	11742	12589	12890	13189	13372	13803	14465	14801	15550	15828
	CH ₄	4.80	4.87	4.83	4.91	4.91	4.98	5.02	5.09	5.21	5.38
	N ₂ O	0.47	0.51	0.60	0.71	0.81	0.91	0.96	1.05	1.15	1.28
Railways	CO ₂	200	156	149	153	165	137	143	133	149	130
	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	1791	1838	1884	1722	1815	1727	1480	1798	2779	2746
	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	14052	14862	15230	15402	15690	16026	16473	17169	18923	19236
kt CH₄	Total	4.94	5.01	4.98	5.04	5.06	5.12	5.15	5.24	5.44	5.61
kt N₂O	Total	0.99	1.04	1.12	1.23	1.3	1.34	1.33	1.44	1.71	1.75
kt CO_{2eq}	Total	14463	15290	15682	15889	16199	16549	16993	17725	19567	19896

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	16020	16365	16964	17998	18108	18308	18895	19785	19066	20964
	CH ₄	5.54	5.65	5.63	5.60	5.62	5.46	5.34	5.12	4.84	4.54
	N ₂ O	0.85	0.87	0.89	0.90	0.93	0.89	0.94	0.95	0.93	0.81
Railways	CO ₂	130	130	130	130	130	129	132	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	0.04	0.04
Navigation	CO ₂	1559	2124	1915	1896	2133	2043	2240	2093	1877	2836
	CH ₄	0.11	0.15	0.13	0.14	0.16	0.15	0.16	0.15	0.13	0.22
	N ₂ O	0.34	0.45	0.43	0.40	0.41	0.43	0.47	0.42	0.40	0.39
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	18384	19226	19534	20626	21050	21098	21864	22607	21565	24427
kt CH₄	Total	5.75	5.91	5.87	5.84	5.88	5.71	5.62	5.38	5.08	4.87
kt N₂O	Total	1.28	1.42	1.41	1.39	1.43	1.41	1.5	1.46	1.42	1.27
kt CO_{2eq}	Total	18902	19790	20094	21180	21617	21655	22447	23173	22112	24923

Table 3.22(c) GHG emissions in the transportation sector per category for the period 2010-2012

	Year	2010	2011	2012
	Emissions (kt)			
Aviation	CO ₂	565	495	490
	CH ₄	0.01	0.01	0.01
	N ₂ O	0.02	0.02	0.02
Road transport	CO ₂	18907	18149	14005
	CH ₄	4.14	3.61	2.67
	N ₂ O	0.61	0.43	0.33
Railways	CO ₂	63	47	79
	CH ₄	0.00	0.00	0.00
	N ₂ O	0.02	0.02	0.03
Navigation	CO ₂	2308	1651	1660
	CH ₄	0.18	0.12	0.13
	N ₂ O	0.37	0.34	0.26
Other	CO ₂	0	0	0
	CH ₄	0	0	0
	N ₂ O	0	0	0
kt CO₂	Total	21843	20342	16234
kt CH₄	Total	4.33	3.74	2.81
kt N₂O	Total	1.02	0.81	0.64
kt CO_{2eq}	Total	22250	20672	16491

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	4359	3791	4172	4590	4592	4869	5224	5936	6037	7219
Road transport	167182	179052	183365	187638	190257	196369	205851	210651	221208	225134
Railways	2730	2123	2037	2080	2253	1863	1950	1820	2037	1773
Navigation	23330	23952	24545	22460	23640	22477	19251	23352	36070	35606
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	197601	208918	214119	216768	220742	225578	232276	241759	265352	269732
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	8027	7183	6172	7054	7640	7224	7627	8023	7717	8645
Road transport	227903	232929	241641	256195	257910	260893	270979	285270	274546	300900
Railways	1773	1773	1773	1773	1773	1758	1801	1630	1587	1329
Navigation	20288	27633	24929	24660	27717	26573	29131	27207	24427	36765
Other	NO	37	97	65	40	68	88	133	257	0
Total	257991	269518	274515	289682	295040	296448	309538	322130	308277	347639
Energy consumption (in TJ)										
International aviation	35360	32863	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 2010-2012*

Energy consumption (in TJ)			
Year	2010	2011	2012
Aviation	7783	6817	6867
Road transport	274056	250509	199354
Railways	859	644	1074
Navigation	29961	21479	21533
Other	0	0	0
Total	312659	279449	228828
Energy consumption (in TJ)			
International aviation	29614	32220	35711
International marine	112372	114475	93842

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.

As had already been discussed in the last year's NIR, the traffic characteristics applied for each vehicle type and category had to be further investigated. 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**.

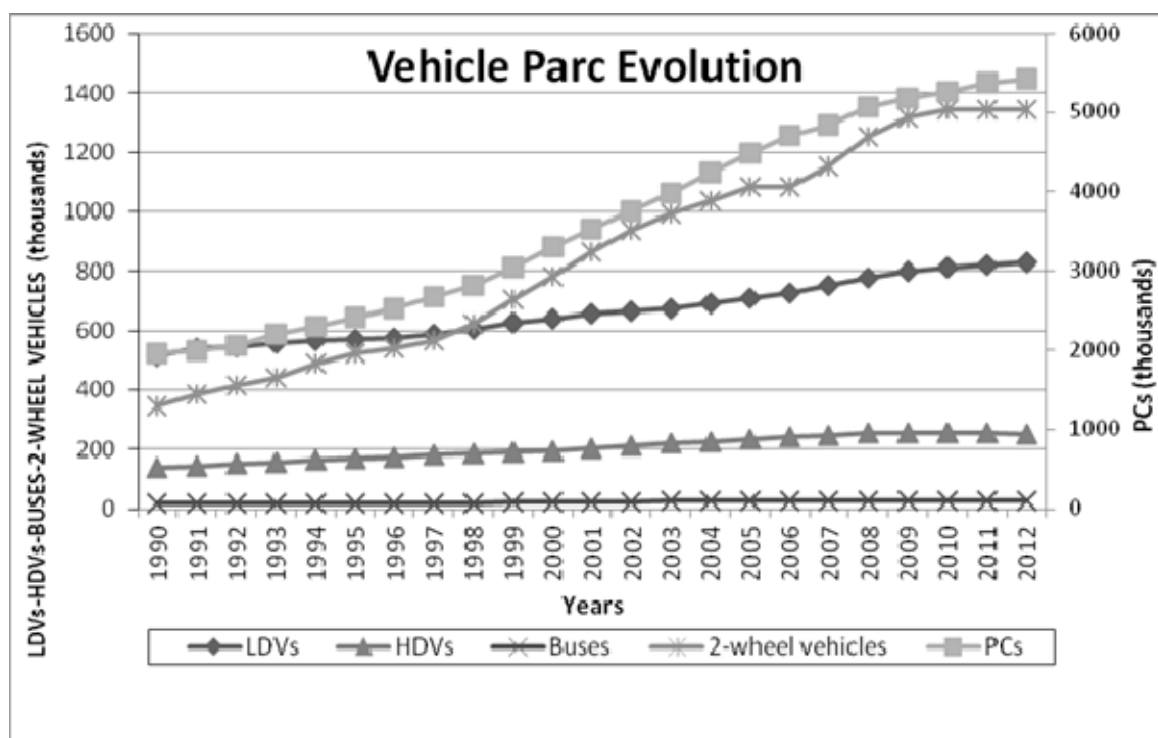


Figure 3.7 Vehicles population evolution for all vehicles categories during the whole time period 1990 – 2012

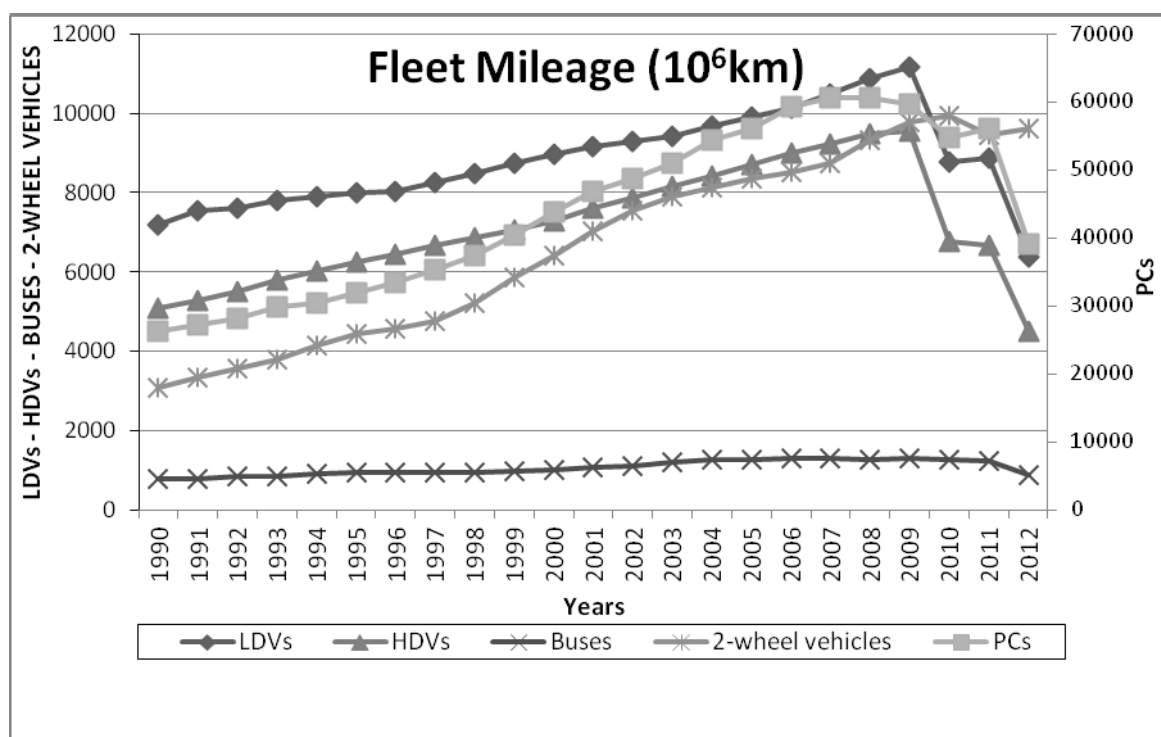


Figure 3.8 Annual mileage driven by all vehicles categories during the whole time period 1990 – 2012

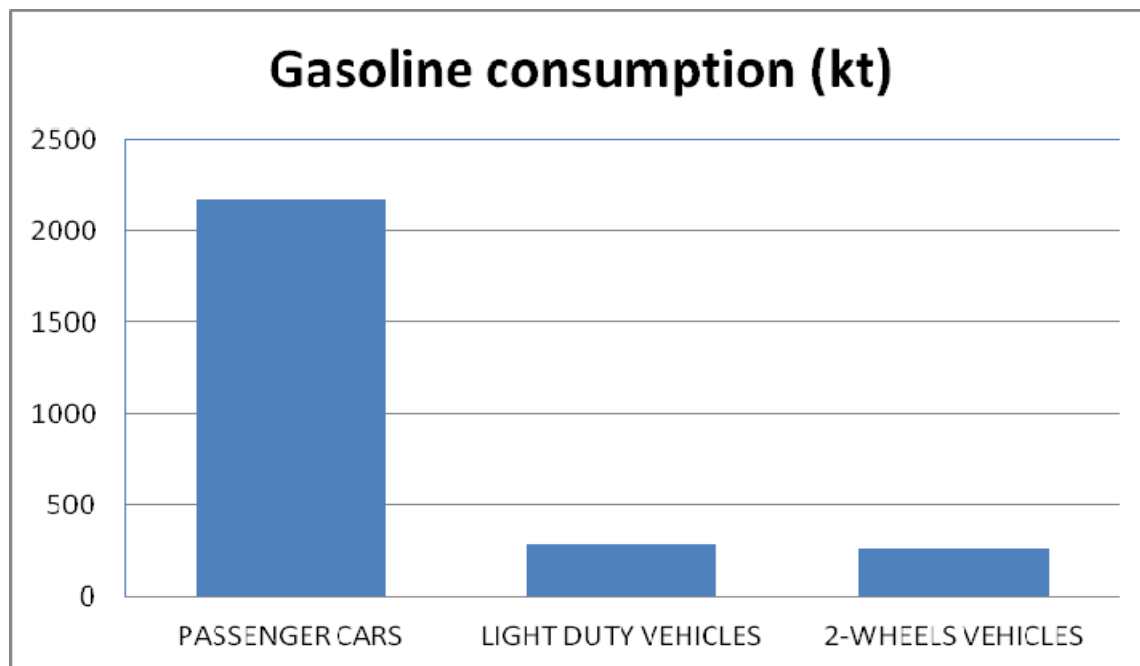


Figure 3.9 Gasoline consumption (kt) by all vehicles categories for 2012

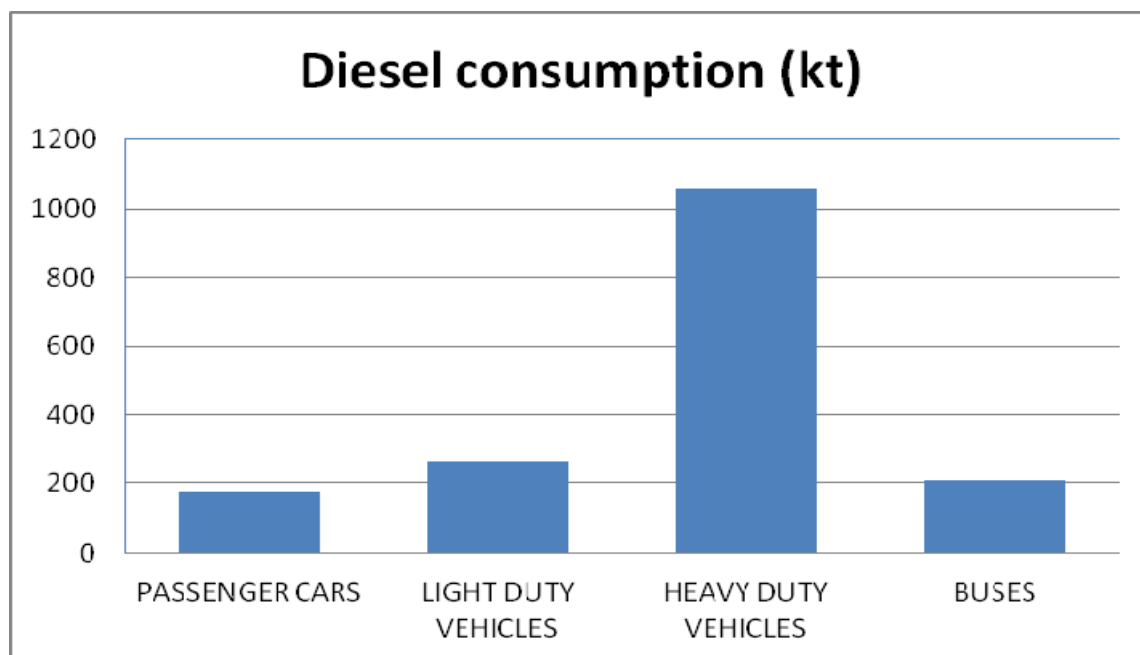


Figure 3.10 Diesel consumption (kt) by all vehicles categories for 2012

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 2012, 25% of passenger cars have an engine capacity greater than 2000cm³).

Road transport is a key category of CO₂ emissions. CO₂ emissions in 2012 increased by approximately 20% compared to 1990 emissions, CH₄ emissions decreased (about 44%), while N₂O emissions decreased by 30% (**Table 3.24(a,b,c)**). During this period, energy consumption augmented by 20%.

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 last year's 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.

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. Therefore, the lubricants emissions for all other gases, except CO₂, are incorporated in the total emissions amount for each gas and are not reported separately.

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)	11742	12589	12890	13189	13372	13803	14465	14801	15550	15828
CH ₄ (kt)	4.80	4.87	4.83	4.91	4.91	4.98	5.02	5.09	5.21	5.38
N ₂ O (kt)	0.47	0.51	0.60	0.71	0.81	0.91	0.96	1.05	1.15	1.28
TOTAL	11988	12850	13176	13510	13727	14191	14869	15235	16016	16338
Energy consumption (in TJ)										
Gasoline	106,310	109,715	113,434	116,211	118,496	122,035	129,472	133,728	139,149	141,792
Diesel	59,015	67,118	67,465	68,808	69,371	71,928	74,138	75,048	80,204	81,807
LPG	1,419.30	1,750.47	1,987.02	2,128.95	1,892.40	1,892.40	1,703.16	1,324.68	1,277.37	946.20
Natural Gas										
Other liquids	436.84	467.86	479.13	490.30	497.14	513.11	537.88	550.43	578.01	588.27
TOTAL	167182	179052	183365	187638	190257	196369	205851	210651	221208	225134

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)	16020	16365	16964	17998	18108	18308	18895	19785	19066	20964
CH ₄ (kt)	5.54	5.65	5.63	5.60	5.62	5.46	5.34	5.12	4.84	4.54
N ₂ O (kt)	0.85	0.87	0.89	0.90	0.93	0.89	0.94	0.95	0.93	0.81
TOTAL	16398	16753	17357	18396	18514	18700	19299	20187	19456	21311
Energy consumption (in TJ)										
Gasoline	144.704	149.453	156.486	163.520	167.100	170.920	172.813	180.593	177.208	177.692
Diesel	81,894	82,11	83,41	90,993	89,173	88,272	94,459	99,187	95,793	120.959
LPG	709.65	756.96	709.65	567.72	520.41	520.41	520.41	567.72	567.73	804.27
Natural Gas			404.00	446.00	444.00	489.80	516.42	600.30	534.60	660.00
Other liquids	595.51	608.64	630.35	668.27	672.77	690.97	712.36	734.46	716.71	784.52
TOTAL	227903	232929	241641	256195	257910	260893	269021	281682	274820	300900

Table 3.24(c) *GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from road transportation for the period 2010-2012*

Year	2010	2011	2012
Emissions (in kt CO₂ eq)			
CO ₂ (kt)	18907	18149	14005
CH ₄ (kt)	4.14	3.61	2.67
N ₂ O (kt)	0.61	0.43	0.33
TOTAL	19184	18359	14163
Energy consumption (in TJ)			
Gasoline	161778	146304	124894
Diesel	108919	94228	71853
LPG	1987	8468	2366
Natural Gas	658	626	617
Other liquids	714	654	241
TOTAL	274056	274056	199971

Internal 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. 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 Revised 1996 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 contrart, 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 2012 were, for the first time in time series, lower (10%) than the emissions in 1990, on the basis of fuel consumption data from this sector (*Table 3.25*). This is another impact of recession.

Table 3.25 *GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from internal navigation for the period 1990 – 2012*

	Emissions (in kt CO ₂)			ktCO ₂ eq	Energy consumption (in TJ)			
	CO ₂	CH ₄	N ₂ O		Diesel	Fuel Oil	Lubricants	Total
1990	8025	0.66	0.79	8285	13816	9513	764	24094
1991	7361	0.60	0.78	7616	14680	9272	161	24113
1992	8451	0.68	0.98	8767	14310	10236	241	24786
1993	9863	0.80	1.08	10215	14392	8068	201	22661
1994	10475	0.85	1.19	10863	13364	10276	281	23921
1995	11254	0.90	1.40	11708	11719	10758	362	22839
1996	9905	0.80	1.15	10278	9416	9834	322	19573
1997	9932	0.80	1.14	10304	9704	13648	442	23794
1998	11091	0.91	1.16	11470	14474	21595	522	36592
1999	9850	0.81	1.07	10198	11884	23723	643	36249
2000	11378	0.94	1.16	11756	10815	9473	482	20770
2001	11055	0.92	0.99	11381	14186	13447	482	28115
2002	9895	0.83	0.89	10187	13570	11360	482	25411
2003	10146	0.86	0.83	10423	12377	12283	683	25343
2004	10230	0.87	0.81	10499	12665	15053	563	28280
2005	9122	0.78	0.68	9349	13487	13086	482	27055
2006	9849	0.84	0.71	10087	14721	14410	804	29935
2007	10044	0.86	0.68	10273	13158	14049	592	27799
2008	9832	0.85	0.64	10050	12706	11721	362	24789
2009	8346	0.72	0.58	8541	11267	25498	161	36926
2010	8701	0.74	0.62	8909	11144	18817	281	30242
2011	8866	0.76	0.58	9063	10568	10911	281	21760
2012	7267	0.62	0.49	7433	7731	13802	281	21814

Domestic aviation

GHG emissions from domestic aviation (key source category) are calculated according to the Tier 2a methodology suggested by the IPCC Guidelines, which is 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 last year's submission do not exist anymore, as this system for aviation was postponed, and, thus, the only reliable source of data is considered to be EUROCONTROL.

Recalculations of the whole time series were performed for domestic aviation. These recalculations are due to the re-estimation of the jet kerosene fuel consumption per flight based on the EUROCONTROL data for 2012. Although no such data were available for the previous years, it was considered that this parameter should be applied for the whole time series. Hence, jet kerosene consumption was derived from 2012 EUROCONTROL data, whereas aviation gasoline data were taken, as usually, from the energy balance.

The fuel consumption per flight taken into account is 0.072 TJ/flight which is close to the corresponding value of 0.08 TJ/flight proposed by the ERT in a previous in-country review. 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 2012 they present an increase of only 54% 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 3.27(a,b,c)**) decreased by about 60% from 1990 to 2012.

Table 3.26(a) GHG emissions (in kt CO₂ eq). energy consumption (in TJ) and air movement (in thousands 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
Energy Consumption (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 thousands 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
Energy Consumption (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 2010-2012

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

Table 3.27(a) GHG emissions from railways for the period 1990 – 1999

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO ₂ (kt)	200	156	149	153	165	137	143	133	149	130
CH ₄ (kt)	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
N ₂ O (kt)	0,08	0,06	0,06	0,06	0,06	0,05	0,06	0,05	0,06	0,05
Total (in kt CO ₂ eq)	225	175	168	171	185	153	160	150	168	146

Table 3.27(b) GHG emissions from railways for the period 2000 – 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO ₂ (kt)	130	130	130	130	130	129	132	119	116	97
CH ₄ (kt)	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
N ₂ O (kt)	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,04	0,04
Total (in kt CO ₂ eq)	146	146	146	146	146	144	148	134	130	109

Table 3.27(c) GHG emissions from railways for the period 2010-2012

Year	2010	2011	2012
CO ₂ (kt)	63	47	79
CH ₄ (kt)	0,00	0,00	0,00
N ₂ O (kt)	0,02	0,02	0,03
Total (in kt CO ₂ eq)	71	53	88

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

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.

Railways

Methane emissions were recalculated for the whole time series using the correct emission factor, which by mistake in the previous year submission was multiplied by a factor of 10.

International Bunkers

Marine Bunkers

For marine bunkers, 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.

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.

Aviation

- In the aviation sector, effort is being made to collect data on aircraft fleet composition but we have still major difficulties to be able to apply a more detailed methodology in the next NIR.

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 3.28**) from the mining of lignite in 2012 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 21% increase for the period 1990 – 2012 is observed.

Table 3.28 *CH₄ emissions from lignite mining (in Mt) and primary production of lignite (in kt) for the period 1990 – 2012*

Year	Production (Mt)	CH ₄ emissions (kt)
1990	51.90	52.16
1991	52.70	52.96
1992	55.05	55.33
1993	54.82	55.09
1994	56.67	56.96
1995	57.66	57.95
1996	59.78	60.08
1997	58.84	59.14
1998	60.88	61.19
1999	62.05	62.36
2000	63.89	64.21
2001	66.34	66.68
2002	70.47	70.82
2003	68.30	68.64
2004	70.04	70.39
2005	69.40	69.74
2006	64.52	64.84
2007	66.46	66.80
2008	65.72	66.05
2009	64.89	65.22
2010	56.52	56.80
2011	58.67	58.96
2012	62.96	63.27

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 3.28) used for the calculation of emissions.
- ↳ The typical emission factor (1.5 m³ / t of lignite) suggested by IPCC Good Practice Guidance (IPCC 2000), 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 of emissions was performed.

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 1.01 kgCH₄/t lignite produced (=1.5m³ 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 19 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 836 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 3.29**) from oil and natural gas in 2012 accounted for 0.2% of total GHG emissions from *Energy*. Overall, emissions in 2012 increased by 28% 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 3.30a** and **Table 3.30b** 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 IPCC Good Practice Guidance (IPCC 2000). This methodology, based on a detailed description of the sub-systems comprising oil and natural gas industry, is different from the default methodology described in IPCC Guidelines (IPCC 1997) where emissions are correlated only to energy data.

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 3.30a) 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).

The CH₄ emission factor used for refining and storage derives from IPCC Guidelines (Table 1.58 – Western Europe, IPCC 1997). The CO₂ and CH₄ emission factors used in the rest sub-sources derive from IPCC Good Practice Guidance (Table 2.16, IPCC 2000). In all cases the emission factors are estimated as the average values of the proposed range.

Table 3.29 *GHG emissions (in kt CO₂ eq) from oil and natural gas for the period 1990 – 2012*

Year	Oil	Natural gas	Venting and flaring	LPG transport	Total
1990	42.12	9.59	110.29	0.00	162.01
1991	40.94	9.19	109.70	0.01	159.84
1992	35.83	8.71	92.37	0.01	136.92
1993	29.44	5.70	75.45	0.01	110.58
1994	30.64	0.86	72.99	0.01	104.50
1995	28.52	0.66	65.15	0.01	94.34
1996	33.14	34.44	84.31	0.01	151.90
1997	31.55	42.71	79.29	0.01	153.56
1998	26.29	61.84	67.98	0.01	156.12
1999	13.28	66.23	29.41	0.01	108.93
2000	25.73	71.20	64.67	0.01	161.62
2001	22.26	77.29	56.08	0.01	155.64
2002	21.75	77.00	57.01	0.01	155.76
2003	20.31	86.35	49.17	0.01	155.85
2004	19.74	89.43	49.16	0.01	158.34
2005	18.83	90.25	45.29	0.01	154.37
2006	18.88	98.16	47.82	0.01	164.86
2007	18.17	102.71	46.16	0.01	167.05
2008	16.46	110.27	45.16	0.01	171.90
2009	16.78	117.87	48.30	0.01	182.97
2010	19.89	124.41	54.43	0.03	198.76
2011	16.98	130.61	50.79	0.15	198.52
2012	19.97	133.87	53.71	0.06	207.61

Table 3.30a *Key activity data for the estimation of GHG emissions from oil systems for the period 1990 - 2012*

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

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

- ↳ Activity data for the estimation of emissions (Table 3.30b) 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).
- ↳ Emissions from transmission and distribution of natural gas for the period 1990 – 1995 (domestic natural gas only) are estimated according the Tier 1 methodology described in the IPCC Guidelines, as the available information does not allow for the application of the Tier 1 methodology described in the IPCC Good Practice Guidance. However, the use of natural gas in that period 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 for the period 1996 – 2012 derive from the IPCC Good Practice Guidance (Table 2.16, IPCC 2000).

Table 3.30b *Key activity data for the estimation of GHG emissions from natural gas systems for the period 1990 - 2012*

Year	Primary production		Distribution	Transmission
	Natural gas (10 ⁶ m ³)	Sour gas (%)	Pipeline (km)	Pipeline (km)
1990	123	29%		
1991	116	37%		
1992	109	33%		
1993	81	33%		
1994	38	79%		
1995	36	69%		
1996	38	68%	519	511
1997	37	51%	1000	558
1998	33	61%	1337	837
1999	2	50%	1720	837
2000	36	47%	1870	862
2001	35	46%	1940	960
2002	37	73%	2014	960
2003	27	7%	2751	960
2004	25	20%	2899	960
2005	16	25%	3048	960
2006	23	17%	3196	1072
2007	21	14%	3332	1127
2008	14	21%	3534	1224
2009	11	36%	3849	1271
2010	7	86%	4346	1280
2011	6	67%	4686	1316
2012	6	67%	4794	1348

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 3.31** 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 recalculations were performed.

Table 3.31 *GHG emissions (in t) from venting and flaring for the period 1990 – 2012*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Venting																							
Oil – Production																							
CO ₂	11.99	12.02	9.85	8.04	7.64	6.55	7.4	6.7	4.55	0.23	4.05	2.8	2.79	2.02	1.95	1.61	1.55	1.18	0.89	1.27	1.79	1.54	1.48
CH ₄	1348.88	1352.09	1108.2	904.79	859.52	736.8	832.63	753.86	512.16	25.94	455.84	314.73	314.09	227.42	219.84	181.48	174.1	132.54	99.97	142.52	200.85	173.18	166.17
Oil – Transport																							
CO ₂	39.19	33.32	37.64	31.74	34.81	41.31	47.24	48.4	50.05	42.97	52.21	50.96	51.52	53.32	54.7	50.4	53.46	54.79	51.98	47.92	54.25	44.51	56.54
CH ₄	425.93	362.15	409.17	345.02	378.33	449.07	513.53	526.06	543.99	467.09	567.49	553.87	560.02	579.53	594.62	547.8	581.11	595.58	565	520.88	589.69	483.79	614.57
N.G. – Production																							
CO ₂	2556	3053	2556	1917	2130	1775	1850.34	1353.74	1427.11	78.11	1214.33	1144.16	1925.16	150.16	363.16	292.16	293.11	222.58	223.4	294.8	436.88	295.19	295.46
CH ₄																							
N.G. – Transmission & Distribution																							
CO ₂							8.18	8.93	13.39	13.39	13.79	15.36	15.36	15.36	15.36	15.36	17.15	18.02	19.58	20.33	20.47	21.06	21.57
CH ₄							1608.19	2019.2	2930.86	3152.6	3376.35	3666.7	3650.11	4103.37	4249.79	4291.64	4666.11	4883.35	5245.24	5607.95	5919.9	6215.94	6371.39
Flaring																							
Oil – Production																							
CO ₂	66945	67104	54999	44904	42658	36567	41323	37414	25418	1287	22623	15620	15588	11287	10910	9007	8641	6578	4961	7073	9968	8595	8247
CH ₄	134.89	135.21	110.82	90.48	85.95	73.68	83.26	75.39	51.22	2.59	45.58	31.47	31.41	22.74	21.98	18.15	17.41	13.25	10	14.25	20.09	17.32	16.62
N ₂ O	0.64	0.64	0.53	0.43	0.41	0.35	0.39	0.36	0.24	0.01	0.22	0.15	0.15	0.11	0.1	0.09	0.08	0.06	0.05	0.07	0.1	0.08	0.08
N.G. – Production																							
CO ₂	221.4	208.8	196.2	145.8	68.4	64.8	68.4	66.6	59.4	3.6	64.8	63	66.6	48.6	45	28.8	41.4	37.8	25.2	19.8	12.6	10.8	10.8
CH ₄	1.35	1.28	1.2	0.89	0.42	0.4	0.42	0.41	0.36	0.02	0.4	0.39	0.41	0.3	0.28	0.18	0.25	0.23	0.15	0.12	0.08	0.07	0.07
N ₂ O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N.G. – Processing																							
CO ₂	165.6	197.8	165.6	124.2	138	115	119.6	87.4	92	4.6	78.2	73.6	124.2	9.2	23	18.4	18.4	13.8	13.8	18.4	27.6	18.4	18.4
CH ₄	1.04	1.25	1.04	0.78	0.87	0.73	0.75	0.55	0.58	0.03	0.49	0.46	0.78	0.06	0.15	0.12	0.12	0.09	0.09	0.12	0.17	0.12	0.12
N ₂ O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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 (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 products
- Chemical industry
- Metal production
- Other production
- Production of halocarbons and SF₆
- Consumption of halocarbons and SF₆

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 (4.2 – 4.15) 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 2012, GHG emissions from *Industrial processes* account for 8.66% of total emissions (excluding LULUCF) and have decreased by 25.25% compared to base year emissions and increased by 9.42% compared to the emissions of 1990 (**Figure 4.1**), while the average annual rate of decrease is estimated at -0.14% for the period 1990 – 2012.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2012 reaching a minimum value of 8.72 Mt CO₂ eq in 2011 and a maximum value of 14.72 Mt CO₂ eq in 1999. The low value for 2012 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 the Chart of **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 and about 2,157 kt are removed from the inventory. It should be noted that in 2012 emissions are lower than the ones in 1990, depicting the low production levels of the country.

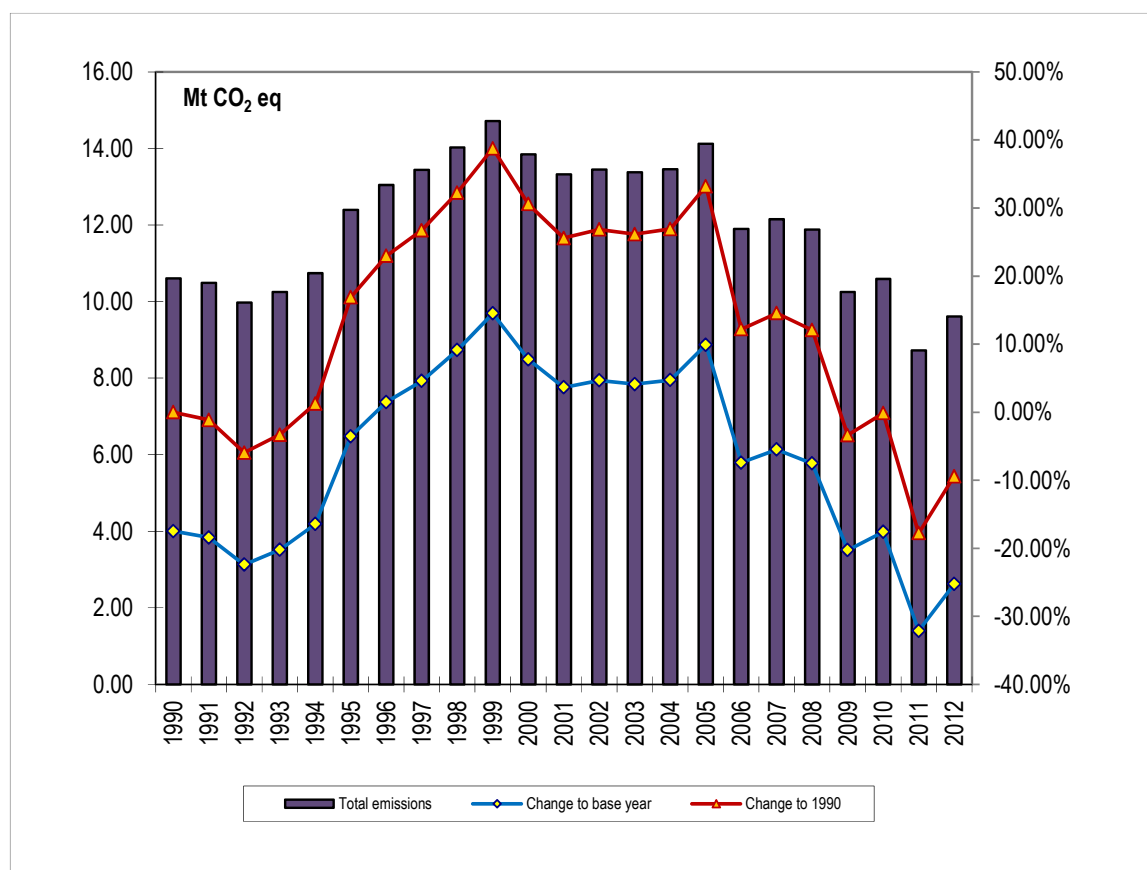


Figure 4.1 *Total GHG emissions (in Mt CO₂ eq) from Industrial Processes for the period 1990 - 2012*

The sector of Industrial Processes 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 54.48% to 79.65%. Overall, CO₂ emissions in 2012 decreased by 36.92% from 1990, with an average annual rate of decrease estimated at -1.68%. CO₂ emissions derive mainly from mineral products.

The contribution of f-gases to total emissions from industrial processes is also very significant, increasing from 10.39% in 1990 to 37.10 % in 1999 (peak). The contribution continues to be important until 2006 where an abrupt decrease is observed (from 29.36% in 2005 to 19.42% in 2006). This abrupt decrease is totally due to the cease of HCFC-22 production in 2006 (the contribution of emissions from HCFC-22 to total F-gases emissions was 52.02% in 2005). In the recent years (2006-2010) the trend is again increasing, following the substitution of CFCs according to the protocol of Montreal. In 2011 a slight decrease was observed mainly due to the decrement in disposal emissions and the introduction of recovery of f-gases while in 2012 the trend is again an increasing one.

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2012, with an average annual rate of change of -4.90%. In 2012 compared to 2011 this trend accounted for 35.43% decrease, in accordance with the economical recession (directly related to the reduction in the nitric acid production).

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 -2.63% for the period 1990-2012.

Table 4.1 *GHG emissions (in kt CO₂ eq) per gas from industrial processes for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO ₂	8,394.22	8,296.07	7,943.70	7,637.79	7,647.93	8,169.12	8,171.60	8,349.57	8,583.54	8,503.30	8,725.13	8,746.83
CH ₄	0.73	0.76	0.71	0.76	0.75	0.80	0.80	0.84	0.82	0.53	0.47	0.27
N ₂ O	1,109.04	914.40	956.20	908.04	882.84	878.50	1,003.21	881.10	725.06	752.96	771.07	648.08
HFC	935.06	1,106.82	908.39	1,606.74	2,144.05	3,290.41	3,817.88	4,097.77	4,579.60	5,365.79	4,243.67	3,849.15
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09	71.16
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06
TOTAL	10,605.49	10,485.38	9,973.47	10,253.66	10,739.40	12,396.38	13,043.32	13,440.67	14,025.84	14,716.77	13,849.43	13,319.55

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂	8,651.25	8,821.03	8,842.51	9,432.35	9,146.10	9,048.41	8,411.27	6,462.60	6,447.55	4,751.31	5,294.94
CH ₄	0.39	0.36	0.41	0.48	0.51	0.54	0.52	0.42	0.38	0.41	0.26
N ₂ O	623.93	575.90	547.53	545.80	442.70	439.53	422.30	367.42	428.39	475.47	307.01
HFC	4,098.81	3,901.17	3,990.80	4,066.71	2,231.52	2,569.37	2,950.25	3,338.70	3,603.28	3,410.13	3,889.05
PFC	73.57	76.90	73.42	74.32	70.77	80.64	93.53	74.28	105.55	78.34	110.39
SF ₆	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14	5.15	5.11
TOTAL	13,452.19	13,379.60	13,459.15	14,126.12	11,899.96	12,148.40	11,885.40	10,248.68	10,591.29	8,720.81	9,606.76

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. In 2012 an increase was also noticed mainly due to the increased production of cement. As a result the contribution of GHG emissions from mineral sources and HFC production to the total sector emissions decreases from 72.95% in 1990 to 38.94% in 2012.

The contribution of halocarbons consumption to total emissions from the sector has increased considerably in the recent years (41.16% in 2012 against 0.33% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons. However, in 2012 emission increased by 14.48% compared to 2011.

Metal Industry in general has a stable contribution to the Emissions of Industrial Processes (10.41% in 1990 versus 11.48% in 2012).

Finally, the contribution of emissions from the chemical production decreases from 16.61% in 1990 to 8.42% in 2012. 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.

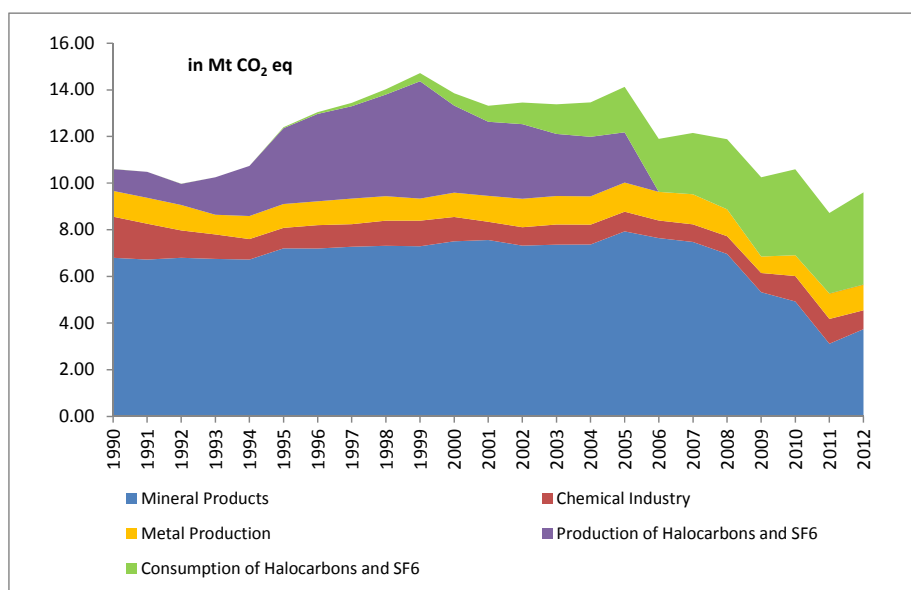


Figure 4.2 *GHG emissions (in Mt CO₂ eq) from Industrial processes per main source category for the period 1990 – 2012*

4.1.2 Methodology

The calculation of GHG emissions from Industrial processes is based on the methodologies described in Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, the 2000 IPCC Good Practice Guidance, the 2006 IPCC Guidelines and the EMEP/CORINAIR Emission Inventory Guidebook 2009. 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 *Consumption of Halocarbons and SF₆* subcategory, the emission factors used are selected by the default range provided in the GPG and 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 IPCC Guidelines and the IPCC Good Practice Guidance 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 2005-2012). It should be noted that in some cases (cement production, hydraulic lime production, glass production, ammonia and 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 *Consumption of Halocarbons and SF₆*, 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. The data provided by the Appliances Recycling SA regarding the recycling amount of f-gases in refrigeration and air-conditioning have been introduced for the first time in the previous inventory preparation, following the Improvement Plan of 2012. As regards to the foam blowing and aerosols subcategories data have been continue to collected by the respective producing industries. It should be noted that private Insulating Companies that are related to

the sales of equipment containing foams have been contacted for the first time in the previous submission in order to evaluate possible imports of equipments containing foams.

- ✎ 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 – 4.15).

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 products	CS, T1	CS, PS, D, OTH						
Chemical industry	T1, T1a	CS	T1	D	D	D		
Metal production	CS, T1	CS, PS	CR	CR			T3	PS
Production of F-gases							T1	D
Consumption F-gases							T2, CS	D, CS

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

Key categories

The key categories for 2012 (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 2012*

Source category	Gas	Level assessment	Trend assessment
Cement production	CO ₂	☒	☒
Lime production	CO ₂		☒
Limestone and dolomite use	CO ₂		☒
Nitric acid production	N ₂ O		☒
Other Chemicals	CO ₂		☒
Ferroalloys production	CO ₂	☒	
Ammonia production	CO ₂		☒
Consumption of halocarbons and SF ₆ (ODS Substitutes)	HFC	☒	☒

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:

- In Category 2.A.1 a recalculation has been performed using the overlap methodology in order to include emissions from non-carbonate carbon sources (TOC) for the years before 2008.
- Emissions from lignite used for ammonia production during years 1990-1991 have been reallocated from the Energy Sector (1.A.2.c) into the Industrial Processes Sector, as one of the two plants operating in Greece used only lignite as feedstock for these two years.
- 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 *organic chemicals production* and *asphalt roofing-road paving with asphalt*). *Potential Emissions from the Consumption of Halocarbons and Sf₆* are not estimated up to the present due to lack of data. In the framework of the recent collaboration with the National Association of Refrigeration Importing & Trading Companies, information on

the imports and exports of gases has been sought. However, for the time being the coverage of the sector is not complete and therefore such information cannot be properly reported.

Table 4.4 Industrial processes – Completeness

	CO ₂	CH ₄	N ₂ O	HFC	PFC	SF ₆		
A. Metallic minerals								
1. Cement production	☒							
2. Lime production	☒							
3. Limestone and dolomite use	☒							
4. Soda ash production and use	NO/☒							
5. Asphalt roofing	NE							
6. Road paving with asphalt	NE							
7. Other								
Glass production	☒	NA	NA					
B. Chemical industry								
1. Ammonia production	☒	NA	NA					
2. Nitric acid production			☒					
3. Adipic acid production	NO		NO					
4. Carbide Production	NO	NO						
5. Other								
Sulphuric acid production	NA	NA	NA					
Organic chemicals production	NA / NE	☒ / NO	NA					
Hydrogen Production	☒	NA	NA					
C. Metal production								
1. Iron and steel production	☒	☒						
2. Ferroalloys production	☒	NA						
3. Aluminium production	☒	NA						☒
4. SF ₆ used in aluminium and magnesium foundries								
D. Other production								
1. Pulp and paper								
2. Food and drink	NA							
E. Production of halocarbons and SF ₆								
1. Production of HCFC-22				☒ , NO				
2. Fugitive				NO	NA, NO	NO		
F. Consumption of halocarbons and SF ₆								
1. Refrigerating and air conditioning equipment				☒	☒	NO		
2. Foam blowing				☒	NO	NO		
3. Fire extinguishers				☒	NA, NO	NA		
4. Aerosols/metered dose inhalers				☒	NO	NO		
5. Solvents				NA, NO	NO	NA		
6. Semiconductor manufacture				NO	NO	NO		
7. Electrical equipment				NO	NO	☒		

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 2012 (**Table 4.5**) accounted for 32.26% of total GHG emissions from industrial processes and for 2.87 % of total national emissions including *LULUCF* (2.79% of total national emissions excluding *LULUCF*). The average annual rate of decrease of CO₂ emissions from cement production during the period 1990 – 2012 was -1.88% (emissions decreased by 46.21% from 1990 to 2012).

Table 4.5 *CO₂ emissions from cement production (in kt) and clinker production (in kt) for the period 1990 - 2012*

Year	Clinker production (kt)	CO ₂ emissions (kt)
1990	10645.13	5761.69
1991	10561.81	5715.77
1992	10831.27	5861.14
1993	10851.82	5875.03
1994	10930.92	5916.41
1995	11743.73	6356.39
1996	11773.82	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

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 2005-2012 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 2012 the average content of the raw materials in CaCO₃ and MgCO₃ has been estimated at 74.34% and 2.54%, whereas the emission factor used is 0.44 and 0.522, respectively, deriving from the stoichiometry of the reaction. Also, the raw material used throughout 2012 was 9,011.15kt.

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.

In the recent years (2008 – 2012) 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 0.18%) and the respective emissions constituted the 1.91% of total emissions from cement production. In 2014 submission, there is 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.

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 2012 the percentage of CaO and MgO content in the clinker was reported 58.14% and 2.04%, respectively.

For reasons of consistency between both the previous years and the other countries, the activity data of the more recent years (2005-2012) 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 a slight increase in emissions is observed compared to 2011, which however no safe projection can be made for the years to come in the current unstable economical circumstances.

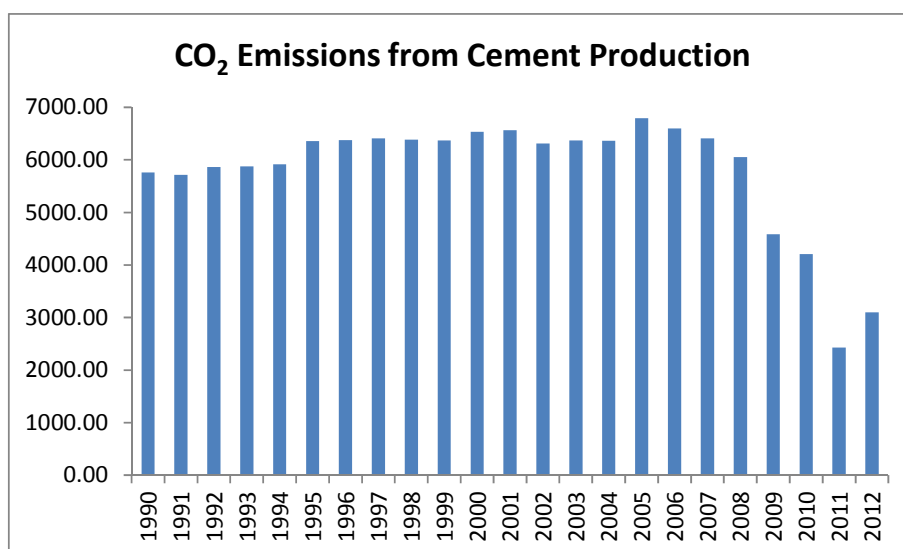


Figure 4.3 *CO₂ emissions (in kt) from Cement Production for the period 1990 – 2012*

Table 4.6 *Country specific CO₂ emission factor (in t / t) for clinker (cement) production for the period 1990 – 2012*

Year	Emission factor (t CO ₂ / t clinker)
1990	0.5413
1991	0.5412
1992	0.5411
1993	0.5414
1994	0.5413
1995	0.5413
1996	0.5414
1997	0.5416
1998	0.5415
1999	0.5413
2000	0.5415
2001	0.5413
2002	0.5412
2003	0.5418
2004	0.5414
2005	0.5458
2006	0.5390
2007	0.5323
2008	0.5328
2009	0.5297
2010	0.5309
2011	0.5319
2012	0.5292

During the years 1990-2005, emissions show some low level fluctuations (**Figure 4.3**). 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 and 2012. This is also verified by the decreased number of new constructions in the recent years.

The IEF of 2012 is close to the mean IEF of the previous years (0.5292 versus a mean of 0.5388), probably because of the fact that the carbonates percentage of the raw materials is close to the

mean values of previous years (*Table 4.6-4.7*). The average CaO and MgO content of clinker, as well as the percentage of CaO/MgO, for the years 2005-2012, as provided by the plants, is presented in *Table 4.7*. 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 4.7 *CaO and MgO content of clinker (2005-2012)*

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	54.20	1.70	31.86

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. However it should be mentioned that the national Prodcum data are provisional and have been provided confidentially to the Inventory Team, since they are not yet officially published.

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. All data seem to agree that the recent trend is decreasing, especially for the years after 2008.

4.2.5 Recalculations

During the 2014 submission emissions from non-carbonate carbon sources (TOC) for the years before 1990-2008 were included and therefore a recalculation, using the overlap methodology, was used. This way the whole time series was updated improving the time-series consistency.

The average difference between the previous and the current estimates and the impact on total emissions from the IP sector are -2.14%, for years 1990-2007. The impact on total emissions excluding *LULUCF* is 0.12%.

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 mainly based on limestone.

CO_2 emissions from lime production in 2012 (*Table 4.8*) are a key source by trend assessment and accounted for 2.17% of total GHG emissions from *Industrial processes* and for 0.19% of total national emissions (including *LULUCF*). Emission factors are characterized by fluctuations, mainly because of the difference between plant-specific data and ElStat data. The average annual rate of decrease of CO_2 emissions from lime production, for the period 1990 – 2012, is estimated at - 2.37%.

Table 4.8 *CO₂ emissions (in kt) from lime production and production of lime (in kt) for the period 1990 - 2012*

Year	CO ₂ emissions (kt)	IEF	Lime production(kt)
1990	404.00	0.823	491.03
1991	391.78	0.823	476.17
1992	379.55	0.823	461.31
1993	362.95	0.821	442.00
1994	351.25	0.821	427.58
1995	362.35	0.820	442.12
1996	370.07	0.819	452.06
1997	377.57	0.812	464.71
1998	414.33	0.814	508.92
1999	445.77	0.824	540.98
2000	411.17	0.826	497.93
2001	394.81	0.826	477.76
2002	408.84	0.825	495.27
2003	359.59	0.826	435.56
2004	359.45	0.825	435.79
2005	403.16	0.779	425.81
2006	408.85	0.836	489.30
2007	468.98	0.844	555.97
2008	341.76	0.758	451.11
2009	288.78	0.758	380.77
2010	229.96	0.700	328.64
2011	193.00	0.732	263.64
2012	208.54	0.765	272.66

4.3.2 Methodology

For years 2005 – 2012, 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 480.41 kt of $CaCO_3$ eq for the production of lime in 2012. 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 EISat for the years 1993-2012, whereas for the years 1990-1993 the missing data have been calculated using the trend extrapolation method as described in the IPCC GPG. It should be noted that the 2012 values are provisional, since the Prodcom file has not been publicly available yet. Hydraulic lime data for 2008-2012 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 EISat 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 2010 and 2011 the $CaCO_3$ content of the raw material was 94.62% and 94.09% and , while for 2012 the calcium carbonate content was 93.73% (**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%.

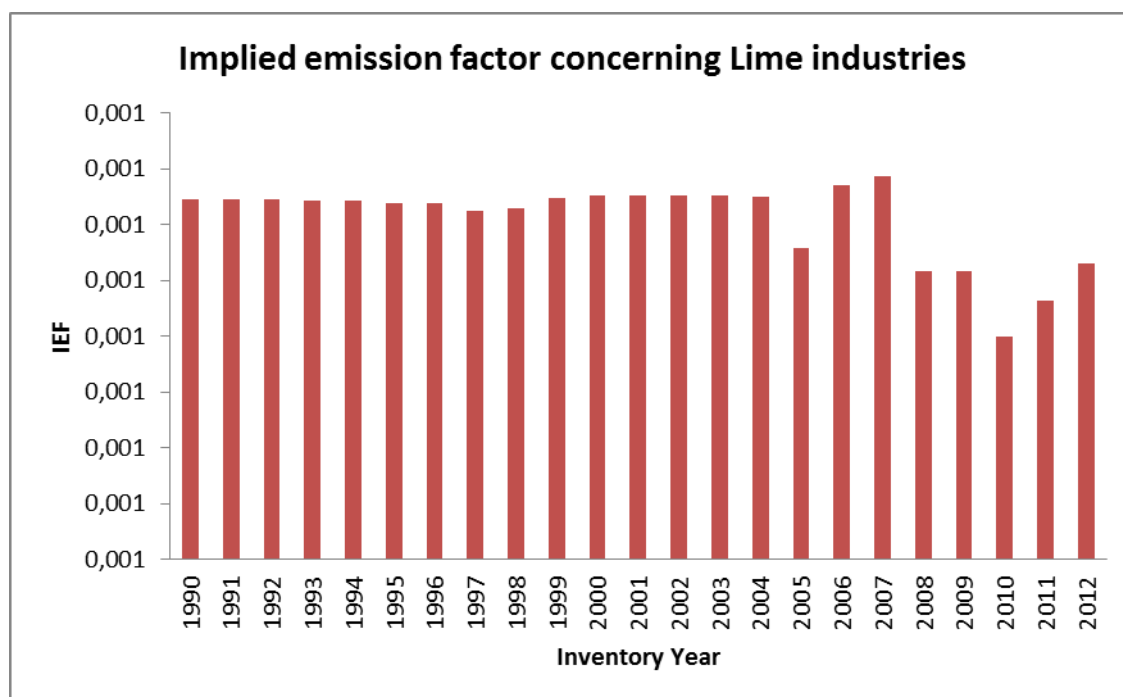


Figure 4.4 *Implied emission factors for lime production) for the period 1990 – 2012*

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. As regards to intermediate production of lime in the metal industry, it is only the aluminium industry that produces CaO by limestone and these emissions are reported under the Limestone and Dolomite Use category. Among the steel industries there is no lime production activity reported. 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.

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.

The use of these data has resulted in a quite different IEF for years 2008-2012 than the one used in the previous years. Comparing to the default factors the above mentioned factor is in an accepted range and is 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. Activity data are being reported both by the plants and ElStat and they are cross checked wherever possible, throughout the timeseries.

4.3.5 Recalculations

No recalculation of emissions was performed.

4.3.6 Planned improvements

The current submission can be considered satisfactory.

4.4 Limestone and dolomite use (CRF Source Category 2.A.3)

4.4.1 Description

Limestone (CaCO_3) and dolomite ($\text{CaCO}_3 \cdot \text{MgCO}_3$) are basic raw materials having commercial applications in a number of industries including metallurgy (e.g., iron and steel), glass manufacture, agriculture, construction and environmental pollution control. In industrial applications involving the heating of limestone or dolomite at high temperatures, CO_2 is generated.

CO_2 emissions from limestone and dolomite use is a key category by trend assessment, according to the results of the key analysis carried out in the present inventory. Emissions in 2012 (**Table 4.9**) accounted for 4.17% of total GHG emissions from *Industrial processes* and for 0.37% of total national emissions (excluding *LULUCF*).

Table 4.9 *Limestone use (in kt) and CO₂ emissions (in kt) for the period 1990 – 2012*

Year	Limestone & magnesite consumption (kt)	CO ₂ emissions (kt)	IEF
1990	1,249.40	582.80	0.47
1991	1,215.96	563.20	0.46
1992	1,108.94	510.54	0.46
1993	1,006.80	466.33	0.46
1994	872.18	406.25	0.47
1995	938.32	439.93	0.47
1996	864.36	402.99	0.47
1997	948.03	442.40	0.47
1998	1,013.40	471.31	0.47
1999	949.46	439.59	0.46
2000	1,111.23	512.37	0.46
2001	1,195.47	549.56	0.46
2002	1,200.82	553.92	0.46
2003	1,287.63	588.84	0.46
2004	1,325.62	605.06	0.46
2005	1,561.11	698.86	0.45
2006	1,282.33	596.60	0.47
2007	1,236.00	577.73	0.47
2008	1,178.90	545.21	0.46
2009	948.24	431.03	0.45
2010	1,017.04	457.50	0.45
2011	1,039.66	462.05	0.44
2012	902.35	400.48	0.44

4.4.2 Methodology

The present inventory includes emission estimates from limestone use in metal production (iron & steel and primary aluminium), SO₂ scrubbing, magnesia and ceramics production.

CO₂ emissions are estimated according to the following general equation:

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

where, CO_2 emissions refer to the emissions from iron & steel, primary aluminium and ceramics, 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 CO_2 emissions from limestone and dolomite use, the following are noted:

- ✎ **Steel production:** Data are generally plant specific, deriving from the EU ETS verified reporting of the plants (for the years 2005-2012) and the reporting performed for the NAP formulation in the previous years. For 2012, the total CaCO_3 equivalent amounts to 8.72 kt. The abrupt reduction in emissions since (resulting from 18.52 kt CaCO_3 eq.) can be attributed to the cease of operation of one big plant in Greece.
- ✎ **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 CaCO_3 . Plant specific data on limestone consumption cover the years 1990 and 1998 – 2012. The specific limestone consumption has been used for filling in missing data. In 2012 the limestone consumption amounts to 53.66 kt of CaCO_3 eq, while in 2011 it was 117.04 kt of CaCO_3 eq.
- ✎ **Ceramics production:** Carbonates consumption data (in the context of the ETS reports) have been used to estimate emissions in the years 2005-2012. 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 2012 amounts to 68.11 kt, showing a decrease with reference to 2011 (99.66 kt). It is also interesting that sixteen ceramics plants have declared zero emissions in 2012, 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.
- ✎ **SO_2 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 2005-2012 data from verified installation ETS reports were used. The emission factor used (0.44 t CO_2 / t limestone) derives from the stoichiometry of the reaction. Emissions have slightly increased in 2012, having an annual increase in emissions of 3.25%.
- ✎ **Magnesia production:** Emissions are estimated using information for the single plant operating in Greece for the years 1999-2012 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 2005-2012: 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.

Figure 4.5 summarizes the contribution of the above mentioned sub-categories in the Limestone and Dolomite use category, depicting the annual variations in CO₂ emissions.

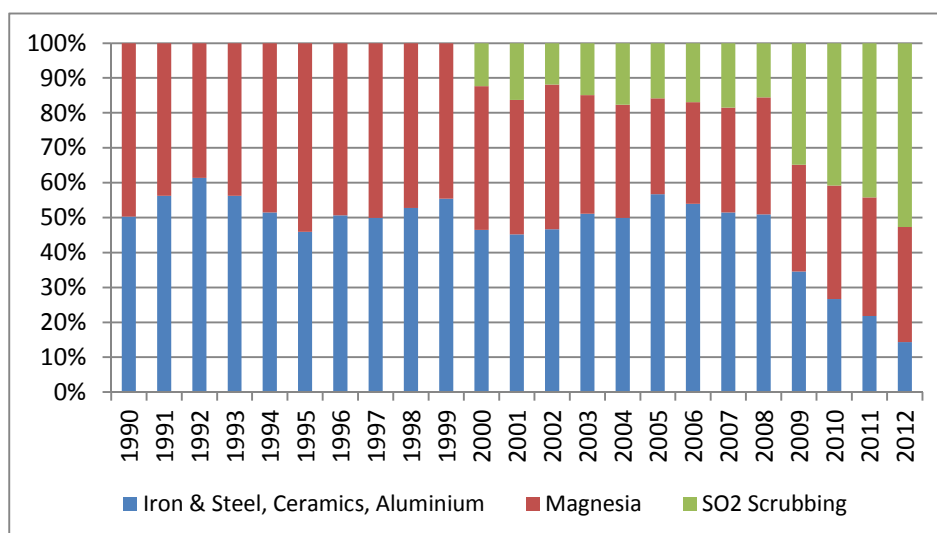


Figure 4.5 *Contribution of each subcategory of the Limestone and Dolomite use category for the period 1990 – 2012*

4.4.3 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. 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. It should be mentioned that in 2012 the respective decrease in emissions in the Ceramics Sector is -27.4%, affecting the overall decrease of the category's emissions by 13.33%.

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 (2005-2012), the deviation from the stoichiometric one is attributed to

the fact that in the years that magnesia 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 1999-2012*

Subcategory	EF Range (Years 1999-2012)
Primary aluminium Production	0.437-0.44
Steel Production	0.435-0.446
SO ₂ scrubbing	0.44
Ceramics	0.428-0.453
Magnesia Production	≈0.491

4.4.4 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 magnesia production).

Especially for the magnesia production data have been available by different sources that include National Statistics, a PhD thesis that includes production data of previous years and available information from the Greek Mining Enterprise Association. The different sources generally agree, mainly due to the low number of the respective industries.

4.4.5 Recalculations

No recalculation has been performed, during this submission.

4.4.6 Planned improvements

The current submission can be considered satisfactory.

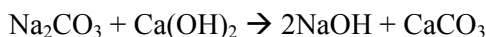
4.5 Soda ash use (CRF Source Category 2.A.4.2)

4.5.1 Description

Carbon dioxide is considered to be emitted during the soda ash use.

In specific, soda ash may be used in:

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

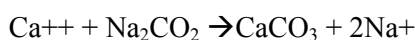


(In Greece is more possible that NaOH is directly purchased by the plants)

b. desulphurization of fuels

All the Greek plants use limestone in the SO₂ scrubbing process, as it is already reported in the respective ETS reports (see also paragraph 4.4).

c. as a 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 CaCO₃ is in the form of sediment that precipitates. In these cases there are no CO₂ emissions.

d. in detergents

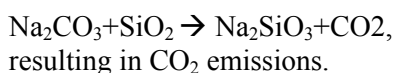
In this case soda ash is used for three reasons:

- 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 CO₂ 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:



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.7.1 and described in Paragraph 4.6)

CO₂ emissions from soda ash are not a key source. In 2012 CO₂ emissions from soda ash have decreased by 48.69% compared to 1990 levels (**Table 4.11**), representing 0.18% of GHG emissions from *Industrial processes* and 0.02% of total GHG emissions (including *LULUCF*).

4.5.2 Methodology

Emissions from soda ash use are estimated based on the default methodology described in the 1996 IPCC Guidelines.

With regards to the implementation of the methodology the following should be mentioned:

- ✎ 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.

Table 4.11 *Soda ash (in kt) and CO₂ emissions (in kt) for the period 1990 - 2012*

Year	Soda ash consumption (kt)	Soda ash use in Glass production (kt)	Soda ash use for other uses (kt)	CO ₂ Emissions (kt)
1990	101.25	21.33	79.92	33.16
1991	98.10	19.69	78.41	32.54
1992	94.95	15.38	79.58	33.02
1993	91.80	14.69	77.12	32.00
1994	88.66	14.05	74.61	30.96
1995	85.51	13.41	72.10	29.92
1996	82.36	12.76	69.60	28.88
1997	79.21	12.12	67.09	27.84
1998	73.51	11.48	62.02	25.74
1999	61.71	10.84	50.87	21.11
2000	54.74	10.25	44.49	18.46
2001	76.29	17.31	58.98	24.48
2002	70.71	17.97	52.73	21.88
2003	69.81	14.91	54.90	22.79
2004	65.36	16.36	49.00	20.33
2005	65.89	15.17	50.71	21.05
2006	66.50	14.76	51.75	21.48
2007	31.46	18.78	12.69	5.27
2008	32.59	19.79	12.80	5.31
2009	36.46	13.20	23.26	9.65
2010	50.43	17.03	33.39	13.86
2011	55.50	10.26	45.24	18.77
2012	57.37	16.36	41.01	17.02

↪ 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 2005-2012 the consumption is estimated based on the data provided by the one plant operating in Greece.

-For years 2000-2004, 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 2000 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 1990-1992, 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 2005-2012 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).

4.5.3 Uncertainty and time-series consistency

The estimated uncertainty concerning soda ash use category is 10% for activity data, since national imports and exports data are being used, and 5% for the EF, to account for the fact that in reality not all soda ash consumption results in emissions, as described in paragraph 4.5.1.

The trend of the timeseries with reference to Soda Ash Consumption quantities can be viewed in **Figure 4.6**. 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 by 2006 there is only one left operating in Greece. This results in trend changes. There is no specific information on the other uses of soda ash, but it is considered that they refer to subcategories c, d and e, based on the list described in paragraph 4.5.1.

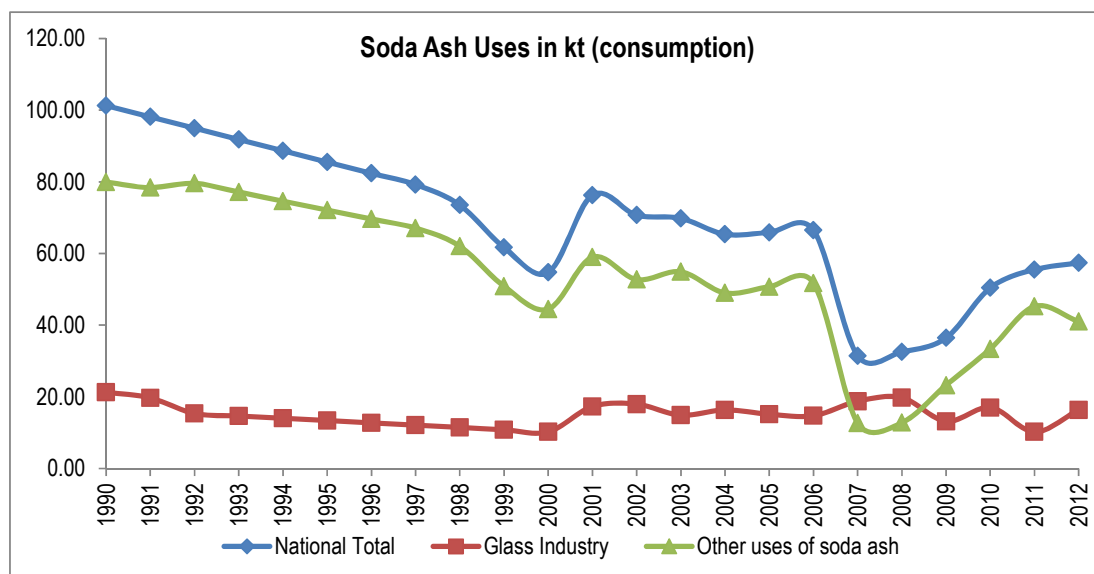


Figure 4.6 Soda ash consumption (in kt) for the period 1990 – 2012

4.5.4 Source specific QA/QC and verification

No specific QA/QC processes are being implemented, apart from the verification of the ‘consumption in glass’ trend with the national glass production. This is caused by the absence of highly detailed data and is in line with the low emissions of the category.

4.5.5 Recalculations

No recalculations were needed during this submission.

4.5.6 Planned improvements

The current submission can be considered satisfactory for the time being. In case any new data become available, they will be filled in as soon as possible.

4.6 Glass production (CRF Source Category 2.A.7.1)

4.6.1 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 2012 have decreased by 22.81% compared to 1990 levels (*Table 4.12*), represent 0.16% of GHG emissions from *Industrial processes* and 0.01% of total GHG emissions (including *LULUCF*).

4.6.2 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 Na_2CO_3 , Ca_2CO_3 and K_2CO_3 with emission factors 0.415, 0.44 and 0.522, respectively. The implied emission factor for 2012 is 0.13 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 left for the years 2007-2012. Also for the years 2005-2012 the reports in the EU ETS context have been extensively used.
- ✎ Activity data (glass production) for the period 1990 – 1992 are provided by the EIStat, 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 4.12 **Glass production (in kt) and CO₂ emissions (in kt) for the period 1990 - 2012**

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	11.39
2012	116.01	15.59

4.6.3 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 method. 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 the **Figure 4.7**, 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 study¹⁴, 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.
- ⇒ 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 2011 there was a decrease in CO₂ emissions of 24.86%, which followed the decrease in production (-22.90%). Especially, for 2011 the cullet ratio used was 8.47% higher than the one used in 2010.
- ⇒ In 2012 an increase in CO₂ emissions of 36.84% was observed, in accordance with the increase in production 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.

¹⁴Development of nine (9) market surveys for SMEs, Sector: “Glass Manufacture and Glass Products”. EOMMEX

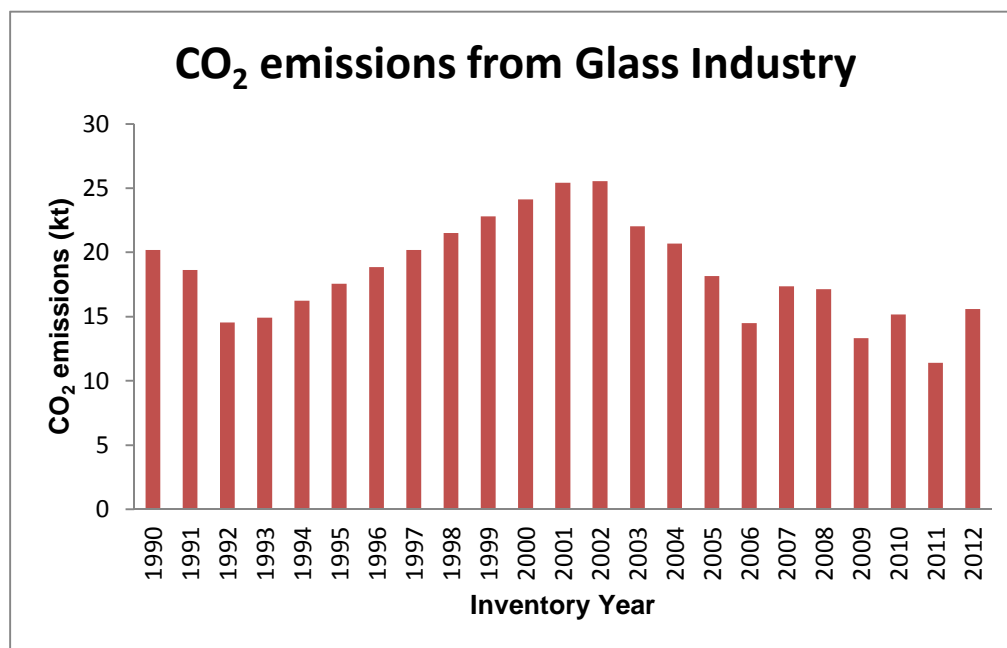


Figure 4.7 *CO₂ emissions (in kt) from Glass Production for the period 1990 – 2012*

4.6.4 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 closed 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, 2008-2012. 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.

4.6.5 Recalculations

No recalculations have been performed in the 2014 submission. This is in line with the conclusions made by the ERTs in 2012 in country review.

4.6.6 Planned improvements

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

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

4.7.1 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 have been reallocated during this submission from the Energy Sector (1A2c) into the Industrial Processes Sector. It should also be mentioned that both plants were closed during year 1994.

CO₂ emissions from ammonia production are a key category by trend assessment. CO₂ emissions have decreased by 72.59% since 1990 and have decreased by 31.91% since 2011, representing 1.86% of GHG emissions from *Industrial processes* and 0.17% of emissions from total GHG emissions (including *LULUCF*).

4.7.2 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 t C/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 basing 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. The CC of imported NG per year is presented in **Table 4.13**.
- The carbon oxidation factor is assumed to be 100%.

Table 4.13 *Carbon Content of imported NG for years 1997-2012*

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

Table 4.14 *Ammonia production, natural gas consumption and CO₂ emissions for the period 1990 - 2012*

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	NO	0.00	NO
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	300.84
2011	157.59	4728.78	262.51
2012	106.69	3214.67	178.73

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. National ammonia production for the whole time-series has been provided by the El.Stat. and for the years 1998-2012 by the one plant still operating in Greece. All the activity data and the estimated emissions are presented in *Table 4.14*.

4.7.3 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, as described in paragraph 4.6.4.

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 2010 (300.84 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 (1.805 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 4.14*). Any other change of the IEF is attributed to the CC and consumption of natural gas.

4.7.4 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 IPCC 1996 Guidelines is 1.6 t CO₂/t ammonia produced for Canada and 1.5 t CO₂/t ammonia produced for Norway. Both values are lower to the

estimated IEF, however according to other sources the country specific emission factor is in the range of reported emission factors. This can be clearly seen in **Figure 4.8**.

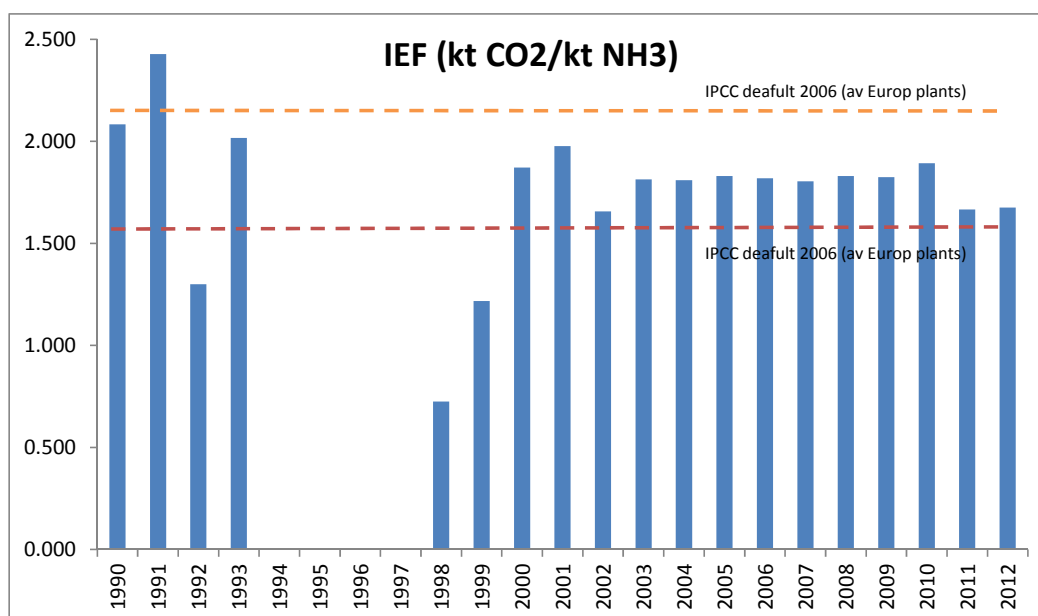


Figure 4.8 *Fluctuation of the IEF in the inventory years*

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 (Prodcum department, confidential data) and the Ministry of Development, Competitiveness, Infrastructure, Transport & Networks 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.

4.7.5 Recalculations

An error in data files was observed for 2011 CO₂ emissions. The natural gas carbon content was updated leading to a slight increase in emissions by 0.49%.

Emissions from lignite used for ammonia production during years 1990-1991 have been reallocated from the Energy Sector (1A2c) into the Industrial Processes Sector, according to the recommendation of the ERT team, as Plant B used only lignite as fuel for these two years. The change in emissions is for 1990 from 240.28 kt CO₂ to 652.04 kt CO₂ and for 1991 from 229.59 kt CO₂ to 620.50 kt CO₂. This led to this category being characterized as a key category by trend assessment for this year. The impact on total emissions excluding LULUCF was -0.39 and -0.37 respectively.

In order to calculate the emissions for the missing years, communication with the one plant operating in Greece was performed in order to specify the liquid fuels used by the second plant. No recalculation has been completed for the moment, but it will be included in next submissions, as soon as adequate data become available.

4.7.6 Planned improvements

Up to now the methodology used is Tier 1a and the EF is country or plant specific. However, Greece would like to kindly indicate that the corresponding methodology is the higher available in the 1996 IPCC Guidelines.

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.

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

4.8.1 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 (N₂O emissions) is a key category by trend assessment. Nitrous oxide emissions from nitric acid production in 2012 (*Table 4.15*), account for 3.20% of total GHG emissions from *Industrial Processes* and for 0.28% of total national emissions (without LULUCF). Emissions in 2012 have decreased by 72.32% from 1990 and decreased by 35.43% since 2011.

4.8.2 Methodology

N₂O emissions from nitric acid production are estimated according to the following equation (default methodology, IPCC 2000):

$$E = P \cdot EF \cdot (1 - D \cdot U)$$

where, E is N₂O emissions, P is nitric acid production, EF is the emission factor, D is the N₂O destruction factor and U is the abatement system utilisation factor on an annual basis.

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

- 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.)

Table 4.15 *Nitric acid production (in kt) and N₂O emissions (in kt) for the period 1990 – 2012*

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

- 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 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 *D* and *U* parameters in the above mentioned equation are not considered.

4.8.3 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. In specific, the plant has communicated to the inventory team that

no further knowledge of the possibility of the unintentional N_2O production is available at the time being. 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 in line with IPCC guidelines. In the case of nitric acid production, the default methodology has been used for the whole time-series.

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.

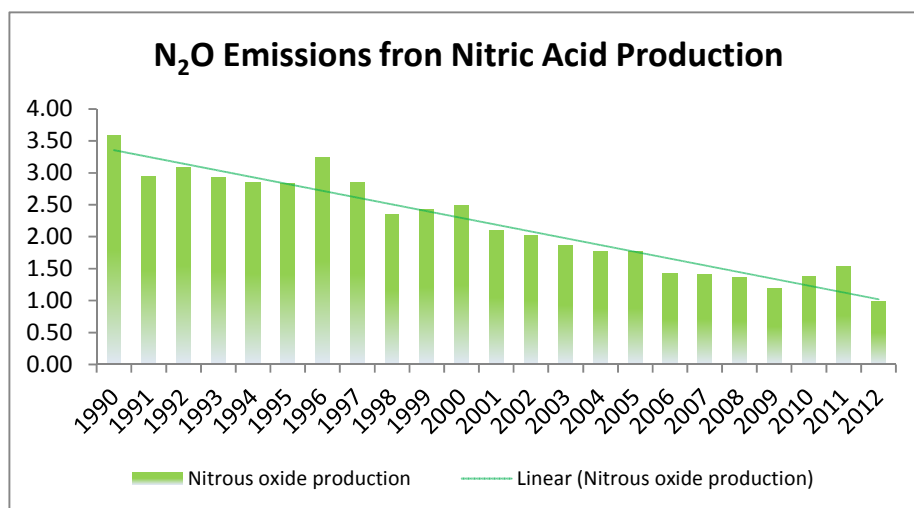


Figure 4.9 *N₂O emissions (in kt) from Nitric Acid Production for the period 1990 – 2012*

4.8.4 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. For the time being, the available data does not allow the estimation of the emissions with an alternative Tier.

Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat and the Ministry of Development, Competitiveness, Infrastructure, Transport & Networks, 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. The Ministry of Development, Competitiveness, Infrastructure, Transport & Networks is also collecting information on the production of HNO₃ in the context of Industrial Activity Reports; however the frequency of the reporting is not always standard. As a result, the use of the specific source for the running of additional QC checks is performed on the basis of data availability.

4.8.5 Recalculations

No recalculations have been performed during the 2014 submission. This is in line with the 2013 ERT report, as no abatement technique is installed in the operating unit.

4.8.6 Planned improvements

Although this category is a key one, it has not been included in the Improvement Plan. This is justified by the fact that the current category is a key one due to the continuous decrease of nitric acid production for the previous years and, thus, the bearing of cost of additional measurements, which are required by higher Tier methodologies, seems quite irrational to the plant at present. However, the plant has reported its intention to implement some abatement technique in the future, however there is no detailed information available in the moment.

The inventory team would also like to indicate that the implementation of the default methodology is in line with the IPCC GPG, and emissions have been estimated using information regarding the categorization of the plant type (the plant operates under medium pressure) and the selection of the appropriate N₂O generation factor. For these reasons, the current submission can be considered satisfactory.

4.9 Production of other chemicals (CRF Source Category 2.B.5)

4.9.1 Description

CH₄ 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. CO₂ emissions from Hydrogen production are also 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.

Production of other chemicals (CO₂ emissions) is a key category by trend assessment. The contribution of CO₂ emissions from Hydrogen Production account for 3.37% of the *Industrial Processes* emissions and for 0.29% of *Total Emissions* (excl LULUCF) for 2012, showing an increase of 0.44% from 2011.

With regards to CH₄ emissions, their contribution to total GHG emissions from *Industrial Processes* is less than 0.01% for the period 1990 – 2000. By 2001 no emissions are reported due to the cease of ethylene and 1,2 dichloro-ethane production in Greece in 1998 and 2000, respectively. **Table 4.16** presents the emissions from Other Chemical Production.

Table 4.16 *Emissions from Other Chemical Production (in kt) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO ₂ emissions	NO	NO	NO	NO	NO	NO	NO	83.17	173.51	60.85	NO	NO
CH ₄ emissions	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	NO
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
CO ₂ emissions	9.75	14.21	15.06	33.62	21.34	18.78	107.69	265.65	362.13	321.88	323.29	
CH ₄ emissions	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	

4.9.2 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 2005-2012. 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 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*

Year	1997	1998	1999	2000	2001	2002	2003	2004
NG Consumption (TJ)	1,509.38	3,149.11	1,104.06	0.00	0.00	176.05	256.52	271.72
CC (t C/TJ)	15.03	15.03	15.03	15.03	15.10	15.10	15.11	15.11
EF (t CO ₂ /TJ) (Oxid Fact=100%)	55.10	55.10	55.11	55.12	55.37	55.38	55.39	55.41
Year	2005	2006	2007	2008	2009	2010	2011	2012
NG Consumption (TJ)	607.30	385.44	339.15	1,942.69	4,785.09	6,459.80	5,745.16	5,766.52
CC (t C/TJ)	15.10	15.10	15.10	15.12	15.14	15.29	15.28	15.29
EF (t CO ₂ /TJ) (Oxid Fact=100%)	55.37	55.37	55.38	55.43	55.52	56.06	56.03	56.06

CH₄ emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

$$(\text{Emissions}) = (\text{Production}) * (\text{Emission factor})$$

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

- ✎ Default emission factors (IPCC Guidelines) are used.
- ✎ Activity data (production of ethylene and 1,2 dichloro-ethane) are confidential and provided by the ElStat. The available data cover the period 1990 – 2007, whereas the ethylene and 1,2 dichloro-ethane production has ceased in 1998 and 2000 respectively.

4.9.3 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.

With reference to CH₄ emissions, the inventory team has used the default emission factor as reported in IPCC Guidelines, whereas the production data are provided by the ElStat. To account for both uncertainties type the value of 5% has been considered.

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. 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.

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. The time-series show an important decrease from year 1998 to 1999 due to the cease of the ethylene production. After 2000 CH₄ emissions have been zeroed, as a result of the production cease.

4.9.4 Source-specific QA/QC and verification

For years where data from both DEPA and the EU ETS are available, namely years 2005-2012, 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.

4.9.5 Recalculations

No recalculation was performed during this submission, which is in line with the reviewers comments.

4.9.6 Planned improvements

The current submission can be considered satisfactory.

4.10 Iron and steel production (CRF Source Category 2.C.1)

4.10.1 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 2012 (**Table 4.18**) accounted for 0.86% 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 – 2012*

Year	Steel production (kt)	CO ₂ Emissions (kt)	CH ₄ Emissions (kt)
1990	999.10	92.70	0.01
1991	980.00	90.93	0.01
1992	924.00	85.73	0.01
1993	980.00	90.93	0.01
1994	848.00	78.68	0.01
1995	939.00	87.12	0.01
1996	809.82	75.14	0.01
1997	1015.67	94.24	0.01
1998	1108.29	102.83	0.01
1999	951.53	88.29	0.01
2000	1104.78	102.50	0.01
2001	1281.51	118.90	0.01
2002	1839.80	170.70	0.02
2003	1700.90	157.81	0.02
2004	1966.24	182.43	0.02
2005	2296.40	221.66	0.02
2006	2415.80	222.02	0.02
2007	2554.52	229.71	0.03
2008	2468.10	207.49	0.02
2009	1999.35	137.04	0.02
2010	1824.14	115.59	0.02
2011	1934.32	125.55	0.02
2012	1247.09	82.99	0.01

Emissions have decreased by 10.48% from 1990 to 2012. Especially in years 1990-2000 there was an increasing trend of the production. It should be noted, however, that emissions in 2009-2012 have significantly decreased from 2008 by 33.95%, 44.29%, 39.49% and 60% respectively, as a result of the decreased economic activity of the sector. Finally, the annual decrease of production level between 2011 and 2012 was 36.64%, followed by a 33.9% decrease in CO₂ emissions.

Methane emissions remain at low levels as in 2011 and account for 0.002% of emissions from *Industrial Processes* in 2012.

4.10.2 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 2005-2012 are plant specific and are based on the verified reports under the EU ETS context.
- ✎ According to information received by the EIStat, 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 EIStat for the years 2004-2012 (in the previous years the relevant Prodcom code did not exist). These data are actually the reported activity data. Especially for 2012 activity data used are received from the data published in the World Steel Association database as data from EIStat are not yet publicly available. The data will be updated as soon as they become available.
- ✎ In 2012 the average carbon content of the scrap and steel produced has been estimated at 0.34% and 0.17% respectively.
- ✎ Electrodes consumption is estimated at 1.66 kg/t steel produced.

The emission factor used for the estimation of methane emissions is the default CORINAIR (SNAP 040207) emission factor (10g/Mg of iron produced), as no emission factor is mentioned in the IPCC guidelines for CH₄ emissions.

4.10.3 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 229.71 kt in 2007. Then and in the next three years emissions are decreased by 49.68%, as 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). In 2011 the production level showed an increase leading to an increase in emissions, followed by a decrease of 33.9% in 2012 (as the steel production decreased by 36.64%). One out of five plants operating ceased its operation during 2012, reporting zero emissions. Therefore, a reduction of emissions can be attributed to that in addition to the economic recession that is also present in the Construction Sector and in cement production, leading to an average reduction in production by all the plants in 2012 equal to 24%.

Figure 4.10 presents the timeseries of production and emissions.

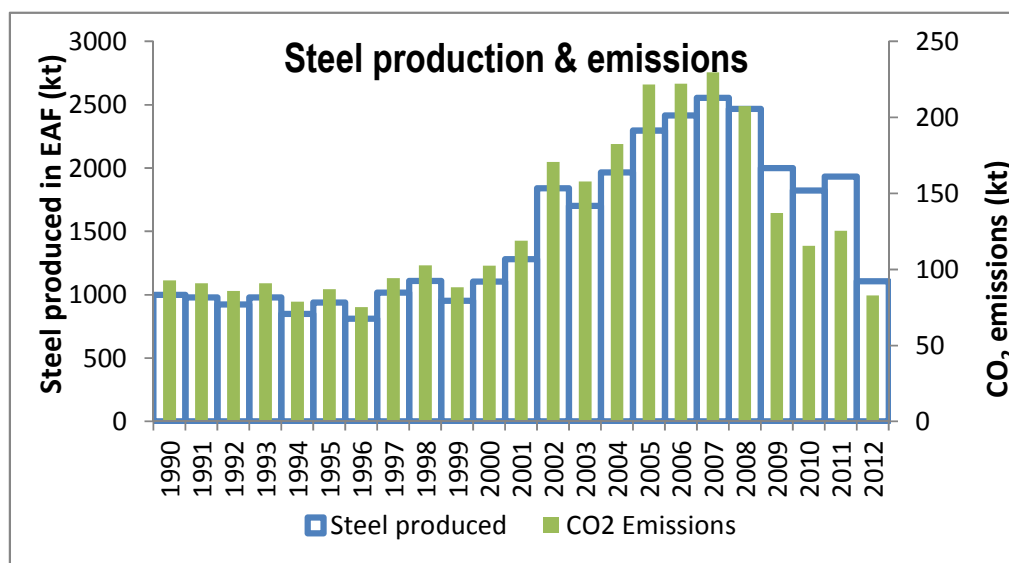


Figure 4.10 *Steel production and CO₂ emissions (in kt) for the period 1990 – 2012*

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 2009, 2010, 2011 and 2012 (0.069, 0.064, 0.066 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.

4.10.4 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 Hellenic Statistical Authority.

4.10.5 Recalculations

An error has been corrected concerning the steel production in 2011, as there was an update of the provisional data provided by ElStat and the plants. No difference in CO₂ emissions was noticed, while CH₄ emissions decreased by 2.94%, having an impact -0.06% on total emissions excluding LULUCF.

4.10.6 Planned improvements

The current submission can be considered satisfactory.

4.11 *Ferroalloys production (CRF Source Category 2.C.2)*

4.11.1 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.

The CO₂ emissions in 2012 account for the 7.27% of total emissions from *Industrial Processes*, and for the 0.63% 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 2012 key category by level assessment.

4.11.2 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 2005-2012 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 2000-2012. 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 2000-2012 has been provided by the plant.

4.11.3 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 2000-2012 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 2000-2012 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, followed by an increase of 2.16% between 2011 and 2012.

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.

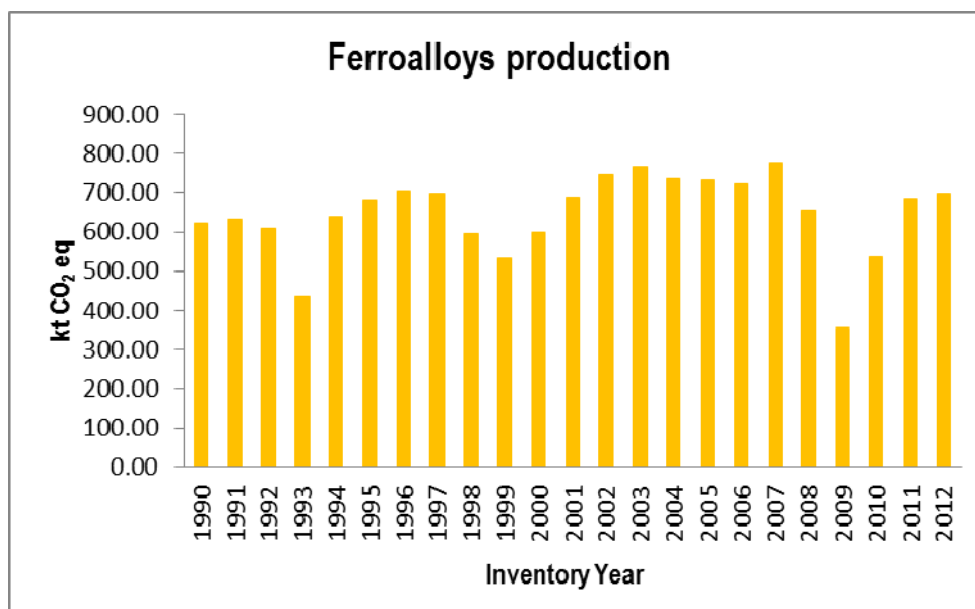


Figure 4.11 *CO₂ emissions (in kt) from Ferroalloys Production for the period 1990 – 2012*

4.11.4 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. Indeed the IEF is between 35 and 43 kt CO₂/kt Ni produced with a mean value of 39.45 t/t, and is not characterised by intense fluctuations in the time-series. The deviation of the IEFs is attributed to the different percentages of the raw material mixtures throughout the years of the time-series.

4.11.5 Recalculations

An error in files was observed concerning the ground coke quantity used for nikel production leading to a change of -0.10% for 2011 and an impact on the total emissions (excluding *LULUCF*) equal to -0.07%.

4.11.6 Planned improvements

The current submission can be considered satisfactory.

4.12 Aluminium production (CRF Source Category 2.C.3)

4.12.1 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 2012 (**Table 4.19**) accounted for 2.82% and 0.24%, respectively, of total GHG emissions from *Industrial processes* and GHG emissions excluding *LULUCF*. CF₄ and C₂F₆ emissions in 2012 accounted for 85.38% and 14.62%, respectively, of the PFC emissions (in CO₂ eq.) and 13.35% and 2.29%, respectively, of the total CO₂ emissions derived from Aluminium production.

The average annual rate of increase of CO₂ emissions during the period 1990 – 2012 was 1.14%. Respectively, the average annual rate of decrease of PFC emissions is estimated at 0.58%, while emissions have decreased by 7.02%, compared to base year emissions (1995).

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 CO₂ eq) from primary aluminium production for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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
PFC emissions	163.37	164.17	161.21	96.98	60.37	53.97	46.14	106.14	129.70	84.35	93.54	58.11
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
CO ₂ emissions	246.85	250.85	250.97	249.08	247.66	249.16	250.32	192.39	207.22	242.03	270.56	
PFC emissions	55.90	49.88	45.66	45.40	38.88	37.52	47.34	22.50	33.80	39.30	50.18	

4.12.2 Methodology

The estimation of emissions from aluminium production is performed in close collaboration with the sole plant operating in Greece.

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 average λ value is 0.0522 for the years 2005-2012. The outcome is then multiplied by 44/12 to express the CO₂ emitted.

2. Pitch Volatiles Combustion Emissions

$$\text{CO}_2(t) = (\text{GA} - \text{H}_w - \text{BA} - \text{WT}) * 44/12$$

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

$$\text{CO}_2(t) = \{ [\text{PC} * (100 - \% \text{Ash}_a - \% \text{S}_a) / 100] - [\text{WPC} * (100 - \% \text{Ash}_b - \% \text{S}_b) / 100] \} * 44/12$$

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 for 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).

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 one 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 CF₄ 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=Over-Voltage Coefficient*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 C₂F₆ emissions are then calculated by using the following formula:

$$C_2F_6 = 0.1 \cdot CF_4$$

4.12.3 Uncertainties and time-series consistency

The uncertainties regarding the CO₂ 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 in 2009 and an increase from 2010 to 2012, which is in line with the reported production levels.

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, leading to emissions only 0.74% lower than 2008
- The increase of total emissions in 2012 accounted for 14.01% since 2011 and 49.25% since 2009.

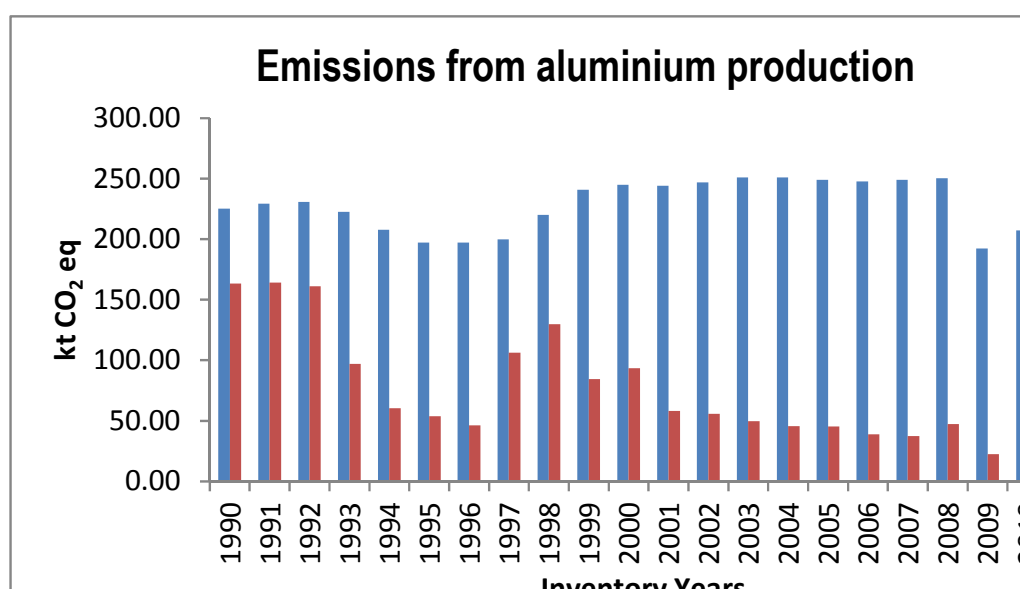


Figure 4.12 *CO₂ and PFCs emissions (in kt CO₂ eq) from aluminium production for the period 1990 – 2012*

4.12.4 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 PricewaterhouseCoopers (PwC). In

addition, the detailed information provided for the years 2005-2012 has been also verified by accredited verifiers.

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 seeked 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 2005-2012 is 1.5 t/t Al, in the range of the default values of 1.5 (1996 IPCC Guidelines) and 1.6 (2006 IPCC Guidelines).

4.12.5 Recalculations

The reported value of aluminium production for year 2010 and 2011, as provided by the US Geological Survey, has been updated (2010: from 137 kt to 136.76 kt, 2011: from 138 kt to 167.49 kt), as the data reported in the previous submission were provisional.

4.12.6 Planned improvements

In general, the current submission can be considered quite satisfactory.

4.13 Production of halocarbons and SF₆ (CRF Source Category 2.E.1)

4.13.1 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 4.20*.

Table 4.20 *HFC-23 emissions (in kt CO₂ eq) from HCFC-22 production for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
HFC-23	935.06	1,106.82	908.39	1,606.64	2,143.91	3,253.07	3,746.34	3,960.22	4,359.89	5,023.04	3,735.11	3,181.46
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
HFC-23	3,194.57	2,661.05	2,550.60	2,157.48	NO	NO	NO	NO	NO	NO	NO	

4.13.2 Methodology

According to the IPCC Good Practice Guidance, 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 IPCC GPG.

4.13.3 Uncertainty and time-series consistency

The estimated uncertainty is estimated at 50% for both activity data and emission factor, as suggested in the IPCC GPG 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.

4.13.4 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.

4.13.5 Recalculations

No recalculations have been performed. The ERT have made no reference to the current sub-category.

4.13.6 Planned improvements

The current submission can be considered satisfactory.

4.14 ODS (Ozone Depleting Substances) Substitutes (CRF Source Category 2.F.1 to 2.F.6)

4.14.1 Description

According to the IPCC Good Practice Guidance there are five 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 (2.F.2)
- Fire extinguishers (2.F.3)
- Aerosols/metered dose inhalers (2.F.4)
- Solvent uses (2.F.5)
- Other applications using ODS substitutes (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 2012 (**Table 4.21**) accounted for 41.68% of total GHG emissions from *Industrial processes* and for 3.56% of total national emissions (without *LULUCF*). The average annual rate of emissions' increase for the period 1995 – 2012 is estimated at 34.14%, with the increase being more moderate in the recent years, following the removal of equipment exceeding lifetime. 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 97.17% to the emissions from ODS substitutes, while emissions from Aerosols and MDIs are at the second place (1.03% contribution to the

emissions from ODS substitutes in the 2012 inventory). **Figure 4.13** shows the contribution from each subcategory to the total emissions from ODS substitutes.

Table 4.21 *F-gases emissions (in kt CO₂ eq) per gas from ODS Substitutes for the period 1990 - 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
HFC-23								5.25	11.50	20.53	32.96	38.47
HFC-32						0.03	0.21	0.70	1.29	2.21	4.61	8.54
HFC-125						4.88	9.69	19.28	31.09	48.40	78.46	108.34
HFC-134a				0.09	0.15	24.85	47.66	86.64	135.69	206.49	296.31	393.93
HFC-143a						7.58	13.98	25.68	40.14	61.03	90.47	108.81
HFC-152a												1.80
HFC-227ea										4.09	5.75	7.79
PFC-116								1.53	3.34	5.97	11.55	13.05
TOTAL				0.09	0.15	37.34	71.54	139.08	223.05	348.72	520.11	680.74
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
HFC-23	48.73	69.88	73.06	77.04	87.25	125.84	136.43	155.61	176.19	118.25	150.75	
HFC-32	14.12	24.80	35.68	46.24	60.27	74.62	90.69	108.26	129.88	155.57	197.83	
HFC-125	154.34	242.35	302.11	395.27	485.02	582.68	692.59	824.42	979.95	1054.21	1318.03	
HFC-134a	504.02	644.88	757.09	1041.82	1202.03	1347.36	1542.86	1697.72	1697.66	1547.25	1591.48	
HFC-143a	140.26	201.37	217.06	286.53	320.97	362.91	409.33	476.33	545.08	461.85	562.83	
HFC-152a	32.68	43.79	37.43	39.96	49.50	43.91	42.92	37.36	32.91	30.33	29.80	
HFC-227ea	10.09	13.07	17.77	22.38	26.49	32.04	35.44	38.99	41.61	42.68	38.33	
PFC-116	17.66	27.01	27.77	28.92	31.89	43.12	46.20	51.77	71.74	39.04	60.24	
TOTAL	921.90	1267.13	1467.97	1938.15	2263.42	2612.49	2996.44	3390.47	3675.02	3449.18	3949.28	

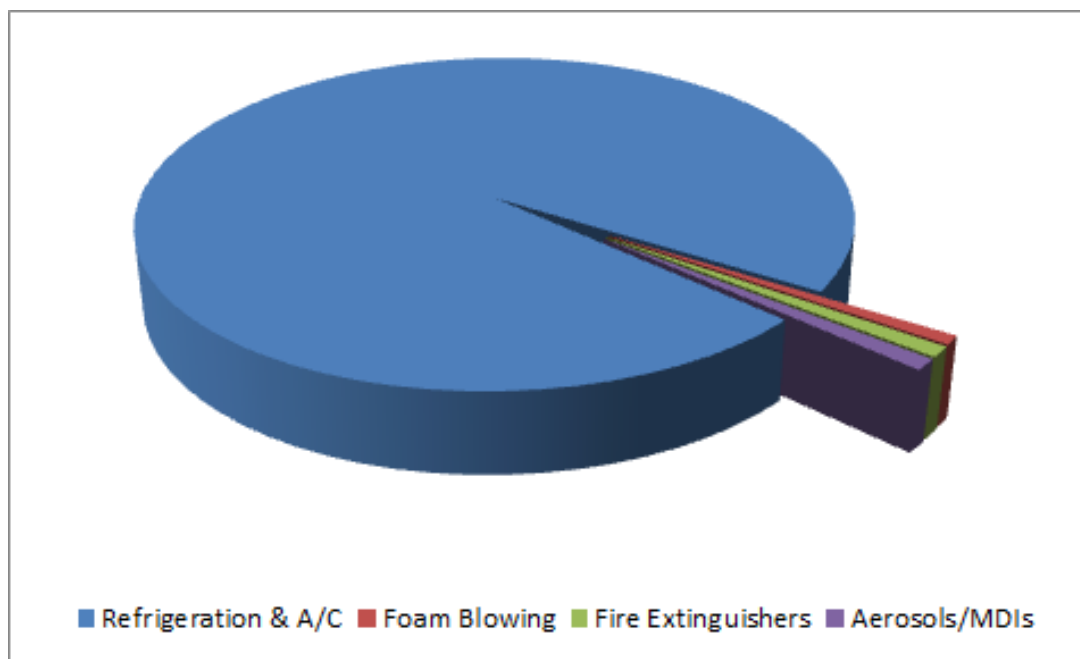


Figure 4.13 *F Gases emissions from ODS substitutes in 2012 (in kt CO₂ eq)*

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. The price is no longer a decisive factor due to multiple credit systems from electrical stores and supermarkets that made this purchase quite affordable for many consumers. However, in the last years this is not the case, since 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).

4.14.2 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:

$$E_C = DOM \cdot CH \cdot k$$

$$E_O = \left(\sum_{t_0}^T (DOM + IMP - EXP)_t \cdot CH \right) \cdot x$$

$$E_D = (DOM + IMP - EXP)_{T-n} \cdot CH \cdot y \cdot (1 - z) - DES$$

where, E_C is emissions related to the production, DOM is domestic production, CH is the initial charge, k is the leakage rate during manufacturing, E_O is emissions during operation, t_0 is the year of F-gases introduction in the market, T is the current year, IMP is imports, EXP is exports, x is the leakage rate during operation, E_D is emissions during disposal, n is lifetime, y is the remaining

percentage from the initial charge of the equipment by the time of disposal, z is the percentage of recycling and DES is the amount of F-gases destroyed.

Assembly emissions are related to the number of units produced in the country (domestic production) that use f-gases as refrigerants, the amount of refrigerant used per unit and the losses during assembly. Operation emissions are related to the total number of equipment with f-gases as refrigerant (domestic production and imports minus the exports) and the leakage rate per equipment type. Disposal emissions depend on the available amount of refrigerant in the equipment, as well as on the existence of disposal practices. The assumption of total emission of remaining refrigerant in the retiring equipment was made since no data on the disposal practice was available. The Inventory Team used data from the official Electrical Appliances Recycling Company regarding the recovery of f-gases in line with the Greek Recycling System.

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, **Tables 4.22a-4.22b**) 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 2010-2012 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. The data used for the in country production of the specific equipment are provisional (January 2012-November 2012) since the respective data are not yet available.

- Data on the number of transport refrigeration for 2000-2012 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 – 2012 are provided by market surveys (ICAP 2000, 2002, 2003, 2005, 2008, 2009, 2011, 2013).
- 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.
- Changes in the time series of Activity Data operating in the system (for the subcategories: small commercial applications, Large commercial applications, Split unit systems and semi-central systems, Central air conditioning – Chillers, Other applications of central air conditioning), and consequently in the emissions of stocks are attributed to updated data. In addition numerical errors have been also corrected in the working files and the timeseries were recalculated.

Table 4.22a Refrigeration and air conditioning equipment (number of units, units are referred to annual flows not the stock) for the years 1993 – 2002

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Refrigeration										
Residential	311,000	320,000	335,000	350,000	355,000	365,000	360,000	387,000	376,000	375,000
Domestic production	80,000	82,000	90,000	120,000	185,000	235,000	260,000	327,000	324,000	335,000
Imports	283,000	315,000	325,000	350,000	340,000	340,000	335,000	340,000	342,000	340,000
Exports	52,000	77,000	80,000	120,000	170,000	210,000	235,000	280,000	290,000	300,000
Other commercial applications			31,556	25,832	24,480	20,284	26,665	22,852	15,151	17,714
Domestic production			20,820	14,800	20,520	17,680	20,200	16,080	13,050	7,254
Imports			14,908	17,410	13,519	9,532	18,634	14,795	17,568	26,114
Exports			4,172	6,378	9,559	6,928	12,169	8,023	15,467	15,655
Small commercial applications			193,287	183,250	191,514	182,560	133,487	129,895	180,319	149,478
Domestic production			58,640	71,680	63,730	44,302	66,856	76,871	77,219	86,218
Imports			163,848	154,481	152,528	166,843	200,530	214,455	225,382	210,541
Exports			29,201	42,911	24,744	28,585	133,899	161,431	122,282	147,281
Transport Refrigeration								517	479	633
In circulation								517	479	633
Stationary air-conditioning										
Split unit systems and semi-central systems	89,570	126,730	154,200	150,880	188,900	229,550	330,655	431,385	617,800	306,250
Domestic production	12,320	17,550	22,000	21,200	2,800	2,250	1,750	1,750	1,400	1,250
Imports	82,250	115,180	141,200	137,380	189,700	240,000	342,205	445,035	647,000	341,500
Exports	5,000	6,000	9,000	7,700	3,600	12,700	13,300	15,400	30,600	36,500
Chillers	1,100	1,080	1,120	1,180	1,140	1,240	1,315	1,585	2,350	2,900
Domestic production	350	380	400	430	420	500	600	950	1,600	1,800
Imports	750	700	740	770	780	840	835	945	1,500	1,500
Exports	0	0	20	20	60	100	120	310	750	400
Other applications of air conditioning	28,800	31,500	32,000	35,700	39,850	43,250	44,830	48,300	53,700	67,400
Domestic production	32,900	33,500	35,200	34,300	34,500	37,730	37,900	39,300	40,100	37,900
Imports	4,900	5,300	6,300	9,300	9,600	12,120	12,130	14,200	18,900	37,300
Exports	9,000	7,300	9,500	7,900	4,250	6,600	5,200	5,200	5,300	7,800
Mobile air-conditioning			133,757	141,589	166,778	183,857	268,716	302,620	289,943	277,567
In Circulation			133,757	141,589	166,778	183,857	268,716	302,620	289,943	277,567

Table 4.22b *Refrigeration and air conditioning equipment for the years 2003 – 2012*

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Refrigeration										
Residential	390,000	406,000	402,000	410,000	433,000	452,000	401,000	431,600	428,880	390,000
Domestic production	368,000	408,000	431,000	507,200	390,700	307,400	257,000	214,320	119,486	368,000
Imports	342,000	320,000	340,000	313,400	350,000	390,000	335,000	365,660	377,668	342,000
Exports	320,000	322,000	369,000	410,600	307,700	245,400	191,000	148,380	68,274	320,000
Other commercial applications	25,825	4,738	4,738	12,312	2,049	5,445	5,342	3,730	3,922	3,225
Domestic production	20,310	23,004	23,004	17,117	16,383	16,378	15,053	14,050	14,146	14,242
Imports	21,357	30,000	30,000	23,306	17,712	13,091	12,849	12,612	11,855	11,025
Exports	15,842	48,266	48,266	28,111	32,046	24,024	22,560	22,931	22,079	22,043
Small commercial applications	213,443	242,483	208,630	139,569	141,329	162,148	268,636	208,269	191,562	177,966
Domestic production	161,789	150,845	104,688	115,885	110,502	115,307	120,748	125,680	120,522	116,190
Imports	231,459	245,152	282,929	276,746	216,429	206,039	267,668	207,909	165,598	129,984
Exports	179,805	153,514	178,987	253,062	185,602	159,198	119,780	125,320	94,558	68,208
Transport Refrigeration	649	826	460	731	817	747	597	456	223	60
In circulation	649	826	460	731	817	747	597	456	223	60
Stationary air-conditioning										
Split unit systems and semi-central systems	503,950	493,100	430,800	489,520	574,310	574,250	436,750	315,600	295,300	312,000
Domestic production	500	700	300	220	210	190	130	50	50	0
Imports	626,350	644,500	522,500	614,200	730,800	732,760	560,120	459,550	438,000	451,000
Exports	122,900	152,100	92,000	124,900	156,700	158,700	123,500	144,000	142,750	139,000
Chillers	2,400	1,950	1,770	1,580	1,860	1,900	1,600	1,350	1,250	1,150
Domestic production	1,100	700	520	480	560	540	400	280	300	250
Imports	1,650	1,450	1,400	1,300	1,600	1,740	1,500	1,370	1,200	1,150
Exports	350	200	150	200	300	380	300	300	250	250
Other applications of air conditioning	72,300	48,250	42,100	44,100	45,950	46,500	32,000	23,400	20,550	17,800
Domestic production	34,500	26,000	19,350	16,700	17,100	16,600	10,500	5,500	4,850	4,300
Imports	47,450	29,600	25,400	32,000	37,600	42,100	29,300	25,750	23,070	20,550
Exports	9,650	7,350	2,650	4,600	8,750	12,200	7,800	7,850	7,370	7,050
Mobile air-conditioning	273,870	317,508	344,339	346,551	316,721	347,727	283,736	184,683	126,550	121,000
In Circulation	273,870	317,508	344,339	346,551	316,721	347,727	283,736	184,683	126,550	121,000

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 2012, 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 presented in **Table 4.23**. These values 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.

Table 4.23 *Basic assumptions for the calculation of F- gases emissions*

	Charge	Leakage rate (%)		Lifetime	Disposal	Recycling						Refrigerant
	(kg/unit)	Charge	Operation	(years)	Initial Charge Remaining (%)	Percentage of Recycling (%) ⁽²⁾						used
Refrigeration - Residential	0.18	0.6	0.25	15	70		5.43	9.98	5.90	5.65	6.53	R134a
Refrigeration – Other commercial & Industrial applications	100	0.5	10	10	85	9.80	8.34	9.97	7.21	10.97	7.00	R134a, R404a, R407c, R507a, R23, R508b, R410a, R422a, R422d, R437a
Refrigeration – Small commercial applications	1.5	1.75	10	10	75	6.09	5.21	11.62	6.35	3.50	2.85	R134a, R410a, R407c
Transport Refrigeration	2.38 ⁽¹⁾	0.6	25	8	75		6.53	12.77	9.57	10.85	10.49	R134a, R404a, R410a
Air conditioning – Split units and semi central systems	2	0.6	5	15	80				2.55	0.51	0.05	R407c, R410a, R417a
Air conditioning – Chillers	50	0.6	15	10	90	1.29	1.38	10.91	15.04	0.81	0.16	R134a, R407c, R410a
Air conditioning - Other applications of central air conditioning	12	0.6	20	10	70	1.39	0.97	7.99	4.82	0.52	0.06	R407c, R410a, R417a
Mobile Air conditioning	1	0.5	12	9	40	2.06	1.61	9.74	13.32	1.89	0.28	R134a

1. In Greece, small transport refrigerators (for domestic transfer of products) are charged by 1 kg refrigerant/unit, while large transport refrigerator's charge (for international transfer of products) is 6 kg refrigerant/unit. Provided that the number of transport refrigerators given by the ministry of Transport includes both categories, and given the fact that the majority concerns small transport refrigerators, the charge used in the calculations is 2.38 kg refrigerant/unit.
2. According to the Electrical Appliances Recycling Company the first year of recycling was 2007. The recycling amount is not the same every year. The percentage of recycling is different for each gas and consequently each blend; thus, an average percentage of recycling is presented in the table for each category and year.

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 1995-2012 is presented in **Figure 4.14**.

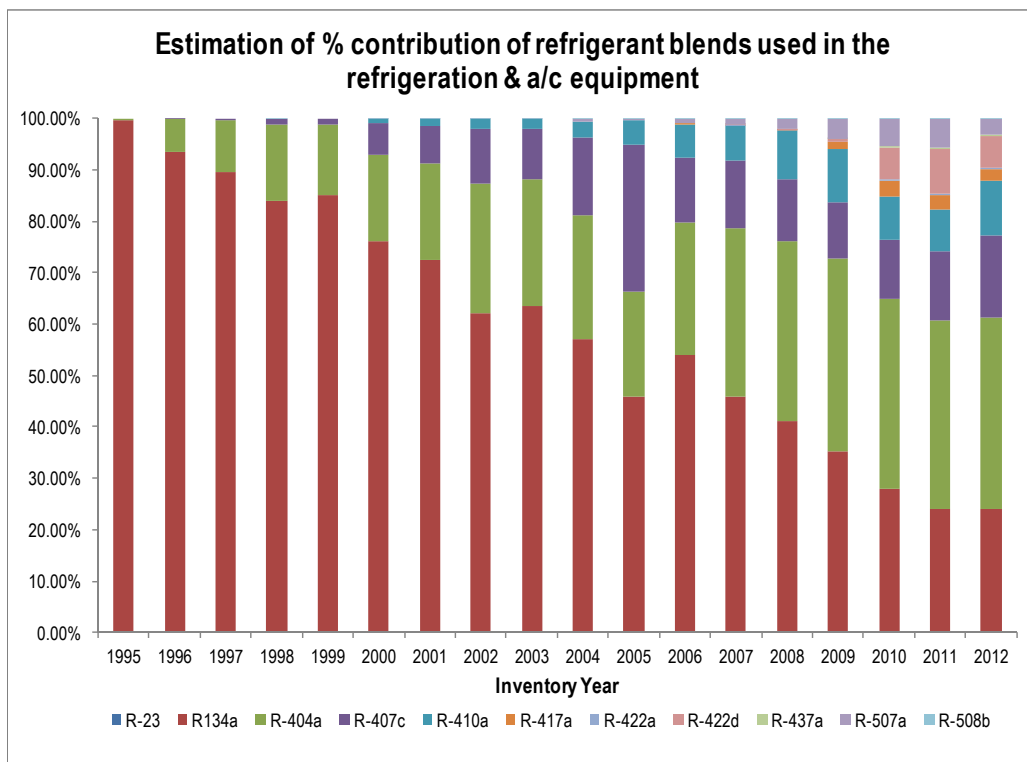


Figure 4.14 *Distribution of refrigerant blends in the Greek market, 1995-2012*

The structure of the emissions from each sub-source for 2012 is presented in **Figure 4.15**.

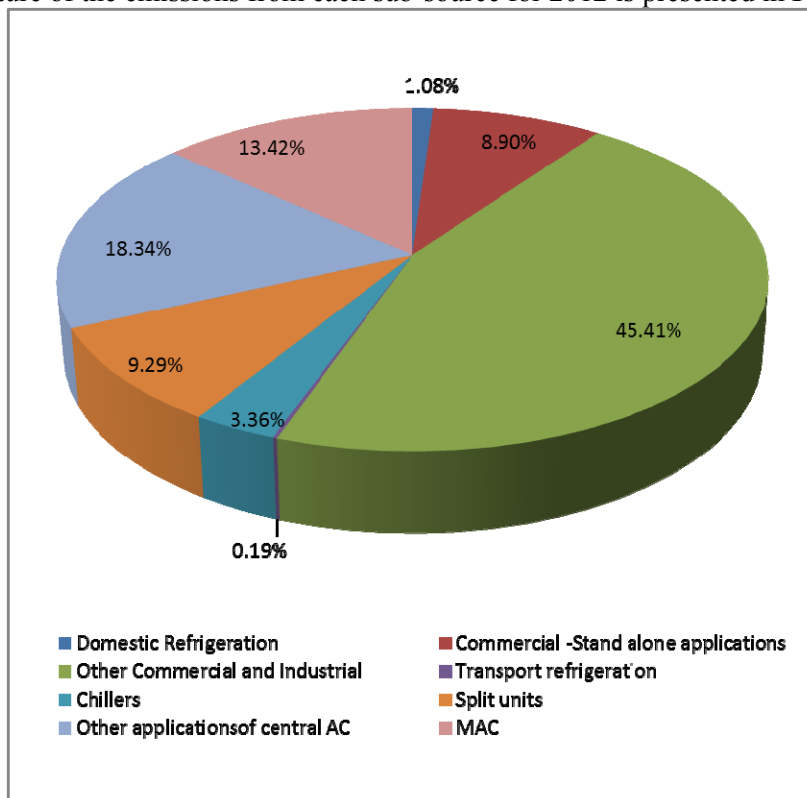


Figure 4.15 *Contribution of each sub-source for 2.F.1(Table 4.24) for 2012*

Total F-gases emissions from the above mentioned applications are presented in **Table 4.24** for the period 1993-2012.

Table 4.24 *F-gases emissions (in kt CO₂ eq) from refrigeration and air conditioning equipment for the period 1993 – 2012*

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Domestic refrigeration	0.09	0.15	0.23	0.35	0.53	0.69	0.86	1.01	1.13	1.24
Commercial-Stand Alone Appl.	0.00	0.00	1.09	2.72	5.85	9.88	12.87	17.42	26.21	35.10
Other Commercial- Industrial Appl.	0.00	0.00	32.45	60.03	116.67	186.32	287.00	404.76	473.36	578.19
Transport Ref	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.81	1.45
Chillers	0.00	0.00	0.07	0.15	0.30	0.72	1.55	2.85	6.51	12.51
Split-Units	0.00	0.00	0.22	0.42	1.00	1.00	1.00	7.63	21.95	31.42
Other Applications of Central AC	0.00	0.00	0.12	0.29	0.64	1.75	3.97	9.94	21.88	47.28
MAC	0.00	0.00	3.13	7.55	14.05	22.66	37.33	70.37	115.61	158.91
TOTAL	0.09	0.15	37.31	71.51	139.05	223.02	344.61	514.37	667.52	763.03
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Domestic refrigeration	1.31	1.37	1.43	1.44	1.52	8.95	12.47	24.00	35.90	41.51
Other Commercial-Stand Alone Appl.	52.07	73.25	97.31	115.88	142.02	172.03	206.88	250.53	313.26	341.47
Commercial- Large Applic.	792.38	838.82	1,120.96	1,206.90	1,411.07	1,553.00	1,792.26	1,892.67	1,479.68	1,742.56
Transport Ref	2.11	2.96	3.46	4.26	5.20	6.79	7.44	7.96	7.66	7.45
Chillers	19.92	28.81	37.71	45.95	57.01	69.90	82.34	93.25	112.66	129.05
Split-Units	51.02	74.03	97.80	129.29	171.41	218.21	257.87	292.78	322.49	356.63
Other Applications of Central AC	88.68	133.88	176.96	219.93	262.34	308.19	342.38	405.09	518.39	703.74
MAC	201.63	258.46	312.06	366.57	414.37	474.16	546.53	570.63	540.81	515.06
TOTAL	1,209.11	1,411.59	1,847.69	2,090.22	2,464.94	2,811.24	3,248.16	3,536.92	3,330.87	3,837.48

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 decrement 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.

In general a slight improvement in Greek market, concerning A/C equipment, is observed for 2012 comparing to the period 2008-2011. It should be noted that these observations refer 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

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 4.16**) is due to the different operation periods of the companies. More specifically one of the companies started the use of HFCs in 2001 until today, while a second company started in 2003 and still reported the use of HFCs. A third company has reported use of HFCs only during the period 2006-2009 and the last company has reported no use of HFCs at all since it uses PBAs. From 2004 the use of HFCs decreased since one of the companies also uses PBAs decreasing the amounts of HFCs emissions.

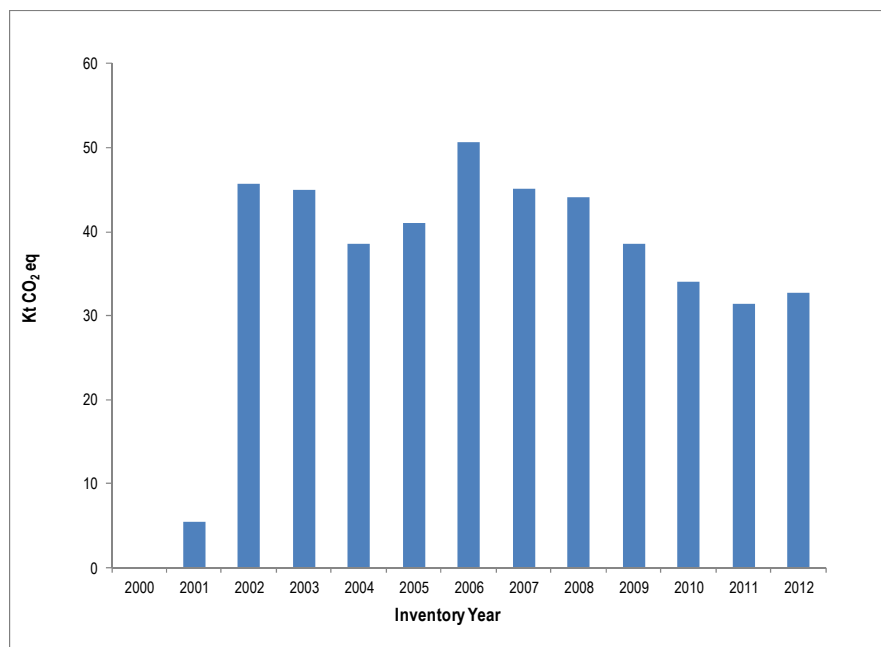


Figure 4.16 HFCs emissions from 2.F.2 Subcategory

From the four companies that report in the Greek system only one has mentioned, apart from XPS production, imports of XPS foams (average of 2.63 % 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, last year 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 rate 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 (for 2011 the 20% was responded), 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 an emission factor of 40% has been selected, while the annual loss emission factor was 3%. Both values are the default suggested in the IPCC GPG.

In the current submission updated data have been used and an error has been also corrected in the working files, thus, emissions have been recalculated as appropriate in the whole timeseries.

Emissions of foam blowing are presented in **Table 4.25**.

Table 4.25 *HFCs emissions (in kt CO₂ eq) from foam blowing for the period 1995 – 2012*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
First Year Emissions (HFC-134a)	3.39	11.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66
Annual Emissions (HFC-134a)	0.25	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.27
First Year Emissions (HFC-152a)	1.68	30.28	38.50	29.90	30.17	36.94	29.17	26.20	19.21	13.72	10.37	9.15
Annual Emissions (HFC-152a)	0.13	2.40	5.28	7.53	9.79	12.56	14.75	16.71	18.15	19.18	19.96	20.65
TOTAL	5.45	45.68	44.93	38.58	41.10	50.64	45.06	44.06	38.51	34.05	31.48	32.73

Fire extinguishers

According to the IPCC Good Practice Guidance, 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.

In the framework of the 2011 Improvement Plan, the Greek Fire Service-Fire Safety Division has been contacted in order to see the availability of information for the use of HFCs and/or PFCs in fire equipment. According to the information received, there is no indication on the identity of the used gases in fire equipment and thus the above mentioned methodology continues to be the currently available one.

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 4.26**.

Table 4.26 *HFC-227ea emissions (in kt CO₂ eq) from fire protection equipment for the period 1999 – 2012*

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
HFC-227ea	4.09	5.75	7.79	10.09	13.07	17.77	22.38	26.49	32.04	35.44	38.99	41.61	42.68	38.33

In the current submission updated data have been used and a numerical error has been corrected in the working files emissions thus, timeseries recalculated as appropriate.

Aerosols/MDIs

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 2000 IPCC Good Practice Guidance, the 5 main sources of aerosols are:

- Metered Dose Inhalers (MDIs)
- Personal Care Products
- Household Products
- Industrial Products and
- Other General Products

According to the IPCC GPG, emissions are estimated using the following equation:

$$\begin{aligned} \text{Emissions in year } t = & [(\text{Quantity of HFC and PFC contained in aerosol products sold in year } t) \cdot \\ & (\text{EF})] \\ & + [(\text{Quantity of HFC and PFC contained in aerosol products in year } (t-1)) \cdot (1 - \text{EF})] \end{aligned}$$

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 4.27*.

Table 4.27 *HFC-134a emissions from Aerosols/MDIs (in kt CO₂ eq) for the period 1995 - 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
HFC-134a Emissions						0.029	0.035	0.032	0.032	0.033	0.033	0.037
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
HFC-134a Emissions	0.035	0.031	0.033	26.987	96.066	70.455	105.710	64.812	62.440	44.155	40.752	

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% according to the provided data.

4.14.3 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.

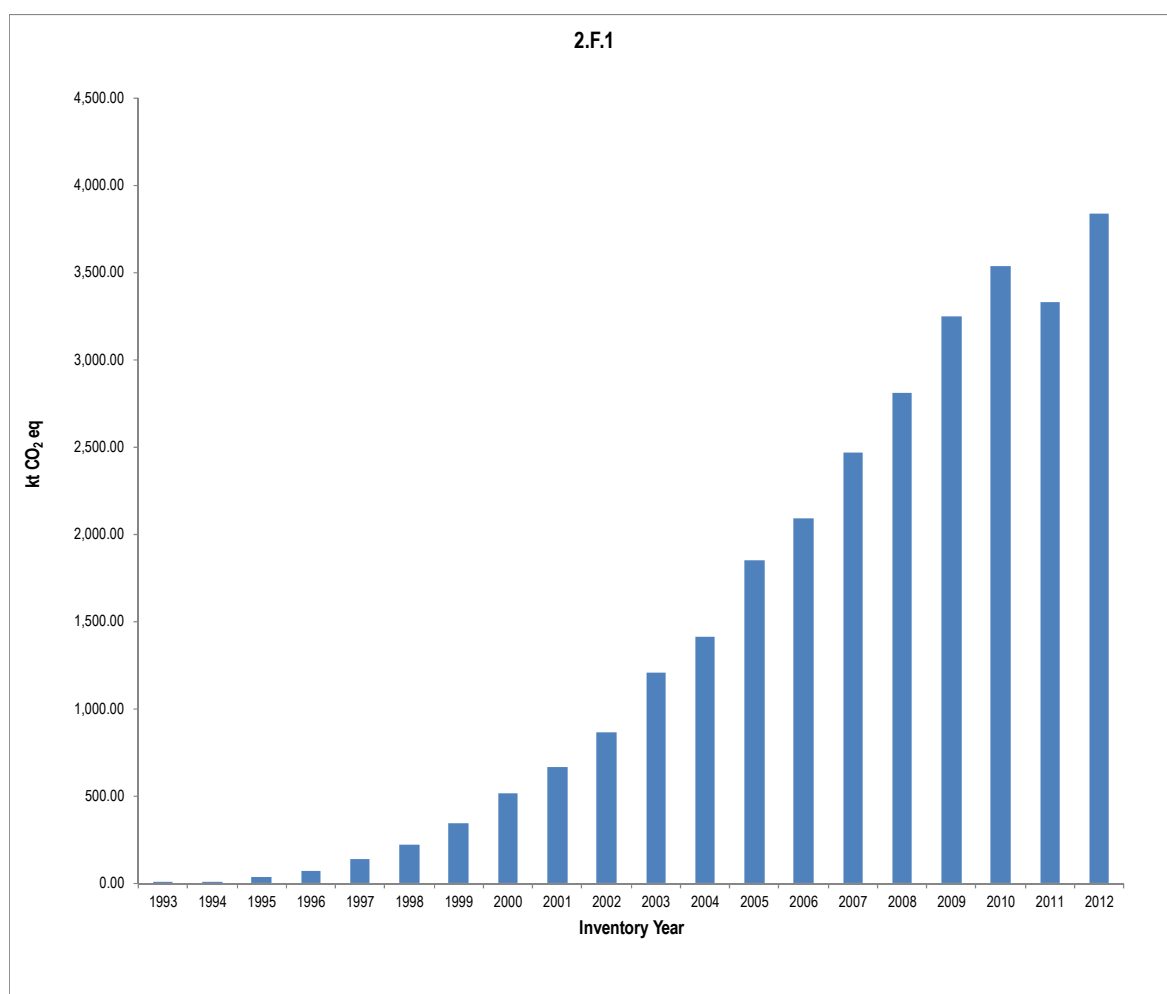
For the refrigeration and A/C equipment (CRF 2.F.1) the activity data uncertainty has been estimated at 100% whereas an EF uncertainty of 150% is used, due to the fact that the emission factors are selected based on expert's opinion (National Association of Refrigerating and Cooling Technicians) but being in the default range suggested by the IPCC GPG and Guidelines.

In the rest three categories (foam blowing and aerosols and fire equipment) the uncertainty associated is quite lower. More specifically, in the foam blowing subcategory (2.F.2) the uncertainty values suggested by the IPCC GPG 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 Equipment 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. Minor inconsistencies derive from the absence of the 2011-2012 values for the domestic refrigeration.

In **Figure 4.17** the trend of 2.F.1 category is presented.



As regards the chart, the general trend is increasing until 2012, with a slight decrease in 2011.

Figure 4.17 HFCs emissions from 2.F.1 for the period 1993-2012 (in kt CO₂ eq)

In **Figures 4.18** and **4.19**, the trend of each subcategory is presented.

Regarding the first chart in each subcategory the trend is similar to the general trend. Production and import levels in 2011-2012 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 2012 production and imports have slightly increased or either on the same levels with 2011. In any case the f-gases penetration percentage is quite lower in the recent years, following the intense use of R600. The decrement on Large commercial refrigeration in 2011 emissions, although the production and imports have increased for the specific year, can attributed to the decrease in disposal emissions due to the increase in recycling in this year along with the decreased amount of disposal equipment (-39.21% comparing to 2010, disposal equipment in 2011=introducing equipment in 2001, 10 years lifetime). In 2012 the trend is again increasing as disposal equipment was again increased (38.17% comparing to 2011, disposal equipment in 2012=introducing equipment in 2002, 10 years lifetime).

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.

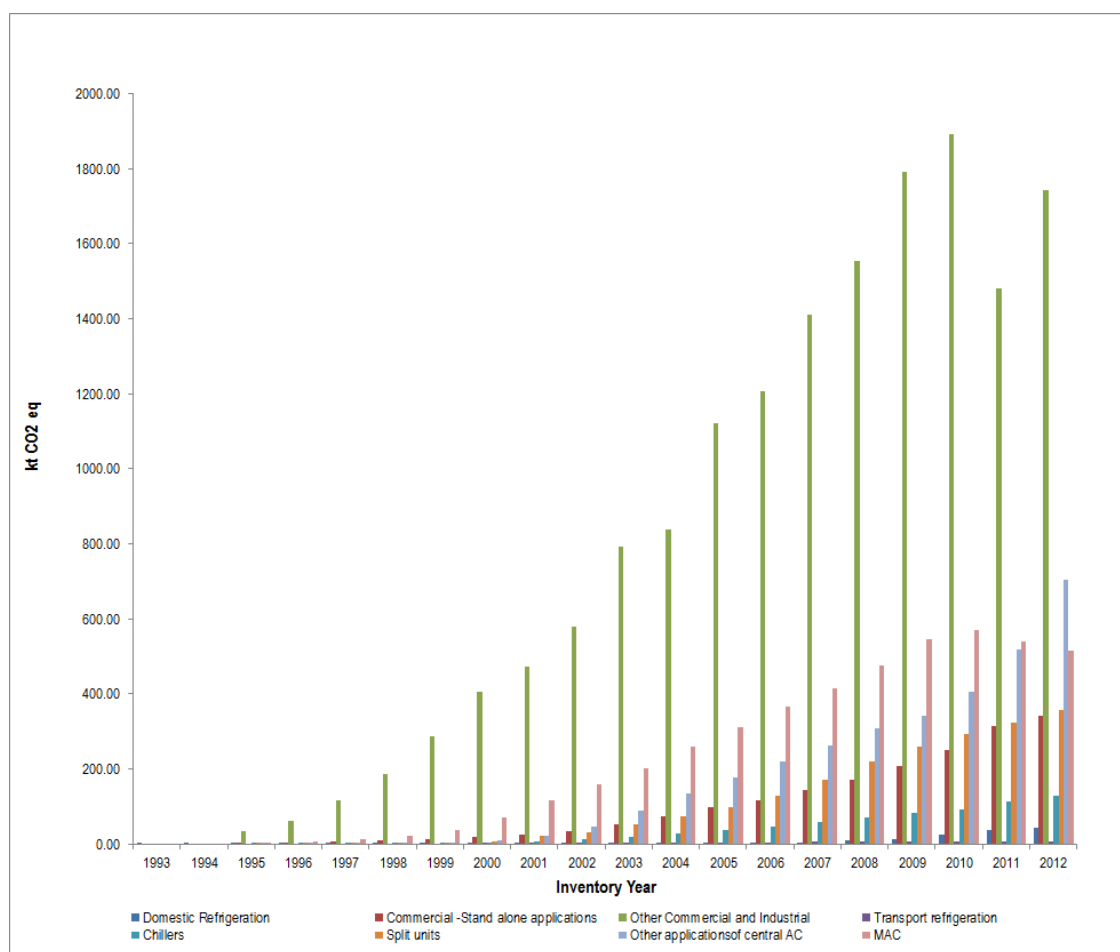


Figure 4.18 *HFCs emissions from Refrigeration and A/C equipment for the period 1993-2012 (in kt CO₂ eq)*

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 and 2012 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 decreasing one until 2011 with a slight increment in 2012.

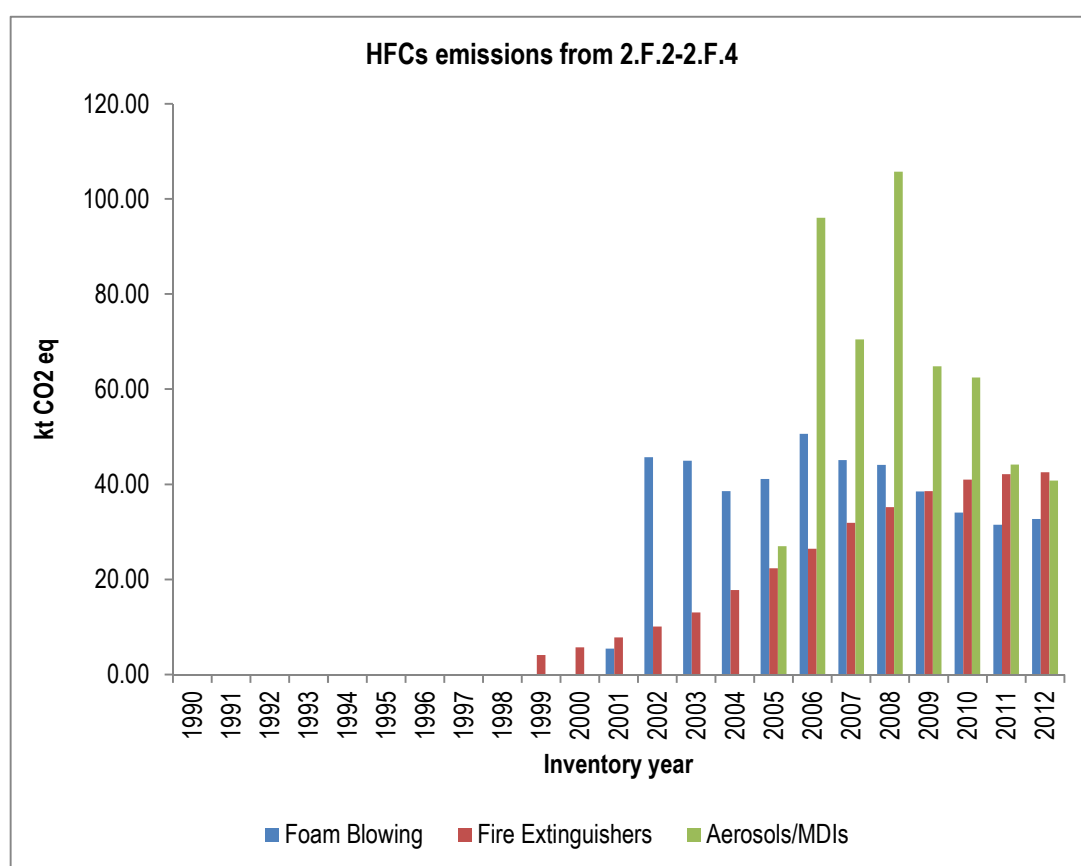


Figure 4.19 HFCs emissions from Foam blowing, Fire extinguishers and Aerosols/MDIs for the period 1990-2012 (in kt CO₂ eq)

4.14.4 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 (see also para 4.14.5). 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.

4.14.5 Recalculations

In the current submission important recalculations have been performed. The reasoning behind this is the priority given to the sector due to its being a key category by level, trend and also expert judgment.

Main recalculations include the following:

- Changes in the time series of Activity Data operating in the system and consequently in the emissions of stocks in almost all of the subcategories of 2.F.1 are attributed to updated data. More specific, new data for 2011 and 2012 concerning Stationary air-conditioning equipment flows, have been available through the new market survey of ICAP in 2013. In addition, updated data have been available for 2011-2012 in imported and exported quantities in subcategories Other commercial applications (incl. Industrial) and Small commercial applications from El.Stat. Also, new data concerning F-gases penetration has been used for the subcategory Residential applications.
- Updated data for 2010-2012 have been also used in subcategory Foam Blowing concerning the Activity Data.
- Numerical errors in 2.F.1 have been detected during the internal QA/QC procedures and corrected in sub-categories Domestic Refrigeration, Commercial Refrigeration, Stationary air-conditioning, mobile air-conditioning, Chillers, Fan Coils.

- Numerical errors in categories 2.F.2-2.F.4 have been detected during the internal QA/QC procedures and corrected.

The difference between the previous and the current estimates and the impact on total emissions is presented in **Table 4.28**.

The first years (1993-1998) there is no differences. The changes can attributed to updated data and numerical errors in the working files, especially in category 2.F.1 which corresponds to the 97.17% of the emissions from ODS substitutes. Thus, for the period 1999-2011 new data concerning F-gases penetration has been used for the subcategory Residential applications which explains the difference in timeseries since then. In 2002 the difference is higher due to a numerical error which has been detected in the exports value in subcategory “other commercial applications”. This change affect not only the consumption of the specific year but the whole timeseries since the equipment of each year is calculated in the years following until they exceed their lifetime. A numerical error has been also corrected in the consumed quantities in subcategory “Transport refrigeration” from 2008. More over, new data concerning activity data in stationary air-conditioning have been used for 2011.

Table 4.28 *Recalculations of F-gases from ODS substitutes (1993-2012)*

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
F Gases Emissions										
Difference (%)	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	12.57
Impact on total Emissions (incl LULUCF, %)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Impact on total Emissions (excl LULUCF, %)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
F Gases Emissions									
Difference (%)	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02
Impact on total Emissions (incl LULUCF, %)	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.08	-0.09
Impact on total Emissions (excl LULUCF, %)	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.08	-0.08

4.14.6 Planned improvements

As it is obvious from the previous paragraphs, Greece has already implemented various improvements in the current submission. The Improvement Plan of 2012 regarding f-gases

regarded the qa/qc checks and also the update and validation of data providers and the collected data.

To this end, the following should be mentioned:

- In the 2013 Centralized Review the ERT have recommended to collect further information on imports of foam products containing HFCs. In line with this the Inventory Team has tried to to inform them and encourage all the members of the PanHellenic Association of Insulating Companies to fill an excel form with the amount of imported and exported quantities of foam products containing HFCs as explained in details in par. 4.14.2. This year correspond 30% of the companies while last year corresponded 20%. Thus, the inventory team will continue to collect such data and used them as appropriate.
- Concerning fire extinguishers, the use of f-gases is expected to be very low, according to Greek experts of the area. At the present, the inventory team has made an estimation of the emissions using data from other Mediterranean countries and the population as a driver. Since 2009 the inventory team has come to close cooperation with the office of the Ministry of Environment, Energy and Climate Change that is in charge of the implementation of the EC Regulation No 842/2006 on Certain Fluorinated Greenhouse Gases, and a general attempt is being performed in order to achieve the reporting of the fire protection companies on the annual emissions of HFCs. In this context the improvement of the specific sub-category reporting is highly dependent on the progress regarding the above mentioned Regulation.
- *Potential emissions* of F-gases have not been estimated, due to the lack of data. The initial plan of Greece was to collect data concerning imports and exports of F-gases (in bulk) by the Hellenic Statistic authority. Nevertheless since these compounds were not reported per f-gas type but aggregately to the ElStat, the estimation of potential emissions was not possible. Moreover in line to the implementation of the improvement plan of 2012 the inventory team has been into close collaboration with National Association of Refrigeration Importing & Trading Companies and a form sent annually to all their members asking for the quantities of F-gases imported, exported and sold per blend and year. Since the respond of the companies for 2011 and 2012 was 50%, the inventory team couldn't use these data for the estimation of potential emissions. For the implementation of EC Regulation No 842/2006 a Common Ministerial Decision 18694 has been published in Greece on the 11th of April 2012. The above mention regulation defined among others the data collection procedures regarding the enterprises that produce, import, export, recover, recycle and trade F-gases on annual basis until every 31th of March of each year. The inventory team was planning to use the information that shall be gathered in the framework of the Common Ministerial Decision 18694. The inventory team was planning to use the information that will be collected in the framework of the Common Ministerial Decision 18694. With reference to this regulation the importers and exporters of f-gases communicate to the Commission and to the Competent Greek Authority (namely the Ministry of Environment, Energy and Climate Change) the above mentioned information. Considering the scheduled dates for gathering the data, this improvement was planned for the 2014 submission. The Inventory Team is in communication

with the respective Directory and has already viewed some of the reports; however, the filing of the reports is in a rather non-consistent manner (hardcopies, missing information etc.). Additionally, the data are not complete since not all the companies responded. Thus, no safe conclusions can be drawn and the respective information has not proven useful so far. The inventory team is trying to resolve this issue by communicating with each of the company separately trying to encourage all the members to respond and complete the required data. In addition, an excel sheet has been resending to them. It should be mention that any available data will be examined by the inventory team if they are adequate according to the IPCC GPG, and how this information could be introduced in the next submissions.

4.15 Electrical equipment (CRF Source Category 2.F.8)

4.15.1 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.

4.15.2 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 – 2012. 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). The personnel has reassured the inventory team that all the amount reported by the PPC each year refers only to gas escape and not to the filling of new equipment, since this is not performed by PPC. Moreover, the 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 4.29**. Emissions in 2012 have been increased by 66.56% from 1990, whereas they have decreased from 2010 by 16.75%. 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 4.29 *SF₆ emissions (in kg) from electrical equipment for the period 1990 - 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Transmission						115	118	120	122	125	130	132	140	140	148	230	310	375	280	175	217	174	172
Distribution						35	36	36	36	37	37	38	38	38	39	40	40	40	35	45	40	41.5	42
Total	128	132	136	140	144	150	154	156	158	162	167	170	178	178	187	270	350	415	315	220	257	216	214

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.

4.15.3 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.

4.15.4 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.

4.15.5 Recalculations

No recalculations concerning the Emissions from this category were performed in the current submission. However, it has been a change in a Notation Key. More specifically, in 2.F.8 category Greece reported SF₆ emissions from installation losses for high-voltage switchgear used in the country under the subcategory electrical equipment. According to the ERT comments: “These emissions should be reported as emissions “from manufacturing”, in accordance with the IPCC good practice guidance. However, Greece has used the notation key “IE” to report emissions “from manufacturing”, and has reported the total emissions as the emissions “from stocks”. In response to a question raised by the ERT during the review in 2013, Greece informed the ERT that the emissions were estimated on the basis of the quantity of SF₆ consumed during the year according

to the information provided by the Public Power Corporation. The method uses the weighting of the compressed SF6 cylinder before and after the filling of the equipment, but all the amount reported by the Public Power Corporation each year refers only the gas escaped, and emissions from the filling of new equipment are not included. Thus, the Notation Key “IE” in “actual emissions from manufacturing” has been replaced by “NA”.

4.15.6 Planned improvements

Any gaps in activity data time series will be filled in as soon as new data become available.

5. Solvents and other products use (CRF sector 3)

5.1 Overview of sector

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. This sector also includes evaporative emissions of greenhouse gases arising from other types of product use (e.g. N₂O emissions from medical use).

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

- ↳ Paint application
- ↳ Degreasing and Dry Cleaning
- ↳ Chemical products, manufacture and processing
- ↳ Other, including use of other products as well as uses of solvents not listed above.

The remainder of this chapter is organised as follows. Paragraph 5.1 continues with the presentation of emissions trends from the sector of solvents and use of other products, the assessment of the completeness of the GHG inventory for the sector of solvents and use of other products and the presentation of planned improvements. Then in Paragraph 5.2 methodological issues are addressed.

5.1.1 Emissions trends

Table 5.1 presents CO₂, N₂O and NMVOC emissions from the sector *Solvents and other products use*. GHG emissions in 2012 were 318.51kt (0.3% of the total GHG emissions in Greece, without LULUCF), while NMVOC emissions have been estimated at 54.67 kt, accounting for approximately 26% of the total NMVOC emissions in the country.

Table 5.1 *NMVOC, N₂O and CO₂ emissions (in kt) from Solvents and other products use for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO ₂	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33	154.67	155.12	155.50	155.87	157.70	159.64	160.34	160.68	161.38	161.64	161.75	162.72
N ₂ O	0.45	0.45	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.50
Total GHG (ktCO ₂ eq)	308.34	315.54	314.37	312.95	307.39	299.82	298.22	300.20	300.40	308.73	306.61	304.28	305.13	305.93	306.75	309.29	311.92	313.41	314.13	315.60	316.17	316.41	318.47
NMVOC	56.65	58.27	57.45	56.16	54.31	51.64	51.05	51.43	51.36	53.75	53.20	52.35	52.49	52.61	52.73	53.05	53.68	53.90	54.01	54.24	54.32	54.36	54.67

It should be mentioned that the emissions estimates presented in this section are associated with a high level of uncertainty that is related to both emission factors and available activity data used.

5.1.2 Completeness

The main problem concerning the estimation of emissions from this sector is the availability of reliable activity data. **Table 5.2** 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 sector.

Table 5.2 *Solvents and other products use -Completeness*

Solvents and Other Products Use	NMVOC	CO ₂	CH ₄	N ₂ O	HFC	PFC	SF ₆
A. Paint application	☒	☒					
B. Degreasing and dry cleaning	☒	☒					
C. Chemical Products. Manufacture and Processing	☒						
D. Other							
1. Domestic solvent use	☒	☒					
2. Wood preservation	☒	☒					
3. Fat edible and non edible oil extraction	☒	☒					
4. Printing industry	☒	☒					
5. Use of N ₂ O in medicine ¹⁾				☒			
6. N ₂ O from fire extinguishers				NO			
7. N ₂ O from aerosol cans ¹⁾				☒			
8. Other use of N ₂ O				NO			

NO: Not Occurring

¹⁾ Lack of appropriate methodology

5.1.3 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.

5.2 Methodological issues

The calculation of NMVOC emissions requires a very detailed analysis of the use of solvents and other products containing volatile organic compounds. There are two basic approaches for the estimation of emissions from Solvent and Other Product Use, which depend on the availability of data on the activities producing emissions and the emission factors.

- ☞ **Production-based.** In cases that solvent or coating use is associated with centralised industrial production activities (e.g. automobile and ship production), it is generally possible to develop NMVOC emission factors based on unit of product output. Next, annual emissions are estimated on the basis of production data.
- ☞ **Consumption-based.** In many applications of paints, solvents and similar products, the end uses are too small-scale, diverse, and dispersed to be tracked directly. Therefore, emission

estimates are generally based on total consumption (i.e. sales) of the solvents, paints, etc. used in these applications. The assumption is that once these products are sold to end users, they are applied and emissions generate relatively rapidly. Emission factors developed on the basis of this assumption can then be applied to data from sales for the specific solvent or paint products.

The application of both approaches needs detailed activity data, concerning either e.g. the amount of pure solvent consumed or the amount of solvent containing products consumed. The availability of such activity data in Greece is limited and as a result the default CORINAIR methodology is applied for the estimation of NMVOC emissions.

It should be mentioned that evaporative emissions of GHG arising from other types of product use (e.g. N₂O emissions from medical use), are not estimated since appropriate methodologies have not been developed yet.

Carbon dioxide emissions are calculated from NMVOC emissions, assuming that the carbon content of NMVOC is 85%.

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 (0.5 kg / capita).

Metal Degreasing and Dry Cleaning

Emission estimates are given only for the dry cleaning sector. These estimates are based on population figures and default emission factors from CORINAIR (0.25 kg /capita) that is applicable to all types of dry cleaning equipment.

Other Use of Solvents and Related Activities

The emission factors used for some of the activities defined in CORINAIR and for which it was possible to obtain the corresponding activity data from the Hellenic Statistical Authority, are:

- ✎ Production and processing of PVC: 40 kg / t of product produced or processed.
- ✎ Production of pharmaceutical products: 14 g /capita.
- ✎ Ink production: 30 kg / t of product.
- ✎ Glue production, applied emission factor: 20 kg /t of product
- ✎ For the wood preservation: 24 kg / t of wood preserved
- ✎ For fat edible and non edible oil extraction: 14 kg NMVOC/ t of seed processed

↪ For domestic solvent use (except paint application): 2.6 kg NMVOC/capita/year

In the case of **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 (260 kg / t ink) is the average of emission factors for newspaper printing (54 kg /t ink) and for books and other leaflets printing (132-800 kg / t ink).

Solvent and other product use - N₂O emissions (source categories 3D1 & 3D3)

For source categories 3D1 and 3D3, neither national activity data nor IPCC methodology are available for the estimation of N₂O emissions. 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, as concerns the estimation of emissions for the 3D1 and 3D3 source categories.
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 1990-2012 of the 3D1 and 3D3 were estimated.

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6. Agriculture (CRF sector 4)

6.1 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 6.1 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 6.2 – 6.6) 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.

6.1.1 Emissions trends

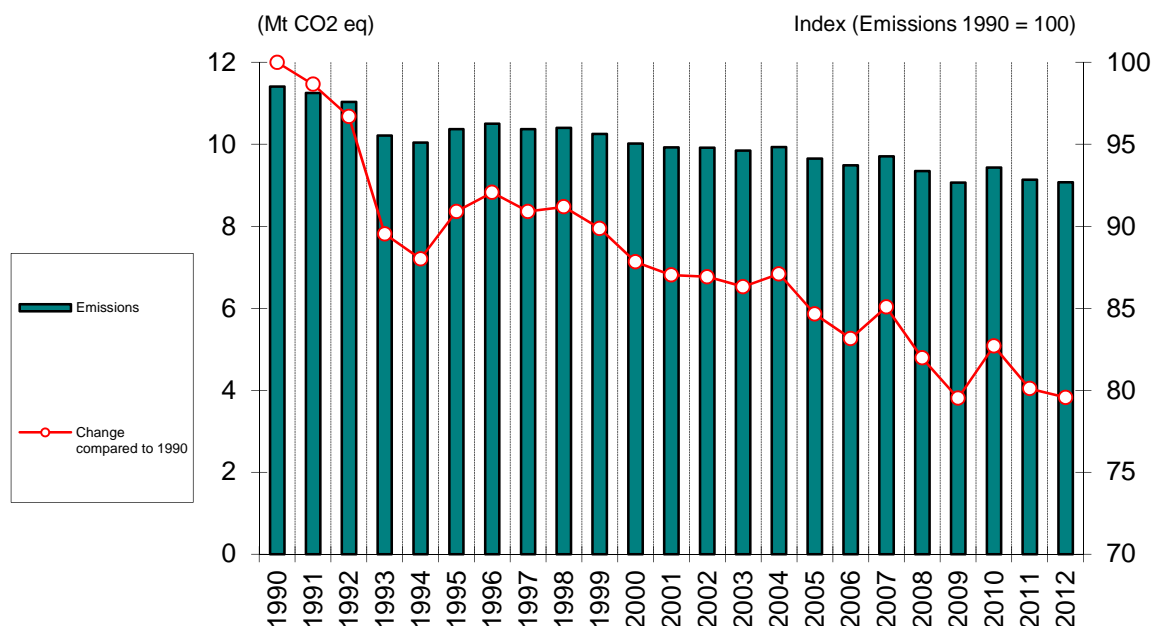
GHG emissions from *Agriculture* decreased by 20.4% between 1990 and 2012 (**Figure 6.1**), with an average annual rate of decrease of 0.93%. The steep decrease observed for the years 1993 and 1994 is due to the cut backs in public incentives for the use of synthetic fertilizers.

Emissions from *Agriculture* and especially N₂O emissions from agricultural soils are characterized by intense fluctuations during the period 1990 – 2012. 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 6.1**.

Table 6.1 *GHG emissions (in kt CO₂ eq) per gas from Agriculture, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N ₂ O	7758	7625	7422	6613	6421	6727	6819	6682	6707	6567	6351
CH ₄	3649	3630	3610	3601	3619	3643	3683	3687	3695	3685	3669
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N ₂ O	6257	6213	6145	6232	5946	5789	6014	5678	5399	5762	5460
CH ₄	3671	3703	3702	3704	3710	3696	3690	3672	3671	3671	3678
Year	2012										
N ₂ O	5404										
CH ₄	3672										

**Figure 6.1** *Total GHG emissions (in kt CO₂ eq) from Agriculture for the period 1990 – 2012*

Nitrous oxide represents the main GHG from *Agriculture*, with a contribution ranging from 59.5% to 68.0%. Nitrous oxide emissions in 2012 decreased by 30.3 compared to 1990 levels with an average annual rate of decrease estimated at 1.38%.

Agricultural soils are the main source of emissions from *Agriculture* (**Figure 6.2**), accounting for 53% - 63% of the total emissions from the sector.

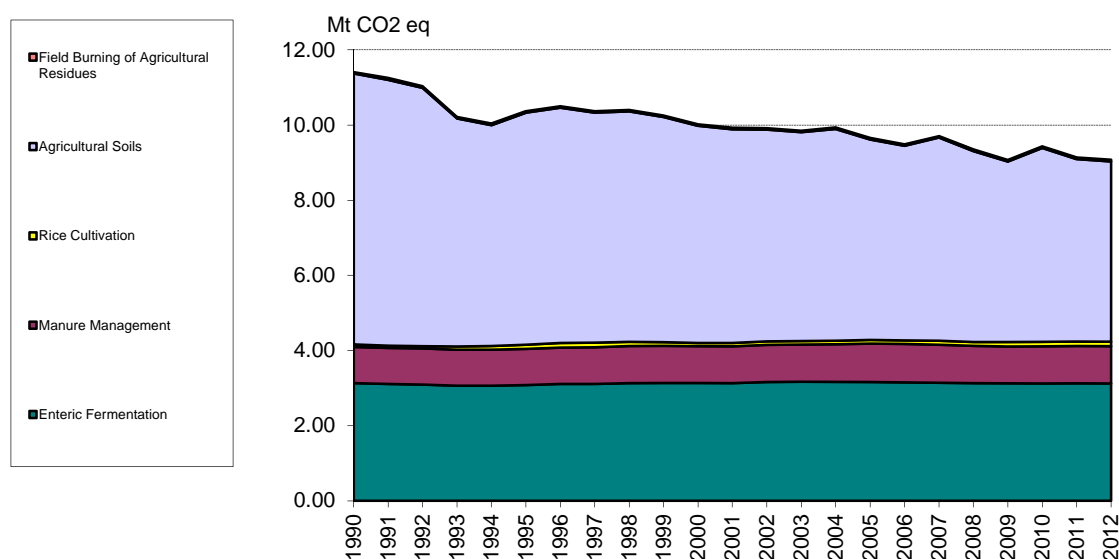


Figure 6.2 *GHG emissions (in kt CO₂ eq) from Agriculture per source category, for the period 1990 – 2012*

6.1.2 Methodology

The calculation of GHG emissions from *Agriculture* is based on the methodologies and emission factors suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

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. Data on animal population for 2009 and 2012 and on agricultural production per crop for 2012 are provisional estimations.

The methodology applied for the calculation of emissions per source category is briefly presented in **Table 6.2**, while a detailed description is given in the corresponding paragraphs (Paragraphs 6.2 – 6.6).

Key categories

If enteric fermentation is considered as a common source, following the suggestion by IPCC good practice guidance, 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 6.2 *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 6.3**.

Table 6.3 *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 which are responsible for 67% of methane emissions from this source and therefore the. 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 emissions estimation's methodology is planning, especially for the most important of these, like goats.

Concerning agricultural soils both simple and detailed methodologies (Tier 1a and Tier 1b) 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.

6.1.3 Completeness

Table 6.4 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 6.4 *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.

6.2 Enteric fermentation (CRF Source Category 4A)

6.2.1 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 Good Practice Guidance. 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 2012 account for 34% of total GHG emissions from *Agriculture* and for 2.8% of total national emissions (excluding *LULUCF*). The average annual rate of decrease of emissions from enteric fermentation for the period 1990 – 2012, is estimated at 0.01% (decrease by 0.22% in 2012 compared to 1990). Emissions from enteric fermentation are presented in *Table 6.5*.

Table 6.5 CH₄ emissions (kt) from enteric fermentation for the period 1990 – 2012

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ emissions (kt)	149.03	148.04	147.31	145.82	145.88	146.66	148.05	148.12	149.12	149.27	149.27
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ emissions (kt)	149.20	150.61	150.64	150.51	150.70	150.40	149.90	148.94	148.55	148.65	148.96
Year	2012										
CH ₄ emissions (kt)	148.71										

Methane emissions from enteric fermentation in 2012 were recalculated for the period 1990 to 2012 due to modification on the figures of digestibility and of methane conversion factor for cattle and the re-estimation of the milk yield for sheep following the strong recommendation by the 2012 and 2013 ERTs.

6.2.2 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:

$$GE = \left[\frac{(NE_m + NE_a + NE_l + NE_p)}{(NE_{ma}/DE)} + \frac{(NE_g)}{(NE_{ga}/DE)} \right] \cdot [DE/100]$$

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

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 6.6** for the period 1990-2012. 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. Portion of cows giving birth is estimated at 0.9 while milk fat content is considered at 4. 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 ($C_a = 0$).

Digestibility for dairy cattle was reconsidered following the strong recommendation by 2012 and 2013 ERTs for investigation of this factor and the conclusions arose by the discussion performed in the framework of the Bilateral Review with agriculture experts from Spain. It was concluded that the figure of 65% is more appropriate for Greece taking into consideration that the milk yield is high and that cattle diets in Greece approach more the characteristics of the good preserved forages, and grain supplemented forage-based than these of crop by-products and range lands.

For the reconsideration of methane conversion factor (Y_m), the correlation proposed by the Cambra-López et al. (2008)¹⁵ for cattle was utilized, i.e.

$$Y_m = -0.0038 \cdot DE^2 + 0.3501 \cdot DE - 0.8111$$

given the fact that Y_m and digestibility are strongly correlated.

Table 6.6 *Number of dairy cattle in 1000s (three-year average) and milk production yield in kg/head/day, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy cattle (1000s)	212	209	212	197	193	181	186	180	170	169	169
Milk prod. yield (kg/head/day)	7.50	7.63	8.15	9.38	9.57	10.44	10.17	10.50	11.22	11.19	11.38
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Dairy cattle (1000s)	168	158	152	153	153	153	148	141	136	134	136
Milk prod. yield (kg/head/day)	11.57	12.72	12.52	13.12	14.02	13.736	13.90	14.69	15.14	15.39	15.26
Year	2012										
Dairy cattle (1000s)	131										
Milk prod. yield (kg/head/day)	15.76										

Finally, in **Table 6.7** information regarding gross energy (Ge_i) and emissions factors (EFs) for the whole of period 1990-2012 is presented.

¹⁵ Cambra-López, M., P. García Rebollar, F. Estellés and A. Torres (2008). Estimation of emissions from ruminants in Spain: the methane conversion factor. Archivos de Zootecnia (http://www.uco.es/organiza/servicios/publica/az/php/az.php?idioma_global=0&revisiones=143&codigo=1640)

Table 6.7 *Gross energy (GE) and emissions factor (EF) for dairy cattle for the period 1990 - 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GE (MJ/head/day)	199	200	205	216	218	226	224	227	233	233	235
EF (kg CH ₄ /head/yr)	76.9	77.3	79.2	83.5	84.2	87.3	86.4	87.5	90.1	90.0	90.6
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
GE (MJ/head/day)	236	247	245	251	259	256	258	265	269	271	270
EF (kg CH ₄ /head/yr)	91.3	95.4	94.7	96.8	100.0	99.0	99.6	102.4	104.0	104.9	104.4
Year	2012										
GE (MJ/head/day)	275										
EF (kg CH ₄ /head/yr)	106.2										

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 IPCC Good Practice Guidance.

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 6.8** for the period 1990-2012.

The calculation of the emission factors for each activity is based on the equation presented above for the dairy cattle (Equation 4.14 of IPCC Good Practice Guidance). In **Table 6.9** 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 2012. 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 EL.STAT. 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. ($C_a = 0.17$).

As for the dairy Cattle, the digestibility was reconsidered for the other cattle as well (Strong recommendation by 2012 and 2013 ERTs) and the figure of 65% was considered more appropriate for Greece.

Table 6.8 *Number of other cattle (in 1000s) for each sub-category (three-year average), for the period 1990 – 2012*

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
< 1 year											
For slaughter as calves	100	101	93	80	66	58	59	52	69	66	69
Females	65	62	56	54	57	57	58	55	52	63	50
Males	43	42	39	44	52	59	59	59	55	55	51
1-2 years											
Females	54	53	52	47	45	43	45	45	46	44	45
Male	65	64	59	52	50	53	56	57	59	57	52
> 2 year											
Females	143	139	129	118	114	121	126	135	145	142	142
Males	7	7	7	6	6	6	7	8	11	13	13
Total	479	468	436	402	390	397	411	410	438	440	422
Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
< 1 year											
For slaughter as calves	53	58	66	69	71	70	67	74	76	77	70
Females	56	57	61	60	59	60	59	53	50	55	65
Males	56	59	63	65	64	67	61	52	47	48	57
1-2 years											
Females	47	52	56	56	57	56	58	59	63	69	73
Males	45	49	60	70	74	72	67	65	65	61	58
> 2 year											
Females	142	161	171	174	180	180	187	181	190	197	204
Males	12	13	13	13	13	14	15	17	18	20	20
Total	411	450	490	506	517	519	515	501	509	527	546
Sub-categories	2012†										
< 1 year											
For slaughter as calves	70										
Females	70										
Males	57										
1-2 years											
Females	75										
Males	54										
> 2 year											
Females	206										
Males	21										
Total	552										

† Provisional data

For the reconsideration of the methane conversion factor (Y_m), the correlation proposed by the Cambra-López et al. (2008) ¹⁶ for cattle was utilized, i.e.:

$$Y_m = -0.0038 \cdot DE^2 + 0.3501 \cdot DE - 0.8111$$

given the fact that Y_m and digestibility are strongly correlated.

Table 6.9 *Mean Weight, Gross energy (GE_i), CH_4 conversion rate (Y_m) value and emissions factor (EFs) for each subcategory of other cattle for 2012*

	Mean Weight (kg)	Gross Energy (GE_i) MJ/day/head	Conversion rate (Y_m)	Emissions factors (EF) KgCH ₄ /head/yr
< 1 year				
For slaughter as calves	200	83.3	0.0589	32.2
Females	180	87.5	0.0589	33.8
Males	230	97.2	0.0589	37.6
1-2 years				
Females	450	129.3	0.0589	50.0
Males	500	140.9	0.0589	54.4
> 2 year				
Females	550	146.6	0.0589	56.6
Males	750	161.6	0.0589	62.5
Average	415	123.7	0.0589	47.8

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:

$$EF_i = \frac{GE_i \cdot Y_{m_i} \cdot 365}{55.65}$$

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 Y_m is the methane conversion rate which is the fraction of the gross energy in feed converted to CH₄.

¹⁶ Cambra-López, M., P. García Rebollar, F. Estellés and A. Torres (2008). Estimation of emissions from ruminants in Spain: the methane conversion factor. Archivos de Zootecnia (http://www.uco.es/organiza/servicios/publica/az/php/az.php?idioma_global=0&revisiones=143&codigo=1640)

The calculation of gross energy for sheep is based on the following equation:

$$GE = \left[\frac{(NE_m + NE_a + NE_l + NE_p)}{(NE_{ma}/DE)} + \frac{(NE_g + NE_{wool})}{(NE_{ga}/DE)} \right] \left[\frac{DE}{100} \right]$$

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

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 6.10**.

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 IPCC Good Practice Guidance, based on experts' estimates regarding the types of feed intake for Greece. In **Table 6.11** information regarding gross energy (Ge_i), CH_4 conversion rate (Y_m) values and emissions factors (EFs) for each subcategory of sheep (such as grazing, lactation and growth) is presented for 2012.

Table 6.10 *Number of sheep (in 1000s) for each sub-category (three-year average), for the period 1990 – 2012*

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milking ewes											
Milk production	5254	5243	5252	5274	5315	5353	5370	5382	5393	5415	5454
Only suckling	395	395	395	397	400	403	404	405	406	408	411
Other female sheep > 1 year	734	733	734	737	743	748	751	752	754	757	762
Males > 1 year old	395	395	395	397	400	403	404	405	406	408	411
Female lambs	1530	1526	1529	1536	1547	1559	1563	1567	1570	1577	1588
Male lambs	382	382	382	384	387	390	391	392	393	394	397
Total	8692	8673	8688	8725	8792	8856	8883	8904	8922	8958	9023
Born sheep	8490	8487	8590	8664	8728	8787	8841	8855	8882	8910	8966
Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
Milking ewes											
Milk production	5476	5478	5418	5364	5329	5330	5363	5383	5370	5357	5333
Only suckling	412	412	408	404	401	401	404	405	404	403	401
Other female sheep > 1 year old	765	766	757	750	745	745	750	753	751	749	745
Males > 1 year old	412	412	408	404	401	401	404	405	404	403	401
Female lambs	1594	1595	1577	1562	1552	1552	1561	1567	1564	1560	1553
Male lambs	399	399	394	390	388	388	390	392	391	390	388
Total	9059	9062	8962	8874	8816	8818	8872	8906	8884	8862	8822
Born sheep	9005	9039	9038	9024	9008	8998	9002	9019	9017	9008	8981
Sub-categories	2012†										
Milking ewes											
Milk production	5328										
Only suckling	401										
Other female sheep > 1 year old	745										
Males > 1 year old	401										
Female lambs	1551										
Male lambs	388										
Total	8813										
Born sheep	8972										

† 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 6.11 *Gross energy (Gei), CH₄ conversion rate (Ym) value and emissions factor (EFs) for each subcategory of sheep for 2012*

	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) KgCH ₄ /head/yr
Female lamb	16.2	0.05	5.3
Female sheep - milking ewes	22.5	0.07	10.3
Female sheep – other	17.4	0.07	8.0
Male lamb	21.0	0.05	6.9
Male sheep	22.7	0.07	10.4
Average	20.9	6.64	9.09

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 IPCC Guidelines (Developed countries, Table 4-3, IPCC 1997).

The number of animals used for the calculation of methane emissions (**Table 6.12**) is a three-year average centred at the year of reference.

6.2.3 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.

Table 6.12 *Number of animals (in 1000s) by category (three-year average), for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
------	------	------	------	------	------	------	------	------	------	------	------

Buffalo	0.827	0.865	0.910	0.827	0.765	0.709	0.741	0.796	0.843	0.906	0.954
Goats	5339	5345	5360	5395	5449	5513	5565	5595	5610	5623	5640
Horses	46	42	40	38	36	35	33	32	31	30	29
Mules and ashes	187	174	161	150	140	130	122	114	108	101	95
Swine	994	994	1000	1008	1005	997	993	995	990	979	957
Poultry	28747	28648	28972	29151	29231	29198	29266	29482	30005	30480	30150
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
Buffalo	1.003	1.048	1.141	1.212	1.305	1.338	1.599	1.731	1.819	1.904	2.017
Goats	5658	5652	5600	5517	5444	5409	5341	5279	5215	5155	5113
Horses	29	28	28	27	27	27	28	28	28	27	27
Mules and ashes	90	84	79	74	69	66	60	55	51	46	42
Swine	946	937	939	942	930	918	891	885	880	875	869
Poultry	29937	29312	29936	30429	31251	31592	30896	30067	29110	29079	29048
Year	2012†										
Buffalo	2.126										
Goats	5089										
Horses	27										
Mules and ashes	40										
Swine	866										
Poultry	29016										

† Provisional data

6.2.4 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:

- 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.
- 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.
- Comparison of information regarding animal population, agricultural crop production and emissions factors with this of other neighbour countries.

- Estimations were checked with several calculation tools such as emissions trends and sum deviations.

6.2.5 Recalculations

CH₄ emissions from enteric fermentation have been recalculated for 1990 to 2011, because of the updating of the DE and Ym figures for Cattle and the Milk Yield for sheep. Moreover, emissions for 2008 to 2011 have been recalculated because of the updated activity data of the population of cattle for 2009.

The deviation of the emissions from enteric fermentation in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in *Table 6.13*.

Table 6.13 *Recalculations of CH₄ emissions from enteric fermentation (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	-3.592	-3.553	-3.486	-3.335	-3.266	-3.250	-3.314	-3.289	-3.348	-3.333	-3.267
Impact on total emissions (excl LULUCF)	-0.111	-0.110	-0.105	-0.101	-0.096	-0.094	-0.094	-0.090	-0.088	-0.088	-0.084
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	-3.229	-3.345	-3.476	-3.591	-3.693	-3.693	-3.648	-3.413	-3.440	-3.167	-2.976
Impact on total emissions (excl LULUCF)	-0.082	-0.086	-0.087	-0.089	-0.090	-0.092	-0.089	-0.085	-0.090	-0.087	-0.084

6.2.6 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.

6.3 Manure management (CRF Source Category 4B)

6.3.1 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 2012 accounted for 4.4% and 6.5% of total GHG emissions from *Agriculture* respectively, and for 0.36% and 0.54% of total national emissions respectively (without *LULUCF*). CH₄ emissions in 2012 decreased by 5.74% compared to 1990 levels, with an average annual rate of decrease estimated at 0.26% for the period 1990 - 2012. N₂O emissions in 2012 decreased by 9.8% compared to 1990 levels, with an average annual rate of decrease estimated at 0.45%. CH₄ and N₂O emissions from manure management for the period 1990 – 2012 are presented in *Table 6.14*.

Table 6.14 CH₄ and N₂O emissions (in kt) from manure management, for the period 1990 – 2012

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ (kt)	20.16	20.09	20.19	20.20	20.20	20.15	20.20	20.21	20.24	20.22	20.07
N ₂ O (kt)	1.74	1.73	1.73	1.73	1.72	1.74	1.76	1.77	1.81	1.82	1.81
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ (kt)	19.98	19.85	19.84	19.89	19.91	19.84	19.55	19.37	19.17	19.11	19.06
N ₂ O (kt)	1.80	1.84	1.86	1.90	1.94	1.94	1.92	1.90	1.89	1.90	1.91
Year	2012										
CH ₄ (kt)	19.00										
N ₂ O (kt)	1.92										

CH₄ emissions from the manure management sector have been recalculated for the period 1990 to 2011, because of the updating of the DE and Y_m figures for Cattle. Moreover, N₂O emissions from manure management sector have been recalculated for the period 1990 to 2011, because of the modification of dairy cattle Nex value estimation methodology and updating of the manure management sector system allocation of sheep, goats and poultry. These recalculations were performed following the recommendation by the 2012 and 2013 ERTs for reconsideration of these parameters.

6.3.2 Methodology

Manure management systems per animal species

The shares of manure management systems per animal species are presented in *Table 6.15* considering 100% conditions of temperate climate region for Greece.

Country-specific data for dairy cattle, other cattle, buffalo, sheep, goats, poultry and swine are considered, while for the rest that there are no country specific data, the assumption of utilized values referring to Near East and Mediterranean category on IPCC (1997) guidelines for the allocation of manure to animal waste management systems per animal species was followed.

Table 6.15 *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 asses	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.

CH₄ emissions from manure management

CH₄ emissions from manure management were estimated using IPCC Tier 2 approach for dairy cattle and other cattle and sheep. For the rest of the animals, Tier 1 approach was used (IPCC 1997, Tables 4-5 and 4-6). Livestock population has been already presented in Tables 6.6, 6.8, 6.10 and 6.12..

For the estimation of EF of dairy and other cattle and sheep the equation suggested by IPCC (1997) guidelines was used:

$$EF_i = VS_i \cdot 365 \cdot Bo_i \cdot 0.67 \cdot \sum_{ijk} MCF_{jk} \cdot MS_{ijk}$$

where:

EF_i is the annual emission factor for defined livestock population i , in kg

VS_i is the daily VS excreted for an animal within defined population i , in kg

Bo_i is the maximum CH_4 producing capacity for manure produced by an animal within defined population i , m^3/kg of VS

MCF_{jk} is the CH_4 conversion factors for each manure management system j by climate region k

MS_{ijk} is the share of animal species/category i 's manure handled using manure system j in climate region k

The daily VS excretion rates for dairy cattle, other cattle and sheep was estimated using the feed intake estimated through the CH_4 emissions' calculation from enteric fermentation. The proposed equation by IPCC guidelines (Equation 4.16, IPCC 1997) was used:

$$VS = GE / 18.45 \cdot (1 - DE / 100) \cdot (1 - ASH / 100)$$

where:

GE is the estimated daily average feed intake in MJ/day

DE is the digestible energy of the feed in percent

ASH is the ash content of the manure in percent (8%)

In **Table 6.16** the parameters used for the estimation CH_4 emissions from manure management of dairy cattle, other cattle and sheep are presented for 2012. As it is shown, Bo values proposed by IPCC Rev. 1996 (Appendix B) and default MCF values provided by IPCC Guidelines for different manure management systems were used.

For Dairy Cattle, the figure 1.5% was used for the cases of 'Solid storage and dry lot' and 'Pasture/ range/ paddock' while the figure of 45 % for the case of 'liquid systems'.

For Other Cattle, the figure 1.5% was used for the cases of 'Solid storage and dry lot' and 'Pasture/ range/ paddock' while the figure of 0.5 % for the case of 'Daily spread' .

For sheep, the figure of 1.5% for the case of 'Pasture/ range/ paddock' is utilized and the figure of 29% for the manure managed with solid practices as manure is being collected by the stall only two times per year. Therefore it is considered that the case of 'Pit storage below animal confinements' exists, following the recommended categorization by the IPCC 2006, Chapter 10: Emissions from Livestock and Manure Management, Page 10.45. The figure of 29% is selected considering that the mean temperature in Greece is about 16 °C (Please refer to National Communication 2014, Page 50, Figure 2.4).

Table 6.16 *Parameters for the estimation CH₄ emissions from manure management of dairy cattle, other cattle and sheep for 2012*

	Dairy cattle	Other cattle	Sheep
DE, %	65	65	65
ASH, %	8	8	8
VS, kg/day	4.8	2.2	0.36
Bo, m ³ /kg of VS	0.24	0.17	0.19
MCF	1.5 / 45	1.5 / 0.5	1.5 / 29
EF, kg/year/head	10.99	1.32	0.72

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.

$$E = \sum_S \left(\sum_T (N_T \cdot Nex_T \cdot MS_{(T,S)}) \right) \cdot EF_S$$

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 emission factors for N excretion and N₂O-N/N are those suggested by the IPCC Guidelines. N excretion for dairy cattle value was reconsidered in the framework of the current submission following the recommendation of the 2013 ERT. The proposed correlation for Europe by the International Institute for Applied Systems Analysis ‘Modelling of Emissions of Air Pollutants and Greenhouse Gases from Agricultural Sources in Europe’ (Page 18) was utilized:

$$\text{N excretion (kg N/animal-year)} = 0.0178 \times \text{Milk Yield (kg/animal-year)} + 0.2271$$

For other cattle and buffalo N excretion values for dairy cattle referring to West Europe countries were used.

For the other animal, Nex values that are recommended by the IPCC guidelines for the Mediterranean countries are used.

Finally, for the estimation of other cattle and sheep N excretion, the adjustment factors for young animals proposed by IPCC guidelines (Table 4.14, IPCC 1997) were used.

In order to meet the recommendation of previous ERT review, it must be mentioned that the Nex values recommended by the IPCC guidelines for the Mediterranean were used for all the animals except of cattle taking into consideration that although they seem to be lower than those recommended for West Europe countries, they are already higher than those estimated with higher

approaches by the West Europe countries. To make this clear, the Nex value of 10.68 kg/head/year for sheep for Greece is higher than the mean value estimated for the European Union of 15 and 27, about 7.35 kg/head/year and 9.15 kg/head/year, respectively, as well as for the majority of the European Countries, although the recommended value by IPCC for Western Europe is 20 kg/head/year. Similarly, the Nex value for swine, 16 kg/head/year is higher than the mean value estimated for the European Union of 15 and 27, about 11.35 kg/head/year and 12.5 kg/head/year, respectively, as well as for the majority of European Countries, although the recommended value by IPCC for the Western Europe is 20 kg/head/year.

6.3.3 Uncertainties and time-series consistency

The combined uncertainty of CH₄ 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 N₂O 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.

6.3.4 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.

6.3.5 Recalculations

CH₄ emissions from manure management sector have been recalculated for 1990 to 2011, because of the updating of the DE and Ym figures for Cattle. Moreover, emissions for 2008 to 2011 have been recalculated because of the updated activity data of the population of cattle for 2009.

The deviation of the emissions from manure management sector in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in **Table 6.17**.

Table 6.17 *Recalculations of CH₄ emissions from manure management sector (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	20.399	20.476	20.352	20.616	20.909	21.263	21.199	21.325	21.390	21.569	22.015
Impact on total emissions (excl LULUCF)	0.068	0.069	0.068	0.069	0.068	0.068	0.066	0.063	0.061	0.061	0.060
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	22.265	22.409	22.090	21.572	21.198	21.311	21.992	22.512	22.744	22.804	22.751
Impact on total emissions (excl LULUCF)	0.060	0.060	0.057	0.056	0.054	0.056	0.055	0.057	0.060	0.063	0.065

N₂O emissions from manure management sector have been recalculated for 1990 to 2011, because of the modification of dairy cattle Nex value estimation methodology and the updating of the manure management sector system allocation of sheep, goats and poultry. Moreover, emissions for 2008 to 2011 have been recalculated because of the updated activity data of the population of cattle for 2009.

The deviation of the emissions from the manure management sector in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in **Table 6.18**.

Table 6.18 *Recalculations of N₂O emissions from manure management sector (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	77.624	79.531	83.037	95.398	99.155	105.492	101.711	104.518	108.220	110.110	111.594
Impact on total emissions (excl LULUCF)	0.226	0.228	0.230	0.249	0.247	0.253	0.244	0.239	0.238	0.241	0.234
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	113.246	113.975	111.718	111.549	113.357	112.902	113.301	116.954	115.602	116.624	116.266
Impact on total emissions (excl LULUCF)	0.233	0.239	0.233	0.236	0.236	0.242	0.2353	0.2427	0.2532	0.270	0.278

6.3.6 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.

6.4 Rice cultivation (CRF Source Category 4C)

6.4.1 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 in 2012 account for 1.3% of total GHG emissions from *Agriculture* and for 0.11% of total national emissions (without *LULUCF*). CH₄ emissions increased by 70.2 % in 2012 compared to 1990, with an average annual rate of increase of 3.2% for the period 1990 - 2012. CH₄ emissions from rice cultivation for the period 1990 – 2012 are presented in *Table 6.19*.

Table 6.19 CH₄ emissions (in kt) from rice cultivation for the period 1990 – 2012

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄	3.29	2.95	2.94	4.05	4.74	5.22	5.72	5.82	5.25	4.67	3.98
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
CH ₄	4.22	4.48	4.52	4.55	4.62	4.46	5.00	5.00	5.60	5.60	5.60
Year	2012†										
CH ₄	5.6										

† Provisional data

The fluctuations in emissions trends are attributed to the annual changes in the amount of the cultivated areas as provided by the HEL.SAT..

6.4.2 Methodology

In order to estimate methane emissions from rice cultivation, the default methodology suggested by the IPCC Good Practice Guidance was followed. The cultivated areas provided by the NSSG and the default 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.

6.4.3 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.

6.4.4 Recalculations

No recalculations were performed.

6.5 Agricultural soils (CRF Source Category 4D)

6.5.1 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 animal manure deposited to soils during pasture, range and paddock accounted for 16.3% of total GHG emissions from *Agriculture* and for 1.33% of total national emissions (without *LULUCF*) in 2012. Emissions decreased in 2012 by 3.8% compared to 1990 levels, with an average annual rate of decrease of 0.17% for the period 1990 – 2012. Direct N₂O emissions from agricultural soils in 2012 accounted for 16.9% of total GHG emissions from *Agriculture* and for 1.38% of total national emissions (without *LULUCF*). Direct emissions in 2012 decreased by 46.2% compared to 1990 levels, with an average annual rate of decrease of 2.1% for the period 1990 - 2012. Finally, indirect N₂O emissions in 2012 accounted for 19.7% of total GHG emissions from agriculture and for 1.33% of total national emissions (without *LULUCF*). Indirect emissions in 2012 decreased by 36.7% compared to 1990 levels, with an average annual rate of decrease estimated at 1.7% for the period 1990 – 2012. Emissions from agricultural soils for the period 1990 – 2012 are presented in **Table 6.20**.

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 – 2012.

N₂O emissions from agricultural soils are recalculated for the period 1990 to 2011, because of the modification of dairy cattle Nex value estimation methodology and the updating of the manure management sector system allocation of sheep, goats and poultry following the recommendation by the 2012 and 2013 ERTs for reconsideration of these parameters.

Table 6.20 *N₂O emissions (in kt) from agricultural soils for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Animal production	4.96	4.93	4.91	4.91	4.92	4.96	4.98	4.99	5.00	5.01	5.02
Direct emissions	9.19	9.02	8.64	7.16	6.80	7.31	7.46	7.20	7.18	6.92	6.53
Indirect emissions	9.09	8.86	8.61	7.50	7.23	7.65	7.76	7.56	7.60	7.40	7.09
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
Animal production	5.03	5.04	5.00	4.95	4.91	4.89	4.88	4.86	4.83	4.81	4.78
Direct emissions	6.36	6.24	6.13	6.33	5.81	5.52	5.95	5.40	4.90	5.58	5.04
Indirect emissions	6.96	6.89	6.80	6.90	6.49	6.29	6.62	6.13	5.76	6.26	5.83
Year	2012†										
Animal production	4.77										
Direct emissions	4.95										
Indirect emissions	5.75										

† Provisional data

6.5.2 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, using the default factors suggested by IPCC Guidelines (see Paragraph 6.3). Nitrogen input from pasture, range and paddock and N₂O emissions for the period 1990 – 2012 are presented in **Table 6.21**.

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 1a methodology suggested by the IPCC Good Practice Guidance was applied. The data regarding the annual quantities of synthetic fertilizers consumed in the country derive from Pan-Hellenic Association of Professional Fertilizers Producers & Dealers.

Table 6.21 *Nitrogen input (in kt) and N₂O emissions (in kt) from pasture, range and paddock, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	157.96	157.00	156.36	156.12	156.68	157.73	158.40	158.71	159.18	159.32	159.75
N ₂ O emissions	4.96	4.93	4.91	4.91	4.92	4.96	4.98	4.99	5.00	5.01	5.02
Year	2001	2002	2003	2004	2005	2006	2007	2008†	2009†	2010†	2011†
N input	159.94	160.34	159.06	157.39	156.13	155.64	155.28	154.61	153.75	152.94	152.23
N ₂ O emissions	5.03	5.04	5.00	4.95	4.91	4.89	4.88	4.86	4.83	4.81	4.78
Year	2012†										
N input	151.89										
N ₂ O emissions	4.77										

† Provisional data

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.

As a part of the nitrogen contained in the fertilizer is volatised in ammonia and nitrogen oxides, the relevant conversion factor suggested by IPCC was used (IPCC 1997, Table 4-19). The amount of

synthetic nitrogen applied to soils and the subsequent N₂O emissions for the period 1990 – 2012 are presented in **Table 6.22**.

Table 6.22 *Synthetic nitrogen applied (in kt) and N₂O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	381.60	367.20	351.00	276.30	257.40	284.40	290.70	276.30	277.20	263.70	243.00
N ₂ O emissions	7.50	7.21	6.89	5.43	5.06	5.59	5.71	5.43	5.45	5.18	4.77
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N input	234.00	227.70	222.30	229.50	201.60	189.00	212.40	180.90	157.50	191.70	163.25
N ₂ O emissions	4.60	4.47	4.37	4.51	3.96	3.71	4.17	3.55	3.09	3.77	3.21
Year	2012†										
N input	157.90										
N ₂ O emissions	3.10										

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 (IPCC 1997, Table 4-19). In **Table 6.23** nitrogen input to soils from animal manure and subsequent N₂O emissions are presented, for the period 1990 – 2012.

For the estimation of N₂O emissions from N-fixing crops and crop residues, the Tier 1b methodology suggested by the IPCC Good Practice Guidance has been followed, using the default factors per crop regarding residue to crop product ratio, dry matter fractions and nitrogen content (IPCC 2000, Table 4-16). The fraction of residue dry biomass that is N (FRAC_{NCRO}) was estimated to be about 0.005. This figure is a little lower than the IPCC default value (0.015). This occurred due to the fact that cereal production of Greece consists mainly of wheat (36 per cent of cereal production) and maize (52 per cent of cereal production) crops, whose FRAC_{NCRO} is significantly lower than 0.015, 0.0028 of wheat and 0.0081 of maize according to IPCC Good Practice Guidance. As far as the fractions of residues used as fuel and for construction, there has not been any estimation yet due to the lack of relevant data.

The fraction of residues that is burned on-site in fields, which needs to be subtracted, was assumed to be 10% according to IPCC Good Practice Guidance (IPCC 2000, Appendix 4A-2). Data on

agricultural crop production used for the calculation of emissions was obtained from the annual national statistics of the EL.STAT.

Table 6.23 *Nitrogen input to soils from animal manure (in kt) and N₂O emissions (in kt) from animal manure used as fertilizers, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	57.43	57.13	57.32	57.31	57.13	57.63	58.08	58.46	59.48	59.44	59.00
N ₂ O emissions	1.13	1.12	1.13	1.13	1.12	1.13	1.14	1.15	1.17	1.17	1.16
Year	2001	2002	2003	2004	2005	2006	2007	2008†	2009†	2010†	2011†
N input	58.73	59.66	60.25	61.22	62.34	62.17	61.37	60.68	60.41	60.70	60.98
N ₂ O emissions	1.15	1.17	1.18	1.20	1.22	1.22	1.21	1.19	1.19	1.19	1.20
Year	2012†										
N input	61.02										
N ₂ O emissions	1.20										

† Provisional data

N₂O emissions from N-fixing crops and crop residues for the period 1990 – 2012 are presented in **Table 6.24**.

Table 6.24 *N₂O emissions (in kt) from N-fixing crops and crop residues, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N-fixing crops	0.022	0.025	0.024	0.023	0.021	0.022	0.024	0.022	0.021	0.022	0.022
Crop residues	0.463	0.581	0.516	0.504	0.520	0.490	0.502	0.515	0.466	0.470	0.491
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	2011†
N-fixing crops	0.021	0.021	0.020	0.019	0.019	0.019	0.020	0.016	0.017	0.016	0.015
Crop residues	0.506	0.493	0.474	0.512	0.525	0.485	0.470	0.552	0.517	0.524	0.537
Year	2012†										
N-fixing crops	0.015										
Crop residues	0.546										

† Provisional data

For the estimation of N₂O direct emissions from the sewage sludge used in agriculture, the default emission factor of 1.25% N₂O-N per kg N (IPCC Good Practice Guidance) was applied while the annual amount of sewage sludge used in agriculture in Greece for the period 1990-2012 was provided by the Waste Management Sector of the Ministry of Environment, Energy and Climate Change (MEECC). As it is shown, the application of sewage sludge in agriculture as fertilizer was started in 2004 and it remains limited, mainly in the frame of research projects and pilot studies. The N content of sewage sludge (dry matter) used in agriculture is assumed to be 3.0%. This value was obtained from the report ‘Disposal and recycling routes for sewage sludge Part 3 – Scientific and technical report’, Table 3, Page 24, European Commission, 2001.

Nitrogen input to soils from Sewage sludge used in Agriculture and N₂O emissions from sewage sludge used in Agriculture for the period 1990 – 2012 are presented in **Table 6.25**.

Table 6.25 *Nitrogen input to soils from Sewage sludge used in Agriculture (in kg) and N₂O emissions (in t) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N-Sewage sludge											
N ₂ O emissions											
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N-Sewage sludge				781.2	829.92	1353.6	7.2	7.2	7.2	6480	4320
N ₂ O emissions				15.35	16.30	26.59	0.14	0.14	0.14	127.29	84.86
Year	2012										
N-Sewage sludge	224640										
N ₂ O emissions	4412.57										

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 NH_3 , followed by atmospheric deposition as NO_x , HNO_3 and NH_4 on soils and surface waters and subsequent N_2O formation.

↳ Leaching and runoff of nitrogen contained in applied fertilizers (synthetic, animal manure and sewage sludge).

For all sources of N_2O emissions, the Tier 1a methodology suggested by IPCC Good Practice Guidance has been applied. 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 (IPCC 1997, Table 4-23). 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 N_2O emissions for the period 1990 – 2012 are presented in **Table 6.26**.

For the estimation of the fraction of nitrogen that volatilizes as NH_3 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.

6.5.3 Uncertainties and time-series consistency

The combined uncertainty of N_2O 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 400 % (country specific value).

The combined uncertainty of N_2O 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 N_2O 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).

Table 6.26 *Deposited nitrogen (in kt) and indirect N₂O emissions (in kt) from agricultural soils, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atmospheric deposition											
N deposited	88.35	86.48	84.60	76.25	74.22	77.55	78.50	77.06	77.51	76.02	73.70
N ₂ O emissions	1.39	1.36	1.33	1.20	1.17	1.22	1.23	1.21	1.22	1.19	1.16
Leaching/Runoff											
N deposited	196.12	190.93	185.40	160.43	154.23	163.73	166.20	161.64	162.46	157.98	151.05
N ₂ O emissions	7.70	7.50	7.28	6.30	6.06	6.43	6.53	6.35	6.38	6.21	5.93
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Atmospheric deposition											
N deposited	72.67	72.28	71.57	72.28	69.21	67.67	70.00	66.19	63.35	67.07	63.83
N ₂ O emissions	1.14	1.14	1.12	1.14	1.09	1.06	1.10	1.04	1.00	1.05	1.00
Leaching/Runoff											
N deposited	148.01	146.38	144.41	146.67	137.42	133.01	140.40	129.44	121.28	132.55	122.96
N ₂ O emissions	5.81	5.75	5.67	5.76	5.40	5.23	5.52	5.09	4.76	5.21	4.83
Year	2012										
Atmospheric deposition											
N deposited	63.23										
N ₂ O emissions	0.99										
Leaching/Runoff											
N deposited	121.17										
N ₂ O emissions	4.76										

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.

6.5.4 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.

6.5.5 Recalculations

N₂O emissions from Agricultural soils have been recalculated for 1990 to 2011, because of the modification of dairy cattle Nex value estimation methodology and updating of the manure management sector system allocation of sheep, goats and poultry. Moreover, emissions for 2008 to 2011 have been recalculated because of the updated activity data of the population of cattle for 2009.

The deviation of the emissions from Agricultural soils in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in **Table 6.27**.

Table 6.27 *Recalculations of N₂O emissions from Agricultural soils (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	77.624	79.531	83.037	95.398	99.155	105.492	101.711	104.518	108.220	110.110	111.594
Impact on total emissions (excl LULUCF)	-3.273	-3.284	-3.313	-3.404	-3.465	-3.092	-3.131	-3.122	-2.967	-3.053	-3.126
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	-3.135	-2.907	-2.972	-2.837	-2.851	-2.997	-2.808	-2.717	-2.739	-2.399	-2.526
Impact on total emissions (excl LULUCF)	-0.145	-0.133	-0.130	-0.125	-0.116	-0.122	-0.116	-0.109	-0.109	-0.108	-0.110

6.6 Field burning of agricultural residues (CRF Source Category 4F)

6.6.1 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 in 2012 accounted for 0.5% of total GHG emissions from *Agriculture* and for 0.04% of total national emissions (without *LULUCF*). Emissions in 2012 increased by 19.4% compared to 1990 levels with an average annual rate of increase estimated at 0.9%. CH₄ and N₂O emissions from field burning of agricultural residues for the period 1990 – 2012 are presented in **Table 6.28**.

Table 6.28 *GHG emissions (in kt) from field burning of agricultural residues, for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ emissions	1.29	1.81	1.47	1.41	1.53	1.44	1.41	1.43	1.34	1.32	1.39
N ₂ O emissions	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH ₄ emissions	1.42	1.38	1.27	1.42	1.43	1.32	1.28	1.54	1.48	1.45	1.50
N ₂ O emissions	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04
Year	2001										
CH ₄ emissions	1.53										
N ₂ O emissions	0.04										

6.6.2 Methodology

For the estimation of CH₄ and N₂O emissions from field burning of agricultural residues the default methodology suggested in IPCC Guidelines 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 proposed by IPCC (IPCC 2000, Table 4-16 and IPCC 1996, Table 4-17) 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. The emission factors used are the default ones suggested by IPCC Guidelines (IPCC 1997, Table 4-16).

6.6.3 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.

6.6.4 Recalculations

No recalculations were performed.

7. Land Use, Land Use Change and Forestry (CRF sector 5)

7.1 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 according to 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) for use in preparing annual inventories due in 2005 and beyond, and according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use (henceforth in this chapter 2006 GL AFOLU). 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-use¹⁷ 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 outlined in the GPG LULUCF 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.

The remainder of this chapter is organized as follows. Paragraph 7.1 continues with a presentation of emission / removal levels and trends from the sector, a brief discussion 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 in the sector since the previous

¹⁷ 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.

submission. Then (in Paragraphs 7.2 – 7.7) detailed information (descriptions, references and sources of specific methodologies, assumptions, emission factors and activity data used and the rational for their selection) on each category is presented.

7.1.1 Emissions/Removals trends

The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2012. During this period, the LULUCF sector offset on average 2.2% (1.2-2.8%) of the total national emissions (without LULUCF). The sink capacity of the LULUCF sector fluctuates between 1.63 Mt CO₂ eq and 3.00 Mt CO₂ eq, showing a slightly 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.

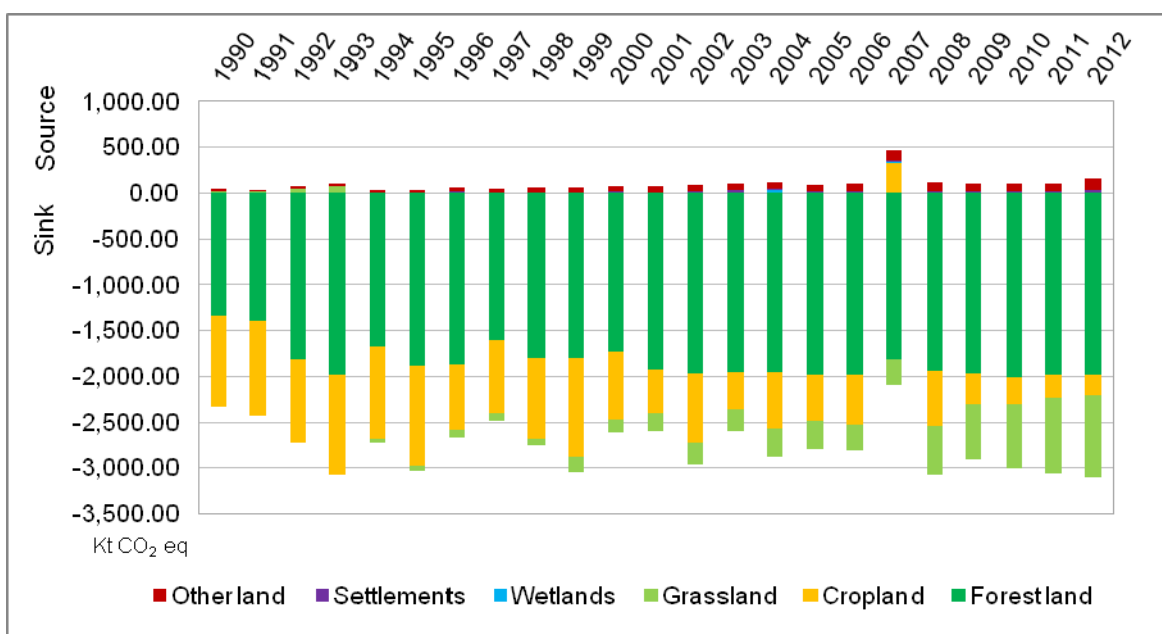


Figure 7.1 Net GHG emissions / removals (in kt CO₂ eq) from the Land Use, Land Use Change and Forestry sector by category for the period 1990 – 2012

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 7.1**, both Forest Land and Cropland (with the exception of the year 2007) categories act as net carbon sinks during the period 1990 – 2012. 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 1.34 Mt CO₂ eq in 1990 to 1.98 Mt CO₂ eq in 2012, i.e. an increase of approximately 47%.

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 – 2012 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 7.1**.

Table 7.1 *GHG emissions / removals (in kt) from the Land Use, Land Use Change and Forestry sector by category and gas for the period 1990 – 2012*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Net CO ₂ emissions / removals (in kt)												
A. Forest Land	-1,359.03	-1,405.46	-1,822.88	-2,004.25	-1,693.62	-1,888.12	-1,879.43	-1,614.53	-1,835.92	-1,807.07	-1,770.29	-1,929.98
B. Cropland	-981.63	-1,027.31	-922.13	-1,086.82	-1,006.04	-1,091.50	-712.43	-801.21	-879.90	-1,072.60	-739.17	-475.60
C. Grassland	0.23	0.21	4.34	41.69	-65.77	-73.43	-85.90	-95.97	-115.86	-174.20	-202.37	-209.87
D. Wetlands	NE,NO	NE,NO	0.04	0.74	0.27	0.08	0.21	0.60	2.27	0.33	2.64	0.75
E. Settlements	6.38	8.16	4.96	5.40	6.21	4.12	14.97	5.87	5.50	8.78	13.68	9.17
F. Other Land	20.60	12.98	30.86	24.01	26.83	28.25	40.14	45.54	46.71	52.05	59.93	64.95
CH ₄ emissions (in kt)												
A. Forest Land	0.62	0.24	0.69	0.72	0.63	0.41	0.17	0.50	1.56	0.10	1.93	0.20
B. Cropland	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
C. Grassland	0.67	0.57	1.71	1.20	1.25	0.53	0.57	0.86	1.69	0.19	2.64	0.53
D. Wetlands	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,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
N ₂ O emissions (in kt)												
A. Forest Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	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	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.00
D. Wetlands	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,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
TOTAL LULUCF (kt CO₂ eq)	-2,283.54	-2,392.85	-2,649.28	-2,974.86	-2,704.47	-3,033.42	-2,665.12	-2,531.00	-2,812.82	-3,108.50	-2,705.95	-2,700.03

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Net CO ₂ emissions / removals (in kt)											
A. Forest Land	-1,973.45	-1,959.47	-1,959.28	-1,987.31	-1,988.10	-1,873.95	-1,950.79	-1,972.46	-2,007.21	-1,985.00	-1,986.30
B. Cropland	-744.45	-406.53	-612.81	-492.67	-546.99	332.98	-602.03	-337.10	-302.79	-246.94	-227.34
C. Grassland	-239.88	-228.27	-318.50	-316.10	-281.29	-406.80	-546.51	-619.66	-704.31	-833.48	-916.56
D. Wetlands	2.49	1.42	27.79	3.10	4.31	3.62	2.82	2.82	2.61	2.59	2.87
E. Settlements	10.55	25.35	15.76	21.77	18.47	18.96	17.31	15.04	14.08	12.50	24.53
F. Other Land	70.71	69.63	78.37	69.81	83.03	108.68	100.04	89.79	86.53	84.36	130.25
CH ₄ emissions (in kt)											
A. Forest Land	0.02	0.03	0.08	0.06	0.19	2.55	0.40	0.43	0.18	0.08	0.29
B. Cropland	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
C. Grassland	0.10	0.13	0.33	0.17	0.27	5.47	0.58	0.57	0.11	0.51	0.93
D. Wetlands	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
E. Settlements	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
N ₂ O emissions (in kt)											
A. Forest Land	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	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
C. Grassland	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01
D. Wetlands	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
E. Settlements	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
TOTAL LULUCF (kt CO₂ eq)	-3,033.64	-2,695.13	-2,979.74	-2,909.50	-2,927.51	-1,967.61	-3,221.15	-3,041.03	-3,112.86	-3,183.43	-3,173.56

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

7.1.2 Methodology

The estimation of GHG emissions from Land Use, Land Use Change and Forestry is based on the methodologies and assumptions suggested by the IPCC Guidelines, the IPCC Good Practice Guidance for LULUCF, and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use.

Activity data and country specific emission / removal factors were obtained from the EL.STAT. (Hellenic Statistical Authority), the Ministry of Environment, Energy and Climate Change 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 7.2**, while a detailed description is given through Paragraphs 7.2 – 7.7.

Table 7.2 *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	T2	CS, D	T1	D	T1	D
A2. Land converted to Forest Land	OTH	OTH	T1	D	T1	D
B. Cropland						
B1. Cropland remaining Cropland	T2, T1	CS, D	NA	NA	NA	NA
B2. Land converted to Cropland	T2, T1	CS, D	NA	NA	T1	D
C. Grassland						
C1. Grassland remaining Grassland	T2	CS	T1	D	T1	D
C2. Land converted to Grassland	T2, T1	CS, D	NA	NA	NA	NA
D. Wetlands						
D1. Wetlands remaining Wetlands ¹⁾						
D2. Land converted to Wetlands	T2, T1	CS, D	NA	NA	NA	NA
E. Settlements						
E1. Settlements remaining Settlements ¹⁾						
E2. Land converted to Settlements	T2, T1	CS, D	NA	NA	NA	NA
F. Other Land						
F1. Other Land remaining Other Land ¹⁾						
F2. Land converted to Other Land	T2, T1	CS, 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

¹⁾ Parties do not have to prepare estimates for these categories

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 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 years¹⁸</i>
		<i>Forest land converted to Settlements</i>	<i>20 years</i>
<u>Land Converted to Wetlands</u>		<i>Forest land converted to Other land</i>	<i>20 years</i>
<i>Forest land converted to Wetlands</i>	<i>10 years¹⁸</i>		
<i>Grassland converted to Wetlands</i>	<i>10 years¹⁸</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 described in the GPG LULUCF. The key categories in the *LULUCF* sector determined by this analysis are presented in **Table 7.3** (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 7.3 **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	☒	☒

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

¹⁸ 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.

is noted that uncertainties in estimates from this sector are possibly higher than these reported, since uncertainties introduced by assumptions made and categories or pools not estimated have not been considered.

7.1.3 Completeness

The **Table 7.4** below summarizes the completeness of the inventory for the sector *Land use, Land Use Change and Forestry*.

Table 7.4 *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 ¹⁾			
2. Land converted to Wetlands	☒	NO	NO
E. Settlements			
1. Settlements remaining Settlements ¹⁾			
2. Land converted to Settlements	☒	NO	NO
F. Other Land			
1. Other Land remaining Other Land ¹⁾			
2. Land converted to Other Land	☒	NO	NO

¹⁾ Parties do not have to prepare estimates for these categories

NO: Not Occurring

7.1.4 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 neighbour 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.
- In the context of QA procedures followed, Greece has been in close cooperation with the Joint Research Centre of the European Commission, which is working on the provision of ad-hoc support on issues related to measurement, reporting and verification of Land Use, Land Use Change and Forestry under the Kyoto Protocol. Under that framework Greece's intention is to improve the current LULUCF reporting for the 1st commitment period, and to increase the level of preparedness for reporting during the 2nd commitment period.
- Greece takes also part in the "Project on Assistance to MS with KP Reporting" which focuses on the 1st commitment period (CLIMA.A.3/SER/2012/0010). The main aim of the project is to provide technical assistance and capacity building during the preparation of 2013 and 2014 GHG inventory submissions through the exchange of experience via discussion forum between project sector experts and country experts, and country visits.

The most important results of the internal audits are:

- Need to seek additional sources of information regarding croplands 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.

7.1.5 Recalculations and improvements

In the current submission the following recalculations and improvements have been performed:

- Correction of the small discrepancies in the land use change matrices for the period 1990 – 2012, in order for the total area of the country to equal the sum of all land use categories and to be stable. Inclusion in the NIR of a complete set of land use change matrices for the period 1990 – 2012.
- 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.

- Performing for the first time, following ERT's recommendation, a verification activity of the results on carbon stock changes in above and below ground biomass pools in "Forest land remaining Forest land" category which were estimated using the carbon stock change method as described in the GPG LULUCF.
- Recalculations of non-CO₂ emissions from wildfires in Forest land remaining Forest land category (use of updated data).
- Use of 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.
- Correction in allocation and reporting to the appropriate categories of carbon stock changes in mineral soils in Cropland converted to Forest land, and in Cropland converted to Grassland, and subsequent change in the reporting of carbon stock changes in mineral soils in Cropland remaining Cropland, following ERT's recommendation.
- Estimation and reporting for the first time of CO₂ and non-CO₂ greenhouse gas emissions resulted from biomass burning in Cropland converted to Forest land category (Afforestation/Reforestation activity under KP).
- Update and fulfillment of the Land Use Change Database.
- Reporting for the first time on methodologies applied on and emissions/removals resulted from carbon stock changes in mineral soils in Grassland converted to Cropland, Grassland converted to Settlements, Grassland converted to Other land categories, as well as from carbon stock changes in dead organic pool and mineral soils in Grassland converted to Wetlands category.
- Estimation and reporting for the first time on N₂O emissions from disturbance associated with land use conversion to cropland, namely N₂O emissions arising from Forest land converted to Cropland (Deforestation activity under KP), and Grassland converted to Cropland, following ERT's recommendation.
- Estimation and reporting for the first time of carbon stock changes in living biomass pool in Cropland converted to Grassland category.
- Correction of the small discrepancies in the area reported in the CRF Tables in Other land remaining Other land category for the period 1990-2012.
- Clarification in the NIR on the use of the IPCC default 20 years land use transition period in the estimation process of carbon stock changes in mineral soils related to land use changes, following ERT's recommendation.
- Correction in the use of notation keys in CRF tables, following ERT's recommendation.

- Improvement in the reporting of CRF table 8(b) by providing detailed explanation about the recalculations and improvements made, respectively, following ERT's recommendation.

7.1.6 Representation of land areas

The various forms of land uses in 2012 are presented in *Figure 7.2*.

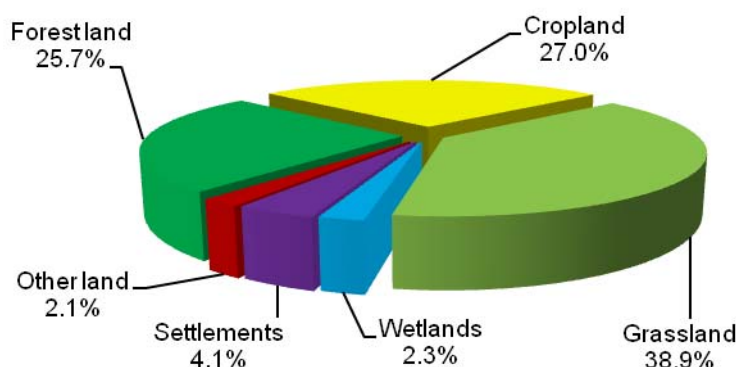


Figure 7.2 *Distribution of the area of Greece in 2012 by land-use category*

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, Energy and Climate Change,
- 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, Energy and Climate Change, which comprises acts of land use change since 1990,
- the "Forest Management Plans Database", of the Ministry of Environment, Energy and Climate Change.

In the following *Table 7.5* 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 7.5 *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, Energy and Climate Change	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, Energy and Climate Change	Managed forest land area	Forest land remaining forest land
The "Land Use Change Database" of the Ministry of Environment, Energy and Climate Change, 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. Following ERT's recommendation, the land use matrices of each year for the period 1990 – 2012 are reported in the **Table 7.6** below.

Table 7.6 *Land-Use Matrix for the period 1990-2012 (areas in kha).*

	1989						Total 1990
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,359	0					3,359
Cropland	0	3,944	0				3,944
Grassland	0	0	4,796				4,796
Wetland	0		0	300			300
Settlements	0		0		530	0	531
Other Land	0		0			265	266
Total 1989	3,359	3,944	4,797	300	530	265	13,196

	1990						Total 1991
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,359	0					3,359
Cropland	0	3,944	0				3,944
Grassland	0	0	4,796				4,796
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	0		0			265	266
Total 1990	3,359	3,944	4,797	300	530	265	13,196

	1991						Total 1992
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,359	0					3,359
Cropland	0	3,941	0				3,941
Grassland	0	3	4,796				4,799
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	0		1			265	266
Total 1991	3,359	3,944	4,797	300	530	265	13,196

	1992						Total 1993
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,358	0					3,358
Cropland	0	3,920	0				3,920
Grassland	1	25	4,796				4,821
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	0		1			265	266
Total 1992	3,359	3,944	4,797	300	530	265	13,196

	1993						Total 1994
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,358	2					3,360
Cropland	0	3,913	0				3,913
Grassland	1	29	4,795				4,825
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	0		1			265	267
Total 1993	3,359	3,944	4,797	300	530	265	13,196

	1994						Total 1995
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,358	6					3,363
Cropland	0	3,906	0				3,906
Grassland	1	32	4,795				4,829
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	1		1			265	267
Total 1994	3,359	3,944	4,797	300	530	265	13,196

	1995						Total 1996
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,357	9					3,366
Cropland	0	3,899	0				3,899
Grassland	1	37	4,795				4,833
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	1		1			265	267
Total 1995	3,359	3,944	4,797	300	530	265	13,196

	1996						Total 1997
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
Forest	3,357	15					3,372
Cropland	0	3,884	0				3,884
Grassland	1	46	4,795				4,842
Wetland	0		0	300			300
Settlements	0		1		530	0	531
Other Land	1		2			265	268
Total 1996	3,359	3,944	4,797	300	530	265	13,196

	1997						Total 1998
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
1998 Forest	3,357	16					3,373
Cropland	0	3,866	0				3,866
Grassland	1	62	4,794				4,857
Wetland	0		0	300			300
Settlements	0		1		530	0	532
Other Land	1		2			265	268
Total 1997	3,359	3,944	4,797	300	530	265	13,196

	1998						Total 1999
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
1999 Forest	3,357	20					3,377
Cropland	0	3,855	0				3,855
Grassland	1	69	4,794				4,864
Wetland	0		0	300			300
Settlements	0		1		530	0	532
Other Land	1		2			265	268
Total 1998	3,359	3,944	4,797	300	530	265	13,196

	1999						Total 2000
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2000 Forest	3,357	23					3,379
Cropland	0	3,848	0				3,848
Grassland	1	73	4,793				4,868
Wetland	0		0	300			300
Settlements	0		1		530	0	532
Other Land	1		2			265	268
Total 1999	3,359	3,944	4,797	300	530	265	13,196

	2000						Total 2001
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2001 Forest	3,357	24					3,380
Cropland	0	3,839	0				3,839
Grassland	1	81	4,793				4,876
Wetland	0		0	300			300
Settlements	0		1		530	0	532
Other Land	1		2			265	269
Total 2000	3,359	3,944	4,797	300	530	265	13,196

	2001						Total 2002
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2002 Forest	3,356	26					3,383
Cropland	0	3,833	0				3,833
Grassland	1	85	4,793				4,879
Wetland	0		0	300			300
Settlements	0		1		530	0	532
Other Land	1		3			265	269
Total 2001	3,359	3,944	4,797	300	530	265	13,196

	2002						Total 2003
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2003 Forest	3,356	28					3,384
Cropland	0	3,811	0				3,811
Grassland	1	105	4,792				4,899
Wetland	0		0	300			300
Settlements	1		2		530	0	533
Other Land	1		3			265	269
Total 2002	3,359	3,944	4,797	300	530	265	13,196

	2003						Total 2004
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2004 Forest	3,356	30					3,386
Cropland	0	3,808	0				3,809
Grassland	1	106	4,791				4,898
Wetland	0		1	300			301
Settlements	1		2		530	0	533
Other Land	2		3			265	270
Total 2003	3,359	3,944	4,797	300	530	265	13,196

	2004						Total 2005
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2005 Forest	3,356	32					3,388
Cropland	0	3,802	0				3,802
Grassland	1	111	4,790				4,902
Wetland	0		1	300			301
Settlements	1		2		530	0	533
Other Land	2		3			265	270
Total 2004	3,359	3,944	4,797	300	530	265	13,196

	2005						Total 2006
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2006	Forest	3,355	33				3,389
	Cropland	0	3,760	0			3,760
	Grassland	1	151	4,790			4,942
	Wetland	0		1	300		301
	Settlements	1		2	530	0	534
	Other Land	2		3		265	270
	Total 2005	3,359	3,944	4,797	300	530	13,196

	2006						Total 2007
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2007	Forest	3,355	33				3,388
	Cropland	0	3,721	0			3,721
	Grassland	1	190	4,789			4,981
	Wetland	0		1	300		301
	Settlements	1		3	530	0	534
	Other Land	2		4		265	271
	Total 2006	3,359	3,944	4,797	300	530	13,196

	2007						Total 2008
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2008	Forest	3,355	33				3,388
	Cropland	0	3,694	0			3,694
	Grassland	1	217	4,789			5,007
	Wetland	0		1	300		301
	Settlements	1		3	530	0	534
	Other Land	2		4		265	271
	Total 2007	3,359	3,944	4,797	300	530	13,196

	2008						Total 2009
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2009	Forest	3,355	33				3,388
	Cropland	0	3,664	0			3,664
	Grassland	1	247	4,789			5,037
	Wetland	0		1	300		301
	Settlements	1		3	530	0	534
	Other Land	2		4		265	271
	Total 2008	3,359	3,944	4,797	300	530	13,196

	2009						Total 2010
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2010	Forest	3,355	33				3,388
	Cropland	0	3,626	0			3,626
	Grassland	1	285	4,788			5,074
	Wetland	0		1	300		301
	Settlements	1		3	531	0	535
	Other Land	2		4		266	272
	Total 2009	3,359	3,944	4,796	300	531	13,196

	2010						Total 2011
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2011	Forest	3,355	33				3,388
	Cropland	0	3,596	0			3,596
	Grassland	1	315	4,788			5,105
	Wetland	0		1	300		301
	Settlements	1		3	531	0	535
	Other Land	2		4		266	272
	Total 2010	3,359	3,944	4,796	300	531	13,196

	2011						Total 2012
	Forest	Cropland	Grassland	Wetlands	Settlements	Other Land	
2012	Forest	3,354	33				3,387
	Cropland	0	3,565	0			3,565
	Grassland	1	343	4,791			5,135
	Wetland	0		1	300		301
	Settlements	1		3	531	0	535
	Other Land	2		4		266	272
	Total 2011	3,359	3,941	4,799	300	531	13,196

7.2 Forest land (CRF Source Category 5A)

7.2.1 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 – 2012 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 7.7*.

The sink capacity of Forest Land has increased from approximately 1.34 Mt CO₂ eq in 1990 to approximately 1.98 Mt CO₂ eq in 2012, i.e. an increase of 47.2%. This rising trend is attributed mainly to the reduction in fellings and the afforestation programmes started in 1994.

Table 7.7 *Net GHG emissions / removals (in kt) from Forest Land by subcategory and gas for the period 1990 – 2012*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest land remaining forest land											
CO ₂	-1,359.03	-1,405.46	-1,822.88	-2,004.25	-1,682.46	-1,859.71	-1,842.34	-1,553.02	-1,763.48	-1,699.56	-1,692.40
CH ₄	0.62	0.24	0.69	0.72	0.63	0.41	0.17	0.50	1.55	0.10	1.91
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Land converted to forest land											
CO ₂	NE,NO	NE,NO	NE,NO	NE,NO	-11.16	-28.42	-37.09	-61.51	-72.44	-107.50	-77.89
CH ₄	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.01	0.00	0.01
N ₂ O	NA,NO	NA,NO	NA,NO	NA,NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO₂ eq)	-1345	-1400	-1807	-1988	-1679	-1879	-1876	-1603	-1800	-1805	-1726

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Forest land remaining forest land												
CO ₂	-1,836.55	-1,839.64	-1,846.93	-1,845.70	-1,840.50	-1,841.07	-1,841.07	-1,841.07	-1,841.07	-1,841.07	-1,841.07	-1,841.07
CH ₄	0.20	0.02	0.03	0.08	0.06	0.19	2.52	0.39	0.43	0.18	0.08	0.29
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Land converted to forest land												
CO ₂	-93.43	-133.81	-112.54	-113.59	-146.80	-147.04	-32.88	-109.73	-131.39	-166.14	-143.93	-145.24
CH ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.03	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
Total (kt CO₂ eq)	-1925	-1973	-1959	-1958	-1986	-1984	-1815	-1942	-1962	-2003	-1983	-1980

NO: Not Occurring; NA: Not Applicable

7.2.2 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

According to the GPG LULUCF, 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 1,229,448 ha, which corresponds to approximately 36.3% 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.

7.2.2.1 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 IPCC Guidelines (Method 2 of the GPG LULUCF). 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:

$$\Delta C_{FF_{LB}} = (C_{t_2} - C_{t_1}) / (t_2 - t_1)$$

where, $\Delta C_{FF_{LB}}$ 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 data from 1,253 forest management plans (FMP) have been used.

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 from table 3A.1.8 of the LULUCF GPG. For the conversion of dry matter to carbon the IPCC default factor ($CF = 0.5$) was used throughout the inventory.

For the conversion of merchantable volume to aboveground tree biomass it is suggested by the GPG LULUCF 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.

Following ERT's recommendation, Greece has 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 in the GPG LULUCF. The Carbon Budget Model¹⁹ (CBM) was used for that purpose and the whole work has been carried out in the framework of the technical

¹⁹ <http://www.nrcan.gc.ca/forests/climate-change/13107>

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 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 analysis made through this work is considered as a "work in progress", and the results of the comparison are presented in **Figure 7.3** below.

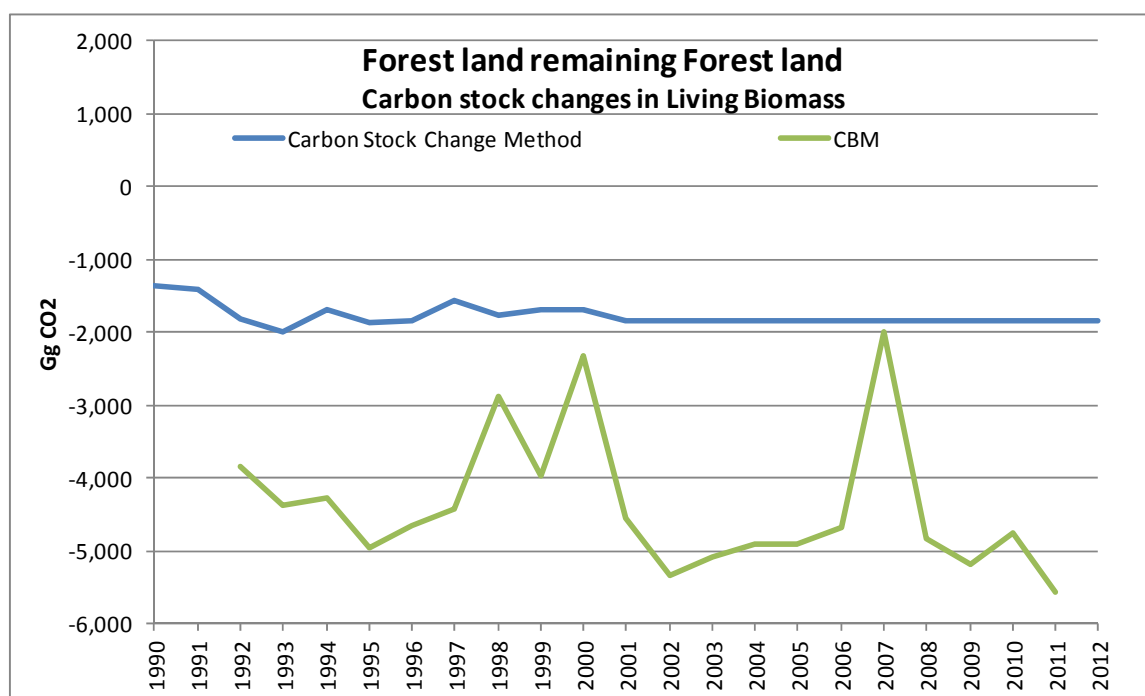


Figure 7.3 Comparison of the carbon stock changes in Living biomass in Forest land remaining Forest land, with the application of Carbon Stock Change Method and the CBM

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.

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. Following the ERT's recommendation more detailed evidence transparently substantiating the assertion above is provided in par. 10.3.1.2.

Table 7.8 *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)

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. Following the ERT's recommendation, more detailed evidence transparently substantiating the assertion above is provided in par. 10.3.1.2.

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 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 ($L_{W_{oxid}}$), 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).

$$CH_4 \text{ emissions} = L_{W_{oxid}} \cdot 0.012 \cdot 16/12$$

$$CO \text{ emissions} = L_{W_{oxid}} \cdot 0.06 \cdot 28/12$$

$$N_2O \text{ emissions} = L_{W_{oxid}} \cdot (N/C \text{ ratio}) \cdot 0.007 \cdot 44/28$$

$$NO_x \text{ emissions} = L_{W_{oxid}} \cdot (N/C \text{ ratio}) \cdot 0.121 \cdot 46/14$$

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:

$$L_{W_{oxid}} = \sum_i A_{disturbance_i} \cdot Bw_i \cdot (1 - f_{BL_i}) \cdot CF$$

where, $L_{W_{oxid}}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere (t C yr⁻¹), $A_{disturbance_i}$ 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), f_{BL_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).

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, Energy and Climate Change 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 3A.1.12 of GPG LULUCF; $fBL = 0.55$ 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:

$$B_W = (V \cdot D \cdot BEF_2 + B_{W_{\text{understorey}}}) \cdot CF$$

where, V is the average volume of growing stock, overbark ($m^3 ha^{-1}$), D is the basic wood density ($t d.m. m^{-3}$), BEF_2 is the biomass expansion factor for converting volumes of growing stock to total aboveground biomass, $B_{W_{\text{understorey}}}$ is the average biomass stock of understorey vegetation ($t d.m. ha^{-1}$) and CF is the carbon fraction of dry matter ($t C (t d.m.)^{-1}$).

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 wood density and biomass expansion factor were selected from Tables 3A.1.9-1 and 3A.1.10 of the LULUCF GPG, 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.

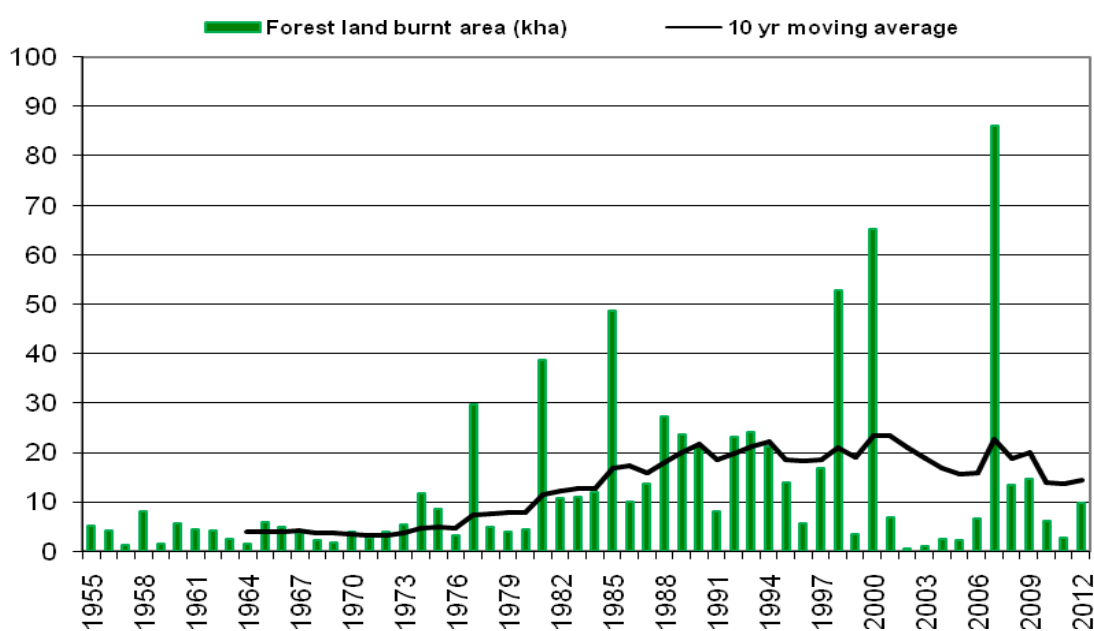


Figure 7.4 Areas of Forest Land burnt since 1955

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.

7.2.2.2 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 that 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. The estimation of carbon change was based on the summary equation.

$$\Delta C_{LF} = (\Delta C_{LFB} + \Delta C_{LFDOM} + \Delta C_{LFSoils})$$

where, ΔC_{LF} is the annual change in carbon stocks in land converted to forest land, t C yr⁻¹, ΔC_{LFB} 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:

$$\Delta C_{LFB} = (\Delta C_{LFGROWTH} - \Delta C_{LFLOSS})$$

where, ΔC_{LFB} 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 neighboring country to be used instead. In particular, an average value each year for the period 1990 - 2012 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 chosen 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, Energy and Climate Change (GDPDFNE, 2001). In **Table 7.9** the IEFs used for the estimation of carbon stock changes in living biomass in land converted to forest land are presented.

Table 7.9 *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	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.09
Below-ground	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.39
IEF for decrease in living biomass (Gg kha⁻¹)											
Above-ground	1.07	0.97	1.02	1.22	1.01	0.91	1.09	1.11	1.07	0.88	1.29
Below-ground	0.22	0.20	0.21	0.25	0.21	0.19	0.22	0.22	0.21	0.17	0.26

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
IEF for increase in living biomass (Gg kha⁻¹)												
Above-ground	2.08	2.08	2.08	2.08	2.08	2.07	2.07	2.07	2.07	2.07	2.07	2.09
Below-ground	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40
IEF for decrease in living biomass (Gg kha⁻¹)												
Above-ground	1.18	0.91	1.14	1.18	1.02	1.05	1.85	1.25	1.16	0.92	1.07	1.09
Below-ground	0.23	0.18	0.23	0.24	0.20	0.21	0.35	0.31	0.23	0.18	0.21	0.21

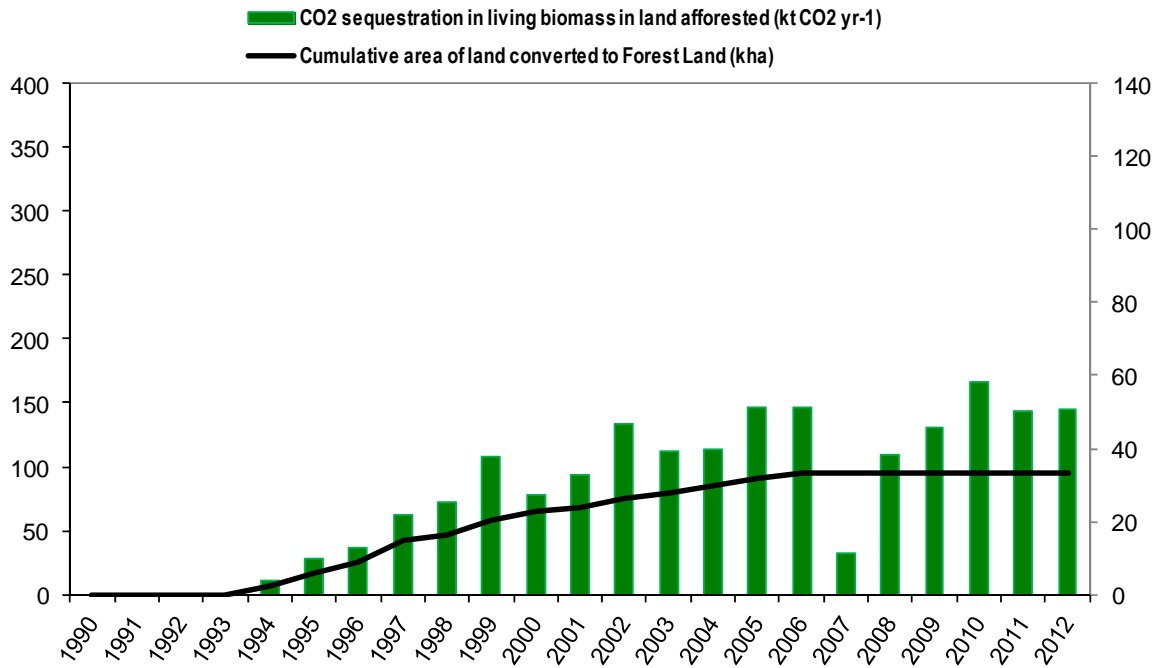


Figure 7.5 *Carbon sequestration in living biomass and area of land converted to Forest land during 1990 - 2012*

Change in carbon stocks in dead organic matter

Dead wood and litter carbon stocks were assumed stable in lands converting to forest land, and thus change in carbon stocks in dead organic matter was taken as zero (Tier 1 assumption).

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:

$$\Delta C_{LF_{Soils}} = \Delta C_{LF_{Mineral}} = \left[\sum_i (SOC_{Ref} - SOC_{Cropland_i}) \cdot A_{aff_i} \right] / T_{aff}$$

$$SOC_{Cropland} = SOC_{Ref} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LF_{Mineral}}$ 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, $SOC_{Cropland_i}$ 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 $SOC_{Cropland}$ 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 10.3.1.2.

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 ($L_{W_{oxid}}$), 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).

$$CH_4 \text{ emissions} = L_{W_{oxid}} \cdot 0.012 \cdot 16/12$$

$$CO \text{ emissions} = L_{W_{oxid}} \cdot 0.06 \cdot 28/12$$

$$N_2O \text{ emissions} = L_{W_{oxid}} \cdot (N/C \text{ ratio}) \cdot 0.007 \cdot 44/28$$

$$NO_x \text{ emissions} = L_{W_{oxid}} \cdot (N/C \text{ ratio}) \cdot 0.121 \cdot 46/14$$

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:

$$L_{W_{oxid}} = \sum_i A_{disturbance_i} \cdot Bw_i \cdot (1 - fBL_i) \cdot CF$$

where, $L_{W_{oxid}}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere (tC yr⁻¹), $A_{disturbance_i}$ 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).

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 3A.1.12 of GPG LULUCF; $fBL = 0.55$ 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:

$$Bw = (V \cdot D \cdot BEF_2 + Bw_{\text{understorey}}) \cdot CF$$

where, V is the average volume of growing stock, overbark ($m^3 \text{ ha}^{-1}$), D is the basic wood density ($t \text{ d.m. m}^{-3}$), BEF_2 is the biomass expansion factor for converting volumes of growing stock to total aboveground biomass, $Bw_{\text{understorey}}$ is the average biomass stock of understorey vegetation ($t \text{ d.m. ha}^{-1}$) and CF is the carbon fraction of dry matter ($t \text{ C (t d.m.)}^{-1}$).

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 wood density and biomass expansion factor were selected from Tables 3A.1.9-1 and 3A.1.10 of the LULUCF GPG, 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, Energy and Climate Change.

7.3 Cropland (CRF Source Category 5B)

7.3.1 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* (Chapter 6). The net CO₂ emissions / removals from each subcategory are presented in **Table 7.10**.

Table 7.10 *Net CO₂ emissions / removals (kt CO₂) from Cropland by subcategory for the period 1990 – 2012*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cropland remaining Cropland	-982	-1,028	-922	-1,087	-1,006	-1,092	-713	-801	-880	-1,073	-739
Biomass	-1,226	-1,272	-1,167	-1,332	-1,251	-1,336	-957	-1,046	-1,124	-1,317	-984
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	0.21	0.20	0.44	0.17	0.30	0.30	0.16	0.21	0.31	0.22
Biomass	0.06	0.17	0.13	0.32	0.05	0.15	0.13	0.02	0.05	0.11	0.06
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	0.03	0.04	0.08	0.09	0.11	0.12	0.12	0.13	0.14	0.15
Cropland	-982	-1027	-922	-1087	-1006	-1091	-712	-801	-880	-1073	-739

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cropland remaining Cropland	-476	-745	-407	-613	-493	-547	333	-602	-337	-303	-247	-228
Biomass	-720	-989	-651	-858	-737	-792	88	-847	-582	-548	-492	-472
Dead Organic matter	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
Land converted to Cropland	0.27	0.32	0.37	0.43	0.24	0.30	0.41	0.28	0.33	0.63	0.42	0.36
Biomass	0.06	0.10	0.14	0.20	0.00	0.06	0.14	0.01	0.05	0.31	0.07	0.02
Dead Organic matter	0.04	0.04	0.04	NO	NO	NO	NO	NO	NO	0.01	NO	NO
Soils	0.15	0.16	0.18	0.21	0.21	0.22	0.24	0.24	0.25	0.28	0.32	0.31
Cropland	-476	-744	-407	-613	-493	-547	333	-602	-337	-303	-247	-227

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 0.2-1.1 Mt CO₂ eq yr⁻¹ during the period 1990 – 2012 (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 such kind of changes have not occurred during the period under investigation, carbon stock changes has been estimated to be zero. Cultivation of organic soils resulted in net emissions of 244 kt CO₂ yr⁻¹ during the same period.

7.3.2 Methodology

Cropland includes all annual and perennial crops as well as temporary fallow land.

7.3.2.1 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:

$$\Delta C_{CC} = \Delta C_{CC_{LB}} + \Delta C_{CC_{Soils}}$$

where, ΔC_{CC} is the annual change in carbon stocks in cropland remaining cropland, t C yr⁻¹, $\Delta C_{CC_{LB}}$ is the annual change in carbon stocks in living biomass in cropland remaining cropland, t C yr⁻¹ and $\Delta C_{CC_{Soils}}$ 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 (GPG LULUCF). 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).

$$\Delta C_{CC_{LB}} = \Delta C_{CC_G} - \Delta C_{CC_L}$$

where, $\Delta C_{CC_{LB}}$ is the annual change in carbon stocks in living biomass in cropland remaining cropland and changes crop type, t C yr⁻¹, ΔC_{CC_G} is the annual increase in carbon stocks due to biomass growth in new plantations, t C yr⁻¹ and ΔC_{CC_L} is the annual decrease in carbon stocks due to biomass loss in eradicated crops, t C yr⁻¹.

Consistent with the GPG LULUCF it was assumed that these plantations accumulate biomass linearly until they reach maturity, assumed to be at half the replacement cycle (**Figure 7.6**). 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:

$$\Delta C_{CC_G} = \sum_i \sum_{j=k-(\lambda_i/2)-1}^k A_{\text{planted}_{ij}} \cdot G_{W_i} \cdot CF, \quad G_{W_i} = \frac{B_{M,i}}{(\lambda_i/2)}$$

where, $A_{\text{planted}_{ij}}$ 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, $\text{t d.m. ha}^{-1} \text{ yr}^{-1}$, 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 .

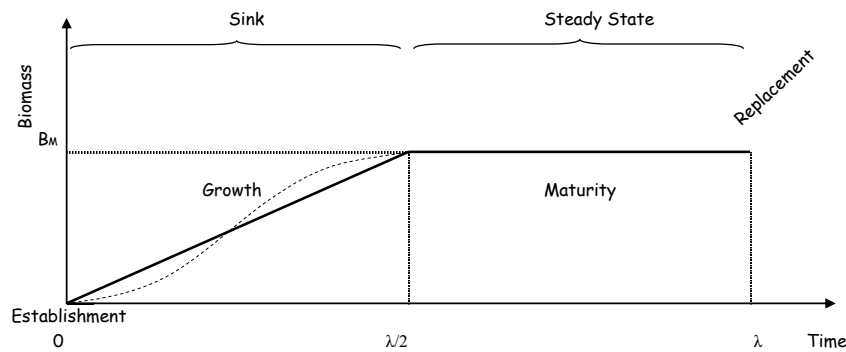


Figure 7.6 Assumed biomass accumulation in new plantations

The default annual loss rate is equal to biomass stocks at replacement (B_M), which are assumed removed entirely in the year of removal (GPG LULUCF). The annual decrease in carbon stocks due to biomass loss from eradication (ΔC_{CC_L}) was estimate as:

$$\Delta C_{CC_L} = \sum_i A_{\text{eradicated}_i} \cdot B_{M_i}$$

where, $A_{\text{eradicated}_i}$ 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 7.11**.

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 ($\Delta C_{CC\text{Soils}}$, t C yr⁻¹) was estimated as the difference between the annual emissions from cultivated organic soils ($\Delta C_{CC\text{Organic}}$, t C yr⁻¹) and the annual change in organic carbon stocks in mineral soils ($\Delta C_{CC\text{Mineral}}$, t C yr⁻¹).

$$\Delta C_{CC\text{Soils}} = \Delta C_{CC\text{Mineral}} - \Delta C_{CC\text{Organic}}$$

According to the GPG LULUCF, changes in dead organic matter and inorganic carbon were assumed to be zero. 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 (Chapter 4).

Table 7.11 *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 ²⁰	71	50

²⁰ Olive groves constitute the majority of new plantations (approximately 90%) during 1990-2012. 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.

Mineral soils

According to the GPG LULUCF for mineral soils, the estimation method 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 below:

$$\Delta C_{CCMineral} = [\sum_i (SOC_0 \cdot A)_i - \sum_i (SOC_{(0-T)} \cdot A)_i] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

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, ($i = 13$), 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 – 2012, 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 3.3.5 of the GPG LULUCF.

$$\Delta C_{CCOrganic} = A_{Organic} \cdot EF$$

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 3.3.5, GPG LULUCF). Area of cultivated organic soils was obtained from a study of the Soil Science Institute of Athens (SSIA, 2001).

7.3.2.2 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 N₂O 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 GPG LULUCF approach, 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.

$$\Delta C_{LC_{LB}} = A_{\text{Conversion}} \cdot (L_{\text{Conversion}} + \Delta C_{\text{Growth}})$$

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

where, $\Delta C_{LC_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to cropland, t C yr⁻¹, $A_{\text{Conversion}}$ is the annual area of land converted to cropland 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 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 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 suggested by the GPG LULUCF (table 3A.1.8). As a result of conversion, it is assumed that the dominant vegetation is removed entirely, thus $C_{\text{After}} = 0$. Carbon stocks increment from biomass growth following conversion – in the cases where a perennial, tree crop is established – were estimated and reported under the Cropland remaining Cropland category.

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 MEECC and are presented in **Table 7.12**.

Table 7.12 *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 inventory²¹ 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

²¹ 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*.

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 7.13**.

Table 7.13 *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 default factor (CF = 0.5) was used.

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 IPCC Guidelines (CO₂ Emissions and Uptake by Soils from Land-Use and Management) using the equation 3.3.3 of the GPG LULUCF, following land conversion:

$$\Delta C_{LCMineral} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{CCMineral}$ 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). 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 3.3.4 of the GPG LULUCF were used, namely $F_{LU} = 0.80$, $F_{MG} = 1.02$, $F_I = 0.94$. 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 7.14**, along with the representative plant species. In the cases where grassland converted to croplands the $SOC_{REF} = 72.3$ t C ha⁻¹ value was used.

Table 7.14 *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

Non-CO₂ Greenhouse gas emissions

In this section the method used to estimate the increase in N₂O emissions arising from the conversion of forest land and grassland to cropland is presented. An increase in N₂O emissions 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 GPG LULUCF following the equations below:

$$\text{Total N}_2\text{O-N}_{\text{conv}} = \sum_i \text{N}_2\text{O-N}_{\text{conv},i}$$

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 N₂O-N yr⁻¹. As shown in the equation, the total emissions of N₂O are equivalent to the sum of all N₂O emissions from land use conversions.

The equation used to estimate N₂O 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 N₂O-N_{conv} are the emissions as a result of the disturbance associated with land use conversion of forest land and grassland to cropland, kg N₂O-N yr⁻¹, N₂O_{net-min-N} are the additional emissions arising from the land use change, kg N₂O-N yr⁻¹, N_{net-min} is the N released annually by net soil organic matter mineralisation as a result of the disturbance, kg N yr⁻¹, and EF₁ is the IPCC default emission factor used to calculate emissions from agricultural land caused by added N, whether in the form of mineral fertilisers, manure, or crop residues, kg N₂O-N/kg N.

The N released by net mineralisation, N_{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 N_{net-min} is the annual N released by net soil organic matter mineralisation as a result of the disturbance, kg N yr⁻¹, ΔC_{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 ratio by mass of C to N in the soil organic matter (SOM), kg C (kg N)⁻¹. The default IPCC values for the EF₁ and the C:N ratio were used, namely 0.0125 kg N₂O-N/kg N and 15, respectively.

7.4 Grassland (CRF Source Category 5C)

7.4.1 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 7.15*).

Table 7.15 *Emissions / removals of greenhouse gases (in kt) from Grassland for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Grassland											
CO ₂	0.23	0.21	4.34	41.69	-65.77	-73.43	-85.90	-95.97	-115.86	-174.20	-202.37
CH ₄	0.67	0.57	1.71	1.20	1.25	0.53	0.57	0.86	1.69	0.19	2.64
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)	15.69	13.30	43.97	69.48	-36.82	-61.16	-72.69	-76.08	-76.80	-169.79	-141.25

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Grassland												
CO ₂	-209.87	-239.88	-228.27	-318.50	-316.10	-281.29	-406.80	-546.51	-619.66	-704.31	-833.48	-916.56
CH ₄	0.53	0.10	0.13	0.33	0.17	0.27	5.47	0.58	0.57	0.11	0.51	0.93
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
Total (kt CO₂ eq)	-197.57	-237.58	-225.19	-310.85	-312.17	-275.05	-280.37	-533.20	-606.41	-701.79	-821.79	-895.10

7.4.2 Methodology

7.4.2.1 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:

$$\Delta C_{GG_{LB}} = A \bullet (C_{After} - C_{Before})$$

where, $\Delta C_{GG_{LB}}$ 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 these 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, $f_{BL} = 0$). However, CO₂ released is assumed to be removed by photosynthesis of vegetation regrowing during the subsequent year and therefore only emissions of non-CO₂ gases are reported. 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 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, Energy and Climate Change (GDPDFNE, annual statistics).

According to the GPG LULUCF, changes in dead organic matter and inorganic carbon stocks were assumed to be zero. 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 3.4.8 of the GPG LULUCF, $F_{LU} = F_{MG} = F_I = 1$ and $\Delta C_{GG_{Mineral}} = 0$, 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. CO₂ emissions from liming of grasslands were not considered since liming is not applied on these lands. Non-CO₂ emissions from other sources (e.g. CH₄ emissions from grazing livestock on grassland) were estimated and reported in the *Agriculture* sector (Chapter 6).

7.4.2.2 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 7.16 *Net CO₂ emissions / removals (kt CO₂) from Land converted to Grassland by subcategory for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
Land converted to Grassland	0.03	0.00	4.29	41.16	-65.81	-73.46	-85.93	-96.07	-115.90	-174.23	-202.41	
Biomass	0.01	NO	13.50	101.90	20.44	17.85	21.06	40.84	68.86	33.56	18.29	
Dead Organic matter	0.01	NO	0.04	11.71	0.08	3.97	1.51	0.02	0.05	0.16	NO	
Soils	0.00	0.00	-9.26	-72.45	-86.33	-95.28	-108.50	-136.93	-184.81	-207.96	-220.70	
IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Land converted to Grassland	-209.89	-240.07	-228.33	-318.52	-316.11	-281.59	-407.02	-546.54	-620.05	-704.34	-833.55	-916.96
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	1.01	0.10	NO	0.05
Soils	-245.49	-257.85	-320.04	-322.12	-335.91	-460.30	-582.18	-663.56	-756.26	-874.39	-968.09	-1054.54

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 GPG LULUCF approach, 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 ($C_{\text{After}} = 0$). According to the GPG LULUCF, 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 suggested by the GPG LULUCF (table 3A.1.8).

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 ($C_{\text{Before}} = 5 \text{ t C ha}^{-1}$) of the GPG LULUCF was used. Finally, for the carbon stocks from one year of growth of grassland vegetation after conversion, a weighted average value from Table 3.4.9 of the GPG LULUCF ($0.8 \cdot 6.1 + 0.2 \cdot 13.5 = 7.6$) was used, according to the climatic classification (by Thornwaite) of Greece, as presented in section 7.2.2.2.

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 (MEECC), were used (*Table 7.12*).

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 7.13*).

For the conversion of dry matter to carbon the IPCC default factor ($CF = 0.5$) 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 ($\Delta C_{LGSoils}$, $t\ C\ yr^{-1}$) was estimated as the difference between the annual emissions from organic soils converted to grassland ($\Delta C_{LGOrganic}$, $t\ C\ yr^{-1}$) and the annual change in carbon stocks in mineral soils in land converted to grassland ($\Delta C_{LGMineral}$, $t\ C\ yr^{-1}$).

$$\Delta C_{LGSoils} = \Delta C_{LGMineral} - \Delta C_{LGOrganic}$$

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 3.4.8 of the GPG LULUCF, was used:

$$\Delta C_{LGMineral} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

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 3.4.5 GPG LULUCF). 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 7.14**).

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 7.2.2.2., namely $F_{LU} = 0.80$, $F_{MG} = 1.02$, $F_I = 0.94$. 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 7.14**, applicable to Evergreen broadleaf & Mediterranean Pine.

7.5 Wetlands (CRF Source Category 5D)

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 reported²². 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 7.17 Emissions / removals of greenhouse gases (in kt) from Wetlands for the period 1990 – 2012

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Wetlands											
CO ₂	NE,NO	NE,NO	0.04	0.74	0.27	0.08	0.21	0.60	2.27	0.33	2.64
CH ₄	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
N ₂ O	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
Total (kt CO₂ eq)	NE,NO	NE,NO	0.04	0.74	0.27	0.08	0.21	0.60	2.27	0.33	2.64

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Wetlands												
CO ₂	0.75	2.49	1.42	27.79	3.10	4.31	3.62	2.82	2.82	2.61	2.59	2.87
CH ₄	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
N ₂ O	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
Total (kt CO₂ eq)	0.75	2.49	1.42	27.79	3.10	4.31	3.62	2.82	2.82	2.61	2.59	2.87

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:

$$\Delta C_{LW_{LB}} = A \bullet (C_{After} - C_{Before})$$

where, $\Delta C_{LW_{LB}}$ 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, ha yr⁻¹,

²² Parties do not have to prepare estimates of emissions and removals from Wetlands remaining Wetlands, although they may do so if they wish.

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 suggested by the GPG LULUCF (table 3A.1.8). According to the GPG LULUCF, 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:

$$\text{CO}_2 \text{ emissions}_{\text{WW flood}} = P \cdot E(\text{CO}_2)_{\text{diff}} \cdot A_{\text{flood, total surface}}$$

where, $\text{CO}_2 \text{ emissions}_{\text{WW flood}}$ 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 CO_2 emissions are limited to 10 years after the flooding took place, was made.

Table 7.18 *Net CO_2 emissions / removals (kt CO_2 eq.) from Land converted to Wetlands by subcategory for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Land converted to Wetlands	NO	NO	0.04	0.74	0.27	0.08	0.21	0.60	2.27	0.33	2.64
Biomass	NO	NO	0.04	0.67	0.19	0.00	0.12	0.46	1.94	NO	2.10
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	0.00	0.07	0.08	0.08	0.09	0.13	0.33	0.33	0.54

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Land converted to Wetlands	0.75	2.49	1.42	27.79	3.10	4.31	3.62	2.82	2.82	2.61	2.59	2.87
Biomass	0.19	1.89	0.85	24.80	0.09	1.26	0.61	NO	NO	NO	NO	0.31
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
Soils	0.56	0.59	0.57	2.99	3.01	3.05	3.02	2.82	2.82	2.61	2.59	2.57

NO: Not Occurring, IE: Included Elsewhere

7.6 Settlements (CRF Source Category 5E)

Settlements²³ include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in other land-use categories.

Changes in living biomass and soil organic matter associated with Forest land and Grassland conversion to Settlements, as well as carbon stock changes in dead organic matter in Forest land converted to Settlements are addressed in this category.

Table 7.19 *Emissions / removals of greenhouse gases (in kt) from Settlements for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Settlements											
CO ₂	6.38	8.16	4.96	5.40	6.21	4.12	14.97	5.87	5.50	8.78	13.68
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)	6.38	8.16	4.96	5.40	6.21	4.12	14.97	5.87	5.50	8.78	13.68

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Settlements												
CO ₂	9.17	10.55	25.35	15.76	21.77	18.47	18.96	17.31	15.04	14.08	12.50	24.53
CH ₄	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
Total (kt CO₂ eq)	9.17	10.55	25.35	15.76	21.77	18.47	18.96	17.31	15.04	14.08	12.50	24.53

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:

$$\Delta C_{\text{LSLB}} = A \bullet (C_{\text{After}} - C_{\text{Before}})$$

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

²³ Parties do not have to prepare estimates of emissions and removals from Settlements remaining Settlements, although they may do so if they wish.

ha^{-1} , C_{Before} is the carbon stocks in living biomass immediately before conversion to settlement, t C ha^{-1} .

The default assumptions of the GPG LULUCF, 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, have been followed.

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 suggested by the GPG LULUCF (table 3A.1.8).

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:

$$\Delta C_{\text{DOM}} = \Delta C_{\text{DW}} + \Delta C_{\text{LT}}$$

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 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 (MEECC), were used (**Table 7.12**).

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 7.13**).

For the conversion of dry matter to carbon the IPCC default factor ($CF = 0.5$) 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:

$$\Delta C_{LS_{Soils}} = \Delta C_{LS_{Mineral}} - \Delta C_{LS_{Organic}}$$

where, $\Delta C_{LS_{Soils}}$ is the annual change in carbon stocks in soils in forest land and grassland converted to settlements, $t\ C\ yr^{-1}$, $\Delta C_{LS_{Mineral}}$ is the annual change in organic carbon stocks in mineral soils, $t\ C\ yr^{-1}$, and $\Delta C_{LS_{Organic}}$, 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 7.14**).

In the following **Table 7.20**, the net CO_2 emissions / removals from each subcategory are presented.

Table 7.20 *Net CO₂ emissions / removals (kt CO₂ eq.) from Land converted to Settlements by subcategory for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
Land converted to Settlements	6.38	8.16	4.96	5.40	6.21	4.12	14.97	5.87	5.50	8.78	13.68	
Biomass	5.04	6.09	2.79	2.94	3.42	1.34	8.59	2.48	1.86	4.21	7.62	
Dead Organic matter	0.14	0.36	0.25	0.36	0.41	0.29	3.40	0.22	0.33	0.87	1.68	
Soils	1.21	1.71	1.93	2.10	2.38	2.49	2.99	3.17	3.31	3.70	4.38	
IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Land converted to Settlements	9.17	10.55	25.35	15.76	21.77	18.47	18.96	17.31	15.04	14.08	12.50	24.53
Biomass	3.51	4.51	14.38	6.35	12.26	7.95	7.22	5.06	3.92	3.78	2.30	10.78
Dead Organic matter	0.95	0.84	4.51	2.32	1.15	1.28	1.84	1.80	0.32	0.04	0.19	2.85
Soils	4.71	5.20	6.47	7.10	8.36	9.24	9.91	10.44	10.81	10.27	10.01	10.90

7.7 Other land (CRF Source Category 5F)

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 GPG LULUCF, 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 7.21 *Emissions / removals of greenhouse gases (in kt) from Other land for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
Other land												
CO ₂	20.60	12.98	30.86	24.01	26.83	28.25	40.14	45.54	46.71	52.05	59.93	
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)	20.60	12.98	30.86	24.01	26.83	28.25	40.14	45.54	46.71	52.05	59.93	
IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Other land												
CO ₂	64.95	70.71	69.63	78.37	69.81	83.03	108.68	100.04	89.79	86.53	84.36	130.25
CH ₄	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
Total (kt CO ₂ eq)	64.95	70.71	69.63	78.37	69.81	83.03	108.68	100.04	89.79	86.53	84.36	130.25

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. 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 suggested by the GPG LULUCF (table 3A.1.8). It is assumed that the dominant vegetation is removed entirely, resulting in no carbon remaining in living biomass after conversion. ($C_{After} = 0$).

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. Through the next sections the methodologies applied for the estimation of emissions/removals from these carbon pools in forest land converted to other land are 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:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

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:

$$\Delta C_{\text{DOM}} = (C_n - C_o) \cdot A_{\text{on}}$$

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 biomass or dead organic matter after conversion to Other land, and that all biomass 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 7.12**). 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 7.13**). For the conversion of dry matter to carbon the IPCC default factor ($\text{CF} = 0.5$) was used.

Change in carbon stocks in mineral soils

In accordance with the GPG LULUCF, 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 following equation:

$$\Delta C_{\text{LOMineral}} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{\text{REF}} \cdot F_{\text{LU}} \cdot F_{\text{MG}} \cdot F_{\text{I}}$$

where, $\Delta C_{\text{LOMineral}}$ 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 7.14*).

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 7.22*, the net CO_2 emissions/removals from each subcategory are presented.

Table 7.22 *Net CO_2 emissions / removals (kt CO_2 eq.) from Land converted to Other land by subcategory for the period 1990 – 2012*

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
Land converted to Other land	20.60	12.98	30.86	24.01	26.83	28.25	40.14	45.54	46.71	52.05	59.93	
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	2.34	0.77	4.45	1.88	1.67	1.85	3.45	2.78	1.67	1.78	2.39	
Soils	4.91	7.31	12.75	15.58	18.52	20.57	25.45	31.87	36.66	41.48	44.95	
IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Land converted to Other land	64.95	70.71	69.63	78.37	69.81	83.03	108.68	100.04	89.79	86.53	84.36	130.25
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	4.63	3.13	2.05	3.98	0.96	2.03	8.92	1.96	0.63	0.66	0.99	10.21
Soils	49.31	54.46	58.91	63.50	65.02	70.43	78.89	84.28	85.86	82.43	80.75	83.39

8. Waste (CRF sector 6)

8.1 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 8.1 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 8.2 – 8.4) 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.

8.1.1 Emissions trends

In 2012 GHG emissions from *Waste* decreased by 19.6% compared to 1990 levels (**Figure 8.1**), while the average annual rate of decrease of emissions for the period 1990 – 2012 is estimated at 0.89%.

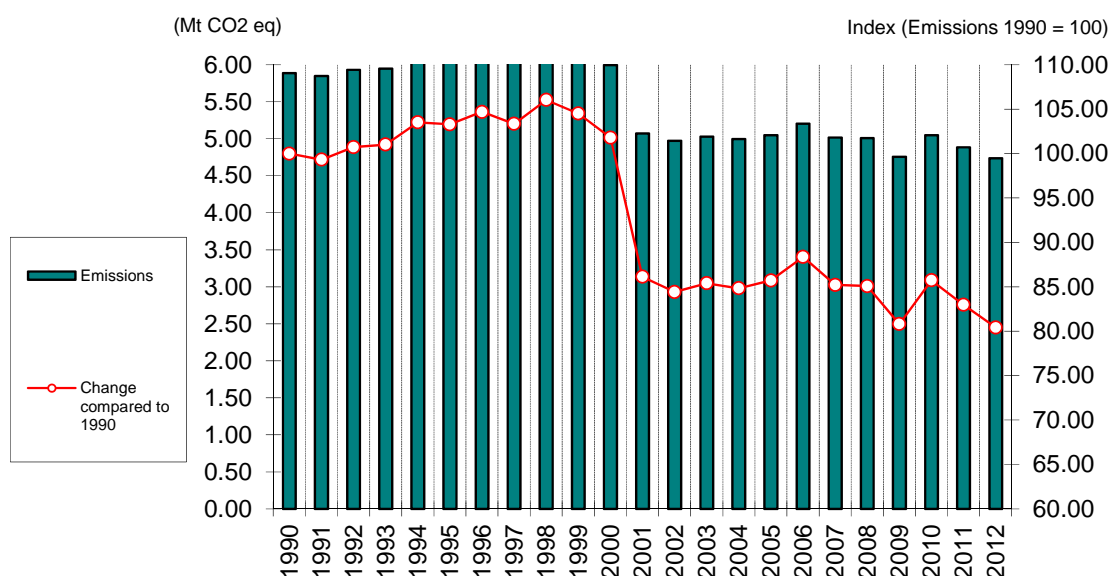


Figure 8.1 Total GHG emissions (in kt CO₂ eq) from Waste for the period 1990 – 2012

The sector *Waste* is responsible for carbon dioxide, methane and nitrous oxide emissions. GHG emissions from *Waste* per gas are presented in *Table 8.1*.

Table 8.1 *GHG emissions (in kt CO₂ eq) from Waste per gas for the period 1990 – 2012*

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	5556.4	5511.7	5589.8	5605.7	5745.7	5729.3	5810.6	5725.0	5879.3	5776.2	5612.6
N ₂ O	331.4	335.9	340.6	342.1	349.0	352.3	353.8	360.1	364.0	376.8	381.2
Total	5888.0	5847.8	5930.6	5948.0	6094.9	6081.8	6164.6	6085.3	6243.5	6153.2	5994.0
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	4696.5	4599.7	4647.6	4616.1	4663.5	4806.3	4615.5	4619.3	4369.9	4649.3	4483.3
N ₂ O	375.1	370.8	380.4	377.8	381.4	393.8	398.8	386.2	384.7	395.4	399.1
Total	5071.8	4970.9	5028.8	4994.9	5046.9	5202.6	5017.5	5009.2	4758.3	5047.9	4885.4
Year	2012										
CO ₂	3.23										
CH ₄	4330.2										
N ₂ O	401.8										
Total	4735.2										

Methane represents the major greenhouse gas from *Waste*, with a contribution which, however, decreased from 94.1% in 1990 to 91.5% in 2012. Overall, CH₄ emissions in 2012 decreased by 22.7% 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 8.2*) since 1999 is solid waste disposal on land with a contribution increasing from 37.8% in 1990 to 67.7% in 2012. On the contrary, GHG emissions from wastewater handling present a declining trend, with an average annual rate of -2.69% for the period 1990 – 2012. Emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2012; though the contribution of this source to total GHG emissions of the sector is negligible.

8.1.2 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.

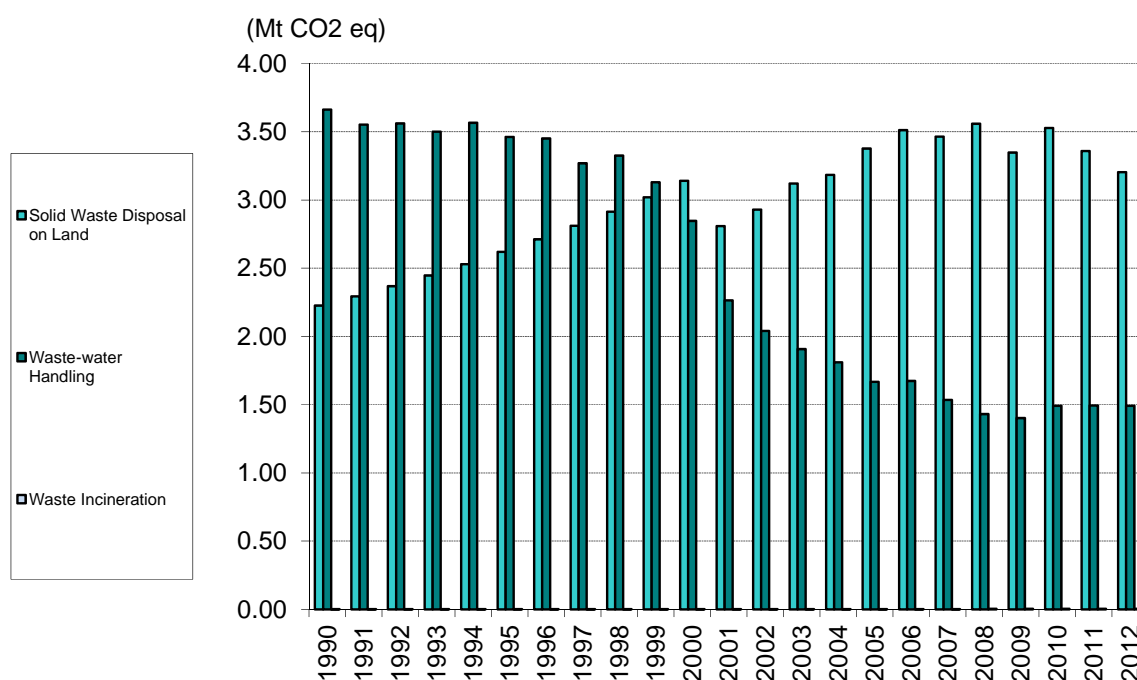


Figure 8.2 *Greenhouse gases emissions (in kt CO₂ eq) from Waste per source category for the period 1990 – 2012*

The methodology applied for the calculation of emissions per source category is briefly presented in **Table 8.2**, while a detailed description is given in Paragraphs 8.2 – 8.4.

Key categories

The following key categories are included in the sector *Waste* (**Table 8.3** - 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 8.2 *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 8.3 *Key categories from the Waste sector*

Source category	Gas	Level assessment	Trend assessment
Solid waste disposal on land	CH ₄	☑	☑
Wastewater handling	CH ₄	☑	☑

8.1.3 Completeness

Table 8.4 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 8.4 *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	☑	☑
2. Hospital waste	☑	☑	☑
3. Other	☑	☑	☑
D. Other			
1 Composting	NO	☑	☑

NO: Not Occurring, NA: Not Applicable

8.2 Solid waste disposal on land (CRF Source Category 6A)

8.2.1 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 2001-2012 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 2012 accounted for 68% of total GHG emissions from Waste and for 2.9% of total national emissions (without LULUCF). The average

annual rate of increase of emissions from solid waste disposal on land, for the period 1990 – 2012 is estimated at 2.0%. CH₄ emissions from managed and unmanaged solid waste disposal sites are presented in **Table 8.5**.

CH₄ emissions from managed SWDS in 2012 increased by 1604% compared to 1990 levels, while emissions from unmanaged SWDS decrease by 17.6%. This difference is due to the reduction of the number of the unmanaged SWDS in operation. Emissions from sewage sludge disposal in 2012 are 19 times higher compared to 1990.

Table 8.5 *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	3.32	6.60	9.87	13.12	16.54	20.01	23.53	27.19	31.09	35.30	40.29
Unmanaged SWDS	102.0	101.5	101.2	101.2	101.3	101.5	101.9	102.4	102.8	103.1	103.4
Sludge treatment	0.6	1.2	1.7	2.2	2.7	3.2	3.7	4.3	4.8	5.3	5.9
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Managed SWDS	23.85	28.88	36.99	39.83	48.66	54.79	54.08	60.46	53.53	65.40	60.72
Unmanaged SWDS	103.5	103.6	104.0	103.5	102.8	102.0	100.2	98.1	94.3	90.8	87.3
Sludge treatment	6.4	7.0	7.6	8.3	9.3	10.4	10.7	10.9	11.6	11.8	11.9
Year	2012										
Managed SWDS	56.57										
Unmanaged SWDS	84.1										
Sludge treatment	11.9										

8.2.2 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.

Solid waste flow

Before the detailed presentation of the emissions from each solid waste disposal on sites activity, a general solid waste flow diagram is presented in order the waste generation sources and the final management of each solid waste to be clearly shown (see **Figure 8.3**). This flow diagram was added after the recommendation of the 2012 ERT suggesting the preparation of a flow chart with all the solid waste flows including the waste amounts of each content for the final last year, i.e. 2012 for the current submission. With this flow chart the transparency of this category increases.

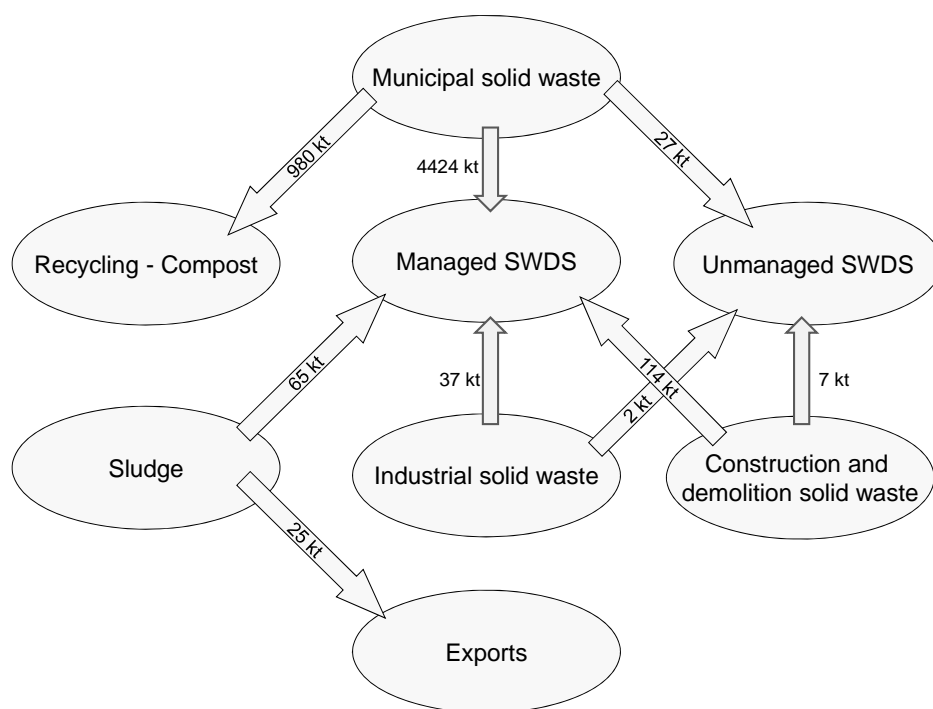


Figure 8.3 *Waste flow in Greece and amounts for 2012*

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 2001-2012 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 8.6* the estimated data on population served for the whole period 1960-2012 is presented.

Table 8.6 *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	11290.67	150.75	11440.82

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 8.7**.

Table 8.7 *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

On the basis of the above, the following MSW quantities for the years 1990 – 2012 were estimated (**Table 8.8**). For the period 2001-2012, 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 8.8**.

Table 8.8 *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†	
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	

†official data

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 1990-2012:

- ↳ 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 8.9**.

Table 8.9 *Estimated composition (%) of MSW generated for the period 1990 - 2012*

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 Soils	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Other	6.61	6.63	6.65	6.67	6.69	6.71	6.73	6.75	6.77	6.79	6.81
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										
Food	42.50										
Non Food	1.50										
Textiles	3.25										
Wood	1.00										
Paper	23.00										
Plastics	11.50										
Metals	3.00										
Glass	4.20										
Rest Soils	3.00										
Other	7.05										

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 8.10*.

Table 8.10 *Estimated composition (%) of MSW disposed for the period 1990 – 2012*

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	3.25
Other	7.30	7.31	7.31	7.30	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										
Food	46.28										
Non Food	1.79										
Textiles	3.88										
Wood	0.97										
Paper	14.20										
Plastics	13.72										
Metals	3.56										
Glass	3.61										
Rest Soils	3.58										
Other	8.41										

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 8.11*).

Table 8.11 *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

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 8.12**, 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.’

Table 8.12 *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										
CH ₄ recovery in Athens and Thessalonica (kt)	57.66										

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 2012. 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 8.13** for the years 2004, 2006 and 2008.

Table 8.13 **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 2012.

Figures for construction and demolition solid waste are provided by ELSTAT for the years 2006, 2008 and 2010, **Table 8.14**, 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 8.14 *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 (p. 5.9).

- ↪ 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)

Finally, **Table 15** is provided to meet the recommendation of the 2012 ERT review for further improvement in the transparency of the NIR by providing the relevant parameters used in the estimation of the emissions in a table format.

Table 8.15 *Parameters used for the estimation of emissions from the Solid waste disposal sector.*

	Managed SWDS			Unmanaged SWDS		
	Municipal	Industrial	Construction and demolition	Municipal	Industrial	Construction and demolition
Methane Correction Factor (MCF) Good Practice P5.9, T5.1	1	1	1	0.8	0.8	0.8
Degradable organic carbon (DOC) for paper IPCC Rev. 1996, P6.9, T 6-3	0.4	0.4		0.4	0.4	
Degradable organic carbon (DOC) for textiles IPCC Rev. 1996, P6.9, T 6-3	0.4	0.4		0.4	0.4	
Degradable organic carbon (DOC) for wood IPCC Rev. 1996, P6.9, T 6-3	0.3	0.3	0.3	0.3	0.3	0.3
Degradable organic carbon (DOC) for food waste IPCC Rev. 1996, P6.9, T 6-3	0.15	0.15		0.15	0.15	
Degradable organic carbon (DOC) for non-food waste IPCC Rev. 1996, P6.9, T 6-3	0.17			0.17	0.17	
Degradable organic carbon (DOC) for sludge IPCC 2006, P2.15						
Fraction of DOC dissimilated (DOCF) for solid waste IPCC Rev. 1996, P6.9	0.6	0.6	0.6	0.6	0.6	0.6
Fraction of methane in landfill gas (F) IPCC Rev. 1996, P6.5	50%	50%	50%	50%	50%	50%
Oxidation factor Good Practice P5.10	0.1	0.1	0.1	0	0	0
Half life (t) for paper IPCC 2006, P3.18, T3.4	17	17		17	17	
Half life (t) for textiles IPCC 2006, P3.18, T3.4	17	17		17	17	
Half life (t) for wood IPCC 2006, P3.18, T3.4	35	35	35	35	35	35
Half life (t) for food waste IPCC 2006, P3.18, T3.4	12	12		12	12	
Half life (t) for non-food waste IPCC 2006, P3.18, T3.4	14	14		14	14	

8.2.3 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.

8.2.4 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.

8.2.5 Recalculations

The estimated CH₄ emissions from solid waste disposal on land have been recalculated for the period 1992-2011 due to updated activity data on the estimation of gas recovery and for the period 2009 – 2011 due to updated activity data. The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in *Table 8.16*.

Table 8.16 *Recalculations of CH₄ emissions from solid waste disposal on land (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference			0.26	0.34	0.41	0.48	0.55	0.61	0.68	0.75	0.81
Impact on total emissions (excl LULUCF)			0.006	0.008	0.010	0.012	0.013	0.015	0.016	0.018	0.020
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	1.02	1.08	1.11	1.20	1.23	1.28	1.37	1.42	1.62	2.49	2.877
Impact on total emissions (excl LULUCF)	0.022	0.025	0.026	0.029	0.030	0.034	0.035	0.038	0.043	0.073	0.082

8.2.6 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.

8.3 Wastewater handling (CRF Source Category 6B)

8.3.1 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. CH₄ emissions from wastewater handling in 2012 accounted for 1.00% of total GHG emissions and for 23.4% of GHG emissions from *Waste*.

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. N₂O emissions from this source in 2012 account for 0.34% of total greenhouse gases emissions and 8.08% of greenhouse gases emissions from *Waste*.

Wastewater handling is a key category of CH₄ emissions, which have a substantial contribution in emissions trends (trend assessment). In **Table 8.17** CH₄ and N₂O emissions from wastewater handling for the period 1990 – 2012 are presented.

CH₄ emissions from domestic wastewater handling and industrial wastewater handling in 2012 decreased by 90% and 0.16%, respectively 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 2012. 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 8.17 *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	117.92	116.18	113.73	109.06	107.71	105.54	103.13	99.06	94.85	89.59	69.39
Human sewage	N ₂ O	1.05	1.07	1.08	1.09	1.11	1.12	1.12	1.13	1.14	1.19	1.20
Industrial wastewater	CH ₄	40.69	37.01	39.64	41.35	45.41	42.56	44.40	39.57	46.27	41.60	48.16
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	39.80	33.84	27.69	21.11	17.27	14.63	12.84	12.56	12.02	12.27	12.21
Human sewage	N ₂ O	1.19	1.17	1.21	1.20	1.20	1.22	1.24	1.20	1.21	1.21	1.22
Industrial wastewater	CH ₄	50.14	45.68	45.03	47.11	43.99	46.74	41.62	37.61	36.54	40.58	40.67
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										
Domestic and commercial wastewater	CH ₄	12.20										
Human sewage	N ₂ O	1.21										
Industrial wastewater	CH ₄	40.63										
Industrial wastewater	N ₂ O	0.019										

8.3.2 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 in order to meet the recommendations for the use of an advanced methodology approach on the estimation of this category taking into account that commercial wastewater handling is a key category.

CH₄ emissions from domestic and commercial wastewater handling

It is estimated that about 91% of Greek population in 2012 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 8.2.2, 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 8.6**, 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 8.18** the degradable organic waste (as kt BOD) for the period 1990 – 2012, 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 8.11**) 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 8.18 *BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2012*

Year	Wastewater	Sludge	Total
1990	206.87	6.51	207.87
1991	208.61	6.51	209.61
1992	211.33	6.51	212.33
1993	213.34	6.51	214.34
1994	215.40	6.51	216.40
1995	216.48	6.98	217.48
1996	217.85	6.98	218.85
1997	218.23	8.24	219.23
1998	219.81	8.02	220.81
1999	220.88	8.13	221.88
2000	220.82	8.96	221.82
2001	221.13	9.16	222.13
2002	220.40	10.49	221.40
2003	220.78	10.78	221.78
2004	220.97	11.27	221.97
2005	217.55	15.78	218.55
2006	217.37	17.02	218.37
2007	217.51	18.10	218.51
2008	218.13	18.39	219.13
2009	216.92	20.47	217.92
2010	223.96	14.04	224.96
2011	226.16	12.25	227.16
2012	225.87	12.16	226.87

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:

$$\text{N}_2\text{O emissions} = \text{Protein} \times \text{P} \times \text{Frac}_{\text{NPR}} \times \text{EF (N}_2\text{O-N/N)}$$

Data on protein consumption (*Protein*) are provided by FAO. The population (*P*) used, is the one presented in **Table 8.6**, 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 (N_2O-N/N)] are those suggested by the IPCC Guidelines.

In **Table 8.19** the consumption of protein (kg/person/year) for the period 1990 – 2012, is presented.

Table 8.19 *Annual protein consumption (in kg/person) for the period 1990 – 2012*

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										
Protein (kg/capita)	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 – 2012.
- ↳ 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 (m^3 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 ($kg\ COD/m^3$ 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.

In **Table 8.20** the degradable organic waste generated by each sector (as COD) for the period 1990 – 2012, is presented.

Table 8.20 *Total industrial wastewater in COD (in kt) produced from each industrial sector for the period 1990 – 2012*

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										
Food and beverage	205.82										
Paper and pulp	4.10										
Organic chemicals	11.24										
Other	28.07										

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 – 2012 is presented in **Table 8.21**.

Table 8.21 *TOW (in COD kt) removed as sludge from industrial wastewater handling for the period 1990 – 2012*

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										
COD (kt)	144.37										

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 – 2012 is presented in **Table 8.22**.

Table 8.22 *Waste water production from the industrial sector (1000000m³) for the period 1990 – 2012*

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										
Waste water	76.46										

8.3.3 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.

8.3.4 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.

8.3.5 Recalculations

The estimated CH₄ emissions from waste-water handling have been recalculated for the period 1990-2011 due to an update on the figure of degradable organic component D_{dom}, and for the 2011 due to updated activity data concerning industrial production. The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in *Table 8.23*.

Table 8.23 *Recalculations of CH₄ emissions from waste-water handling (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	10.40	10.63	10.36	10.10	9.77	9.93	9.72	10.02	9.36	9.52	8.16
Impact on total emissions (excl LULUCF)	0.300	0.296	0.286	0.276	0.266	0.256	0.244	0.226	0.206	0.195	0.147
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Difference	6.00	5.79	5.16	4.16	3.86	3.26	3.24	3.45	3.44	3.90	6.012
Impact on total emissions (excl LULUCF)	0.084	0.072	0.057	0.044	0.035	0.031	0.027	0.027	0.027	0.035	0.055

The estimated N₂O emissions from waste-water handling have been recalculated for the period 2011 due to updated activity data concerning industrial production. The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission is 0.068 % and the impact on total emissions (excl LULUCF) of recalculations is 0.00022%.

8.3.6 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.

8.4 Waste incineration (CRF Source Category 6C)

8.4.1 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.

8.4.2 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 8.24** the amount of waste incinerated and emissions released for the period 1990 – 2012 are presented.

8.4.3 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.

8.4.4 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 8.24 *Waste amounts (in tn) and emissions (in tn) for the period 1990 – 2012*

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										
Clinical waste	3834										
CO ₂	3206										
CH ₄	0.230										
N ₂ O	0.383										
Biogenic (Agr. residues)	19885										
CH ₄	1.193										
N ₂ O	1.989										
Other (Chem. waste)	8										
CO ₂	21										
CH ₄	0.000										
N ₂ O	0.001										

8.4.5 Recalculations

No recalculation was performed

8.5 Biological treatment (CRF Source Category 6.D)

8.5.1 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 8.25** the amount of waste composted and emissions released for the period 1990 – 2012 are presented.

Table 8.25 Waste amounts (in ktn) and emissions (in ktn) for the period 1990 – 2012

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Clinical waste								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
Clinical waste	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										
Clinical waste	199.03										
CH ₄	0.80										
N ₂ O	0.06										

8.5.2 Recalculations

CH₄ and N₂O emissions from biological treatment (Composting) of solid waste have been recalculated because of the updating of activity data for the period 2009-2011.

The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in **Table 8.26**.

Table 8.26 *Recalculations of CH₄ and N₂O emissions from biological treatment (Composting) of solid waste (%)*

Year	2009	2010	2011
CH₄			
Difference	0.00	387.92	511.106
Impact on total emissions (excl LULUCF)	0.00	0.007	0.010
N₂O			
Difference	-0.001	387.916	511.106
Impact on total emissions (excl LULUCF)	0.00	0.008	0.011

9. Recalculations and improvements

9.1 *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. Especially, in the current submission recalculations were performed following several 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.

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.***

9.1.1 Recalculations of 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 – 8. **Table 9.1** provides an overview of the recalculations made with regards to the previous submission according to the classification presented above.

Table 9.1 *Overview of recalculations on preparation of GHG inventory*

IPCC source	Sink categories	Gas	Explanation
1.AA.3.A	Civil Aviation \ Liquid Fuels \ Jet Kerosene	CO ₂ /CH ₄ /N ₂ O	Update of average consumption per flight
1.AA.3.C	Railways \ Liquid Fuels	CH ₄	Correction of EF
1.AA.3.D	Navigation \ Liquid Fuels \ Residual Oil	CO ₂ /CH ₄ /N ₂ O	Use of country specific NCV and CO ₂ EF, Update of AD
1.AA.3.D	Navigation \ Liquid Fuels \ Gas/Diesel Oil	CO ₂ /CH ₄ /N ₂ O	Use of country specific NCV and CO ₂ EF
1.C1.B	Marine \ Gas/Diesel Oil	CO ₂ /CH ₄ /N ₂ O	Use of country specific NCV and CO ₂ EF
1.C1.B	Marine \ Residual Fuel Oil	CO ₂ /CH ₄ /N ₂ O	Use of country specific NCV and CO ₂ EF, Update of RFO consumption
2.B.1	Ammonia Production	CO ₂	Error in files. Natural gas carbon content was updated.
2.B.5	Other (please specify) \ Organic chemicals production	HFCs	Change in notation keys.
2.B.6	2.B.5 Other (please specify) \ Organic chemicals production	PFCs	Change in notation keys.
2.B.7	2.B.5 Other (please specify) \ Organic chemicals production	SF ₆	Change in notation keys.
2.C	Metal Production	CO ₂ /CH ₄	Updated activity data.
2.C.1.1	Steel	CH ₄	Updated activity data.
2.C.2	Ferroalloys Production	CO ₂	Error in files concerning the ground coke quantity used for nikel production.
2.IIA.F.1.1	Domestic Refrigeration \ HFC-134a	HFC-134a	error in file
2.IIA.F.1.2	Commercial Refrigeration \ HFC-134a	HFC-134a	updated data
2.IIA.F.1.2	Commercial Refrigeration \ HFC-134a	HFC-134a	error in file, in exports value which affect the whole timeseries
2.IIA.F.1.2	Commercial Refrigeration \ HFC-125	HFC-125	updated data
2.IIA.F.1.2	Commercial Refrigeration \ HFC-125	HFC-125	updated data, error in file
2.IIA.F.1.2	Commercial Refrigeration \ HFC-125	HFC-125	An error in 2002 export data affect disposal emissions (lifetime:10 years)
2.IIA.F.1.2	Commercial Refrigeration \ HFC-32	HFC-32	Updated data
2.IIA.F.1.2	Commercial Refrigeration \ HFC-32	HFC-32	error in file, in exports value which affect the whole timeseries
2.IIA.F.1.2	Commercial Refrigeration \ HFC-32	HFC-32	An error in 2002 export data affect disposal emissions (lifetime:10 years)
2.IIA.F.1.2	Commercial Refrigeration \ HFC-23	HFC-23	Updated data
2.IIA.F.1.2	Commercial Refrigeration \ HFC-23	HFC-23	error in file, in exports value which affect the whole timeseries
2.IIA.F.1.2	Commercial Refrigeration \ C2F ₆	C2F ₆	Updated data
2.IIA.F.1.2	Commercial Refrigeration \ C2F ₆	C2F ₆	error in file, in exports value which affect the whole timeseries
2.IIA.F.1.2	Commercial Refrigeration \ HFC-143a	HFC-143a	Updated data
2.IIA.F.1.2	Commercial Refrigeration \ HFC-143a	HFC-143a	error in file, in exports value which affect the whole timeseries
2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-125	HFC-125	Updated Data
2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-125	HFC-125	Error in file/Updated data
2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-134a	HFC-134a	Updated data

2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-134a	HFC-134a	Error in File/Updated data
2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-32	HFC-32	Updated Data
2.IIA.F.1.5	Stationary Air-Conditioning \ HFC-32	HFC-32	Error in File/ Updated data
2.IIA.F.2.1	Hard Foam \ HFC-134a	HFC-134a	Error in File
2.IIA.F.2.1	Hard Foam \ HFC-152a	HFC-152a	Error in file
2.IIA.F.2.1	Hard Foam \ HFC-152a	HFC-152a	Error in file
2.F.3	Fire Extinguishers \ HFC-227ea	HFC-227ea	Updated data / Error in file
2.IIA.F.4.1	Metered Dose Inhalers \ HFC-134a	HFC-134a	error in file
2.F.8	Electrical Equipment \ SF6	SF6	Correction of notation key
4.A	Enteric Fermentation \ Cattle \ Option A \ Dairy Cattle	CH ₄	Updated DE and Ym, Updated Activity Data
4.A	Enteric Fermentation \ Cattle \ Option A \ Non-Dairy Cattle	CH ₄	Updated DE and Ym, Updated Activity data
4.A	Enteric Fermentation \ Sheep	CH ₄	Updated Activity data, Updated Milk yield
4.B	Manure Management \ Cattle \ Option A \ Dairy Cattle	CH ₄	Updated DE and Ym, Updated Activity Data
4.B	Manure Management \ Cattle \ Option A \ Non-Dairy Cattle	CH ₄	Updated DE and Ym, Updated Activity Data
4.B	Manure Management \ Sheep	CH ₄	Updated Manure management systems allocation, Updated Activity Data
4.B	Manure Management \ Liquid system	N ₂ O	Updated Activity Data and Nex figures of Dairy Cattle
4.B	Manure Management \ Solid storage and dry lot	N ₂ O	Updated Activity Data and Nex figure of Dairy Cattle and Manure management systems allocation of Sheep, Goats and Poultry
4.B	Manure Management \ Other AWMS	N ₂ O	Updated Manure management systems allocation
4.D.1.2	Animal Manure Applied to Soils	N ₂ O	Updated Activity Data and Nex figure of Dairy Cattle and Manure management systems allocation of Sheep, Goats and Poultry
4.D.1.6	Other direct emissions (please specify) \ Other non-specified	N ₂ O	Updated Activity Data
4.D.2	Pasture, Range and Paddock Manure	N ₂ O	Updated Activity Data and Nex figure of Dairy Cattle and Manure management systems allocation of Sheep, Goats and Poultry
4.D.3.1	Atmospheric Deposition	N ₂ O	Updated Activity Data and Nex figure of Dairy Cattle
4.D.3.2	Nitrogen Leaching and Run-off	N ₂ O	Updated Activity Data and Nex figure of Dairy Cattle
5.A.1	Forest Land remaining Forest Land \ Carbon stock change \ Managed	Carbon stock change in living biomass/Carbon/Gains	Updated AD
5.A.1	Forest Land remaining Forest Land \ 5(V) Biomass Burning \ Wildfires	CH ₄	Updated AD
5.A.2	Land converted to Forest Land \ 5(V) Biomass Burning \ Wildfires	CO ₂ /CH ₄ /N ₂ O	Change of methodology for living biomass/Estimation for the first time.
5.B.1	Cropland remaining Cropland \ Carbon stock change	Net carbon stock change in soils/Carbon/Mineral Soils	Correction in allocation of emission/removals included here previously, reporting in the appropriate category

5.B.2.2	Grassland converted to Cropland	Carbon stock change in living biomass/Carbon/Gains	Notation Key correction
5.B.2.2	Grassland converted to Cropland	Net carbon stock change in soils/Carbon/Mineral Soils	Estimation for the first time
5.B.2.1	Forest Land converted to Cropland	N ₂ O	Estimation for the first time
5.B.2.2	Grassland converted to Cropland	N ₂ O	Estimation for the first time
5.C.2.2	Cropland converted to Grassland	Carbon stock change in living biomass/Carbon/Losses	Estimation for the first time
5.C.2.2	Cropland converted to Grassland	Net carbon stock change in soils/Carbon/Mineral Soils	Correction in allocation of emission/removals, reporting in the appropriate category
5.D.2.3	Grassland converted to Wetlands	Net carbon stock change in soils/Carbon	Estimation for the first time
5.E.2.3	Grassland converted to Settlements	Net carbon stock change in soils/Carbon	Estimation for the first time
5.F.2.3	Grassland converted to Other Land	Net carbon stock change in soils/Carbon	Estimation for the first time
5	LULUCF \ Information Items \ Forest Land converted to Other Land-Use Categories	N ₂ O	Estimation for the first time
5	LULUCF \ Information Items \ Grassland converted to Other Land-Use Categories	CO ₂ /N ₂ O	Inclusion of CSCs in SOM
6.A.1	Managed Waste Disposal on Land	CH ₄	Updated Activity data. Moreover, only official data regarding CH ₄ recovery received by the National Energy Balance are used
6.A.1	Managed Waste Disposal on Land	Recovery/CH ₄	Only official data received by the National Energy Balance are used
6.A.3	Other (please specify) \ Municipal Sludge Disposal on Land	CH ₄	Updated Activity Data
6.A.3	Other (please specify) \ Industrial waste (Managed Waste Disposal on Land)	CH ₄	Updated Activity Data
6.A.3	Other (please specify) \ Industrial waste (Unmanaged Waste Disposal on Land)	CH ₄	Updated Activity Data
6.A.3	Other (please specify) \ Construction and Demolition Waste (Unmanaged Waste Disposal sites)	CH ₄	Updated Activity Data
6.A.3	Other (please specify) \ Construction and Demolition Waste (Managed Waste Disposal sites)	CH ₄	Updated Activity Data
6.B.1	Industrial Wastewater \ Wastewater	CH ₄ /N ₂ O	Updated Activity Data
6.B.1	Industrial Wastewater \ Sludge	CH ₄	Updated Activity Data
6.B.2.1	Domestic and Commercial (w/o human sewage) \ Wastewater	CH ₄	Specific degradable organic component (Ddom) value for Greece is used, Updated Activity data
6.B.2.2	Human sewage	N ₂ O	Updated Activity data
6.D	Other (please specify) \ Composting	CH ₄ /N ₂ O	Updated Activity Data

9.1.2 KP-LULUCF inventory

Table 9.2 *Overview of recalculations made for the preparation of KP-LULUCF inventory*

IPCC source / sink categories		Gas	Explanation
KP.A.1.1	Units of land not harvested since the beginning of the commitment period	CO ₂ /N ₂ O/CH ₄	Change in method used for the living biomass/Correction in allocation of emissions/removals in mineral soils/Estimation for the first time of emissions from biomass burning
KP.A.2	N ₂ O emissions from disturbance associated with land-use conversion to cropland	N ₂ O	Estimation for the first time
KP.B.1	Forest Management	CO ₂ /N ₂ O/CH ₄	Updated Activity Data

9.2 Implications for emissions levels

9.2.1 GHG inventory

The difference of emissions estimates in the present inventory, compared to the previous one, per gas (carbon dioxide, methane, nitrous oxide and F-gases respectively) is presented in **Tables 9.3 – 9.7**.

Table 9.3a *Recalculation of CO₂ emissions (differences compared to previous submission, in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	-444.09	-420.40	-38.98	-44.36	-41.18	-41.07	-42.15	-44.49	-43.18	-47.57	-65.96
Manufacturing Industries and Construction	-403.52	-383.09									
Transport	-40.56	-37.31	-38.98	-44.36	-41.18	-41.07	-42.15	-44.49	-43.18	-47.57	-65.96
Industrial processes	532.56	510.74	122.88	123.17	124.04	133.27	133.64	134.34	133.83	133.47	137.05
Mineral Products	120.80	119.83	122.88	123.17	124.04	133.27	133.64	134.34	133.83	133.47	137.05
Chemical Industry	411.76	390.91									
Metal Production											
Land Use, Land-Use Change and Forestry	213.07	202.19	209.30	227.73	153.78	155.37	171.97	207.92	199.85	151.87	185.63
Forest Land	-14.90	-28.21	-28.21	-27.69	-13.79	2.37	25.03	63.26	71.13	77.84	137.16
Cropland	223.72	223.74	223.75	223.78	223.79	223.80	223.81	223.81	223.82	223.82	223.83
Grassland			4.04	19.95	-70.26	-85.78	-94.50	-101.63	-121.57	-180.24	-207.96
Wetlands				0.07	0.07	0.07	0.07	0.12	0.31	0.31	0.52
Settlements	1.19	1.64	1.82	1.93	2.15	2.22	2.28	2.42	2.52	2.79	3.24
Other Land	3.06	5.02	7.90	9.69	11.82	12.69	15.29	19.93	23.64	27.35	28.83
TOTAL	301.54	292.54	293.20	306.55	236.64	247.56	263.46	297.77	290.50	237.78	256.72

Table 9.3b *Recalculation of CO₂ emissions (differences compared to previous submission, in kt)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy	-59.40	-52.75	-57.47	-59.79	-50.30	21.80	22.92	95.81	135.33	199.76	-486.60
Manufacturing Industries and Construction											
Transport	-59.40	-52.75	-57.47	-59.79	-50.30	21.80	22.92	95.81	135.33	199.76	-486.60
Industrial processes	137.66	132.36	133.51	133.42	142.38	138.36	134.32			0.00	-76.29
Mineral Products	137.66	132.36	133.51	133.42	142.38	138.36	134.32			0.00	
Chemical Industry											1.29
Metal Production											-77.58
Land Use, Land-Use Change and Forestry	140.01	95.03	145.41	79.89	75.90	131.97	123.75	-88.28	-184.83	-304.17	-412.88
Forest Land	96.50	77.96	115.36	133.41	124.47	141.19	255.35	178.50	156.84	122.09	144.30
Cropland	223.83	223.83	223.84	223.87	223.88	223.88	223.90	223.90	223.91	223.95	223.98
Grassland	-215.45	-245.66	-236.26	-324.76	-321.78	-287.37	-412.85	-552.39	-628.77	-710.63	-839.44
Wetlands	0.54	0.54	0.49	2.87	2.89	2.90	2.87	2.67	2.67	2.46	2.44
Settlements	3.46	3.84	4.47	4.86	5.91	6.61	7.04	7.37	7.69	7.17	6.93
Other Land	31.13	34.52	37.51	39.64	40.53	44.74	47.44	51.66	52.83	50.80	48.91
TOTAL	218.27	174.64	221.45	153.52	167.98	292.12	281.00	7.53	-49.49	-104.41	-975.77

Table 9.4a *Recalculation of CH₄ emissions (differences compared to previous submission. in kt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	-2.46	-1.96	-1.91	-1.97	-2.10	-1.80	-1.88	-1.82	-2.02	-1.84	-1.88
Transport	-2.46	-1.96	-1.91	-1.97	-2.10	-1.80	-1.88	-1.82	-2.02	-1.84	-1.88
Industrial Processes											
Metal Production											
Agriculture	-44.87	-42.83	-40.03	-33.16	-30.06	-29.27	-32.37	-31.17	-33.58	-32.73	-29.85
Enteric Fermentation	-116.60	-114.52	-111.72	-105.66	-103.43	-103.46	-106.56	-105.77	-108.47	-108.07	-105.87
Manure Management	71.73	71.69	71.69	72.50	73.37	74.19	74.19	74.61	74.89	75.34	76.03
Land Use, Land-Use Change and Forestry	0.11	0.04	0.12	0.13	0.11	0.07	0.03	0.09	0.27	0.02	0.34
Forest Land	0.11	0.04	0.12	0.13	0.11	0.07	0.03	0.09	0.27	0.02	0.34
Waste	313.67	308.98	308.54	298.08	296.59	293.55	289.31	282.24	273.14	261.93	211.55
Solid Waste Disposal on Land			6.19	8.24	10.40	12.60	14.82	17.12	19.61	22.38	25.32
Waste-water Handling	313.67	308.98	302.34	289.84	286.19	280.95	274.49	265.13	253.52	239.54	186.23
Other											
TOTAL	266.45	264.23	266.72	263.09	264.54	262.55	255.09	249.35	237.82	227.37	180.17

Table 9.4b *Recalculation of CH₄ emissions (differences compared to previous submission. in kt CO₂ eq)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy	-1.85	-1.78	-1.83	-1.87	-1.84	-1.90	-1.78	-1.72	-1.54	-1.14	-2.17
Transport	-1.85	-1.78	-1.83	-1.87	-1.84	-1.90	-1.78	-1.72	-1.54	-1.14	-2.17
Industrial Processes											-0.01
Metal Production											-0.01
Agriculture	-28.16	-33.15	-38.55	-43.61	-48.23	-47.92	-45.18	-35.76	-36.52	-27.57	-21.78
Enteric Fermentation	-104.56	-109.48	-113.93	-117.73	-121.36	-121.12	-119.20	-110.51	-111.13	-102.11	-95.96
Manure Management	76.40	76.33	75.38	74.12	73.14	73.21	74.01	74.75	74.61	74.53	74.19
Land Use, Land-Use Change and Forestry	0.04	0.00	0.01	0.01	0.01	0.03	0.45	0.07	0.08	0.03	0.01
Forest Land	0.04	0.00	0.01	0.01	0.01	0.03	0.45	0.07	0.08	0.03	0.01
Waste	135.29	122.82	109.26	94.93	88.89	85.18	82.56	84.85	87.36	136.16	168.52
Solid Waste Disposal on Land	28.38	31.38	34.36	37.70	41.12	44.50	46.69	49.71	53.44	85.68	93.94
Waste-water Handling	106.90	91.43	74.90	57.22	47.77	40.68	35.86	35.13	33.92	41.67	62.98
Other									0.00	8.81	11.60
TOTAL	105.31	87.88	68.89	49.46	38.84	35.39	36.04	47.43	49.37	107.48	144.57

Table 9.5a *Recalculation of N₂O emissions (differences compared to previous submission, in kt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	-7.25	-7.64	-7.48	-7.55	-7.04	-6.24	-5.12	-5.32	-7.72	-6.51	-6.03
Transport	-7.25	-7.64	-7.48	-7.55	-7.04	-6.24	-5.12	-5.32	-7.72	-6.51	-6.03
Agriculture	-7.60	-2.25	8.24	47.50	54.76	80.17	72.72	83.85	104.80	106.71	109.39
Manure Management	236.30	237.97	243.79	261.29	265.63	277.20	275.15	281.13	292.33	295.45	295.89
Agricultural Soils	-243.90	-240.22	-235.55	-213.79	-210.87	-197.02	-202.43	-197.27	-187.53	-188.75	-186.50
Land Use, Land-Use Change and Forestry	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.05
Forest Land	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.03
Grassland	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Waste											
Waste-water Handling											
Other											
TOTAL	-14.83	-9.88	0.78	39.97	47.74	73.95	67.62	78.56	97.13	100.21	103.41

Table 9.5b *Recalculation of N₂O emissions (differences compared to previous submission, in kt CO₂ eq)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy	-7.65	-7.27	-6.74	-6.93	-6.17	-5.98	-5.32	-4.40	-3.57	-2.81	-8.10
Transport	-7.65	-7.27	-6.74	-6.93	-6.17	-5.98	-5.32	-4.40	-3.57	-2.81	-8.10
Agriculture	112.84	135.10	134.76	145.54	162.84	158.88	160.07	175.09	178.59	190.31	193.05
Manure Management	296.89	303.73	304.95	309.98	319.39	318.82	316.33	316.94	313.80	317.20	318.86
Agricultural Soils	-184.06	-168.63	-170.19	-164.44	-156.55	-159.94	-156.26	-141.85	-135.21	-126.89	-125.81
Land Use, Land-Use Change and Forestry	0.02	0.02	0.02	0.02	0.02	0.03	0.07	0.03	0.04	0.03	0.04
Forest Land	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00
Grassland	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04
Waste									0.00	9.75	13.11
Waste-water Handling											0.26
Other									0.00	9.75	12.85
TOTAL	105.20	127.85	128.04	138.63	156.70	152.93	154.82	170.72	175.05	197.28	198.09

Table 9.6 *Recalculation of F-gases emissions (differences compared to previous submission, in kt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC						0.00	0.00	0.00	0.00	-0.08	-0.11
PFC											
TOTAL						0.00	0.00	0.00	0.00	-0.08	-0.11
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
HFC	-0.14	98.52	98.00	97.90	97.84	97.85	98.35	105.90	112.05	91.11	-97.32
PFC		4.43	4.43	4.43	4.43	4.43	4.43	4.43	4.43	3.97	0.66
TOTAL	-0.14	102.95	102.43	102.33	102.27	102.28	102.77	110.33	116.48	95.08	-96.66

In **Table 9.7** the effect of the recalculations made on the total GHG emissions in Greece excluding LULUCF on a per gas basis is presented.

Table 9.7 *Comparison of the 2013 inventory with the present inventory (in Mt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO₂ emissions											
2013 submission	80.38	80.06	81.44	80.42	83.03	83.17	85.64	90.55	95.14	94.26	99.68
2014 submission	80.68	80.36	81.73	80.72	83.27	83.42	85.90	90.85	95.43	94.50	99.94
Change (%)	0.38	0.37	0.36	0.38	0.29	0.30	0.31	0.33	0.31	0.25	0.26
CH₄ emissions											
2013 submission	10.36	10.31	10.45	10.42	10.61	10.61	10.84	10.76	11.03	10.89	10.93
2014 submission	10.63	10.57	10.72	10.69	10.87	10.88	11.09	11.01	11.27	11.12	11.11
Change (%)	2.57	2.56	2.55	2.52	2.49	2.47	2.35	2.32	2.16	2.09	1.65
N₂O emissions											
2013 submission	10.24	9.94	9.79	8.92	8.73	9.00	9.23	9.01	8.96	8.86	8.55
2014 submission	10.23	9.93	9.79	8.96	8.78	9.07	9.29	9.09	9.06	8.96	8.65
Change (%)	-0.14	-0.10	0.01	0.45	0.55	0.82	0.73	0.87	1.08	1.13	1.21
F-gases emissions											
2013 submission	1.10	1.27	1.07	1.71	2.21	3.35	3.87	4.21	4.72	5.46	4.35
2014 submission	1.10	1.27	1.07	1.71	2.21	3.35	3.87	4.21	4.72	5.46	4.35
Change (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total emissions											
2013 submission	102.09	101.59	102.75	101.47	104.58	106.13	109.57	114.53	119.85	119.48	123.51
2014 submission	102.64	102.13	103.31	102.07	105.13	106.72	110.16	115.16	120.47	120.04	124.05
Change (%)	0.54	0.54	0.55	0.60	0.52	0.55	0.53	0.55	0.52	0.47	0.44
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO₂ emissions											
2013 submission	102.22	101.67	106.07	106.19	110.02	108.38	111.75	107.02	100.94	93.95	92.26
2014 submission	102.44	101.84	106.29	106.34	110.19	108.67	112.03	107.03	100.89	93.85	91.28
Change (%)	0.21	0.17	0.21	0.14	0.15	0.27	0.25	0.01	-0.05	-0.11	-1.06
CH₄ emissions											
2013 submission	10.06	10.06	10.09	10.14	10.17	10.22	10.22	10.03	9.76	9.79	9.64
2014 submission	10.16	10.15	10.16	10.18	10.21	10.26	10.26	10.08	9.81	9.90	9.79
Change (%)	1.05	0.87	0.68	0.49	0.38	0.35	0.35	0.47	0.51	1.10	1.50
N₂O emissions											
2013 submission	8.36	8.28	8.20	8.21	7.91	7.70	7.90	7.48	7.02	7.32	7.01
2014 submission	8.46	8.41	8.33	8.35	8.07	7.86	8.06	7.65	7.19	7.51	7.21
Change (%)	1.26	1.54	1.56	1.69	1.98	1.99	1.96	2.28	2.49	2.70	2.83
F-gases emissions											
2013 submission	3.92	4.07	3.88	3.97	4.05	2.21	2.56	2.94	3.30	3.62	3.59
2014 submission	3.92	4.18	3.98	4.07	4.15	2.31	2.66	3.05	3.42	3.71	3.49
Change (%)	0.00	2.53	2.64	2.58	2.53	4.63	4.02	3.75	3.53	2.63	-2.69
Total emissions											
2013 submission	124.56	124.08	128.24	128.50	132.15	128.51	132.43	127.47	121.02	114.68	112.51
2014 submission	124.99	124.57	128.76	128.95	132.61	129.09	133.01	127.80	121.31	114.97	111.78
Change (%)	0.34	0.40	0.41	0.35	0.35	0.45	0.43	0.26	0.24	0.26	-0.65

9.2.2 KP-LULUCF inventory

Table 9.8 *Comparison of the 2013 inventory with the present inventory (in Kt CO₂ eq)*

Year	2008	2009	2010	2011
KP.A.2. Deforestation				
2013 submission	52.62	47.95	43.87	45.65
2014 submission	52.63	47.95	43.87	45.66
Change (%)	0.01	0.01	0.01	0.01
KP.B.1. Forest Management				
2013 submission	-1769.57	-1768.75	-1774.46	-1776.87
2014 submission	-1831.98	-1831.16	-1836.86	-1839.26
Change (%)	3.53	3.53	3.52	3.51

9.3 Implications for emissions trends

9.3.1 GHG inventory

Total GHG emissions of years 1990-2010 in the current submission are slightly higher than the emissions reported in the 2013 submission. For 2011, a decrease by 0.65 % is observed due to recalculations in the transport sector (update / correction of HFO consumption for 2011 of navigation) and LULUCF sector. The emission trends in Greece for the period 1990 – 2011 according to the inventories submitted in 2013 & 2014 are shown in **Figure 9.1**. Emission trends for the period 1990-2011 have not been affected significantly by the recalculations because in most cases the recalculations concerned the whole period.

The average annual rate of emissions increase for the period 1990 – 2011 in the present inventory is calculated to be similar compared to the one that had been calculated in the previous inventory (0.42% and 0.49%, respectively).

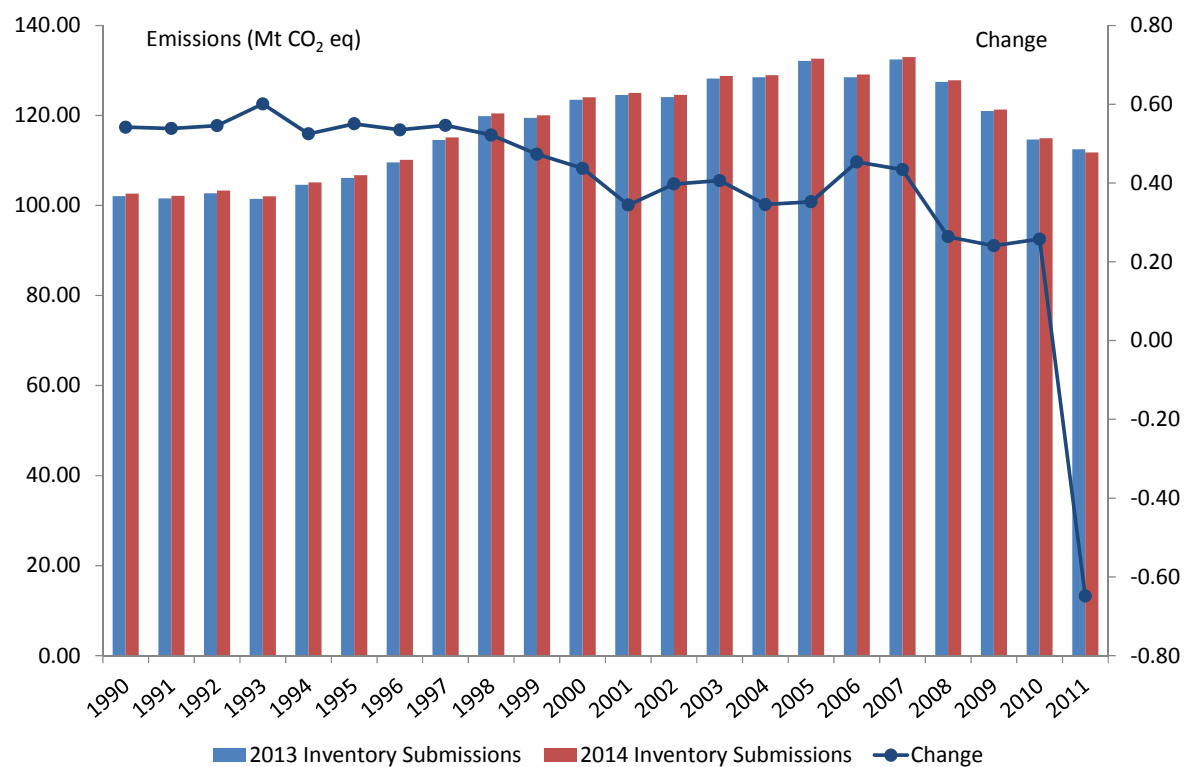


Figure 9.1 *GHG emissions trends in Greece for the period 1990 – 2011 (without LULUCF) according to the inventories submitted in 2013 & 2014*

9.4 Recalculations, including in response to the review process, and planned improvements

9.4.1 GHG inventory

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 MEECC 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 – 8), along with Table 9.1.

The improvement of the completeness of the GHG emissions inventory is further investigated through the inclusion in the next submissions of emissions of categories where IPCC methods and emission factors do not exist.

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.

In **Table 9.9** information regarding major changes in methodological descriptions performed in current NIR compared to previous year NIR is provided. Finally, at **Table 9.10** and **Table 9.11** an overview of the responses to the outcomes of the latest review of Greek GHG inventory is presented (i.e. 2014 centralized review) among with the responses to the outcomes of the one year before of Greek GHG inventory (i.e. 2013 in-country review), since the 2012 ERT review report was not ready (even in draft form) at the time of the writing of the 2013 report, therefore, the responses on the 2012 review was not presented in the 2013 report.

Table 9.9 *Documentation of major changes in methodological descriptions compared to previous year NIR*

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	Please tick where this is also reflected in recalculations compared to the previous year CRF	If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries			
2. Manufacturing Industries and Construction			
3. Transport		√	Chapter 3.2.5.2 navigation and aviation. Navigation: use of country specific NCV and CO2 EF. Domestic Aviation: Use of EUROCONTROL data
4. Other Sectors			
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas			
2. Industrial Processes			
A. Mineral Products			
B. Chemical Industry			
C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6			
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			
A. Enteric Fermentation		√	Methodology of Ym of cattle estimation
B. Manure Management		√	Manure management allocation systems for sheep, goats and poultry. Methodology of Nex of dairy cattle estimation
C. Rice Cultivation			
D. Agricultural Soils			
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues			
G. Other			
5. Land Use, Land-Use Change and Forestry			
A. Forest Land	√		para. 7.2.2.2. CO ₂ , non-CO ₂ emissions/removals. Cropland converted to Forest land (mineral soils, biomass burning)
B. Cropland	√		para. 7.3. CO ₂ , N ₂ O emissions/removals. Cropland remaining Cropland, Land converted to Cropland (mineral soils, disturbances associated with land use conversion to cropland)
C. Grassland	√		para. 7.4.2.2. CO ₂ emissions/removals. Land converted to Grassland (living biomass, mineral soils)
D. Wetlands	√		para. 7.5. CO ₂ emissions/removals. Land converted to Wetlands (DOM, mineral soils)
E. Settlements	√		para. 7.6. CO ₂ emissions/removals. Land converted to Settlements (mineral soils)
F. Other Land	√		para. 7.7. CO ₂ emissions/removals. Land converted to Other land (mineral soils)
G. Other			
6. Waste			
A. Solid Waste Disposal on Land			
B. Waste-water Handling			
C. Waste Incineration			
D. Other			
7. Other (as specified in Summary I.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine			
Multilateral Operations			
CO2 Emissions from Biomass			

9.4.2 KP-LULUCF inventory

Table 9.10 *Reporting on the outcomes of the 2013 review of Greek KP-LULUCF inventory*

Category	Review	Response by Greece
Afforestation and reforestation – CO ₂	Estimate and report the emissions and removals from grassland converted to forest land by mapping the grassland converted to forest land areas and include these in the emissions and removals from the afforestation and reforestation activity	Grassland areas 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.
Deforestation – CO ₂ and N ₂ O	Provide transparent information on how deforestation is distinguished from harvesting and forest disturbance. Specify how local Forest Services track lands that have temporarily lost forest cover but are not classified as deforested	It has been resolved. The necessary information is provided in chapter 10. KP-LULUCF.
	Report the N ₂ O emissions from disturbance associated with land-use conversion to cropland under deforestation	It has been resolved. The necessary information is provided in chapter 10. KP-LULUCF.
Forest management – CO ₂	Apply the IPCC gain–loss method to verify the results of the carbon stock change method and report the results	It has been resolved. The necessary information is provided in chapter 10. KP-LULUCF.

Table 9.11a *Reporting on the outcomes of the 2012 review of Greek GHG inventory*

Category	Review	Response by Greece
Agriculture	78. The inventory for the agriculture sector is complete and includes estimates of all gases and for all categories for the whole time series. The transparency of the NIR is generally sufficient, although the ERT recommends that the Party provide additional information on the AD used for the tier 2 estimates of emissions from enteric fermentation (see paras. 81 and 82 below) for other cattle and sheep, in order to enhance transparency (e.g. the milk yield for sheep is given as 0.23 l/day, whereas it should be given in l/year/ewe; further, sheep should not be mentioned under cattle in the NIR).	Done, please see NIR section 6.2.2.
Agriculture	81. Greece uses the tier 2 methodology from the Revised 1996 IPCC Guidelines and the IPCC good practice guidance for cattle, with default parameters for the Mediterranean area. The NIR indicates that some expert judgement has been made. In response to questions raised by the ERT during the review to provide country-specific input data for the parameterization, Greece explained that no country-specific data are available and so the default values for methane conversion factor (Y _m) and digestibility of feed are used. The default value for digestibility for dairy cattle is 60 per cent for Mediterranean conditions. It is the assessment of the ERT that this value is too low when compared with the Greek milk production level, and that CH ₄ emissions from enteric fermentation may be underestimated. The ERT strongly recommends that Greece investigate the national feeding conditions (Y _m and digestibility), especially for dairy cows, sheep and goats, and recalculate emissions for the entire time series, if appropriate, for the next annual submission.	Done, please see NIR section 6.2.2.
Agriculture	82. The reported CH ₄ emissions for enteric fermentation from sheep are based on the tier 2 methodology from the Revised 1996 IPCC Guidelines and the IPCC good practice guidance, using default values for Y _m and feed digestibility combined with country-specific animal weights and milk production data. The ERT commends the Party for using this approach and recommends that Greece use official statistics for milk production data (i.e. milk delivered to the dairies, including milk for lambs and local consumption) instead of expert judgement. Furthermore, the ERT recommends that, for clarification, Greece provide, in the NIR of the next annual submission, milk production data per ewe for the different types of milking sheep, instead of an average per sheep.	The only available official data for milk production provided by EL.STAT. were used. Please see NIR section 6.2.2.
Agriculture	84. In its 2012 annual submission, Greece provides in the NIR AD on the consumption of mineral fertilizers for the first time. The data were provided by the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers (PHAPFDP). The consumption decreased by 50 per cent from 1990 to 2010. The ERT noted that these data deviate from what is reported by Eurostat and FAO, although the level and trend is approximately the same. During the review, the ERT asked to review the documentation for all of the suppliers that are included in the data set, as well as locally imported mineral fertilizers. The ERT noted that import/export statistics on pure nitrogen exist only on the total amount of fertilizer. The import/export statistics showed a similar decreasing trend, although very variable. The decreasing trend seems therefore justified. The ERT further noted that there are no arrangements in the national system on data delivery with PHAPFDP and no description of the data set is available. The ERT therefore recommends that Greece strengthen its national system and arrangements with data providers, primarily with official bodies such as EL.STAT and secondarily with PHAPFDP, on data delivery, including documentation on how the data set has been elaborated. The ERT noted that the data should be supported by documentation on how the data have been collected, estimates for sales and purchases from non-members of PHAPFDP, and local unregistered imports.	Please see NIR section 6.5.2 for a reply on this recommendation

Category	Review	Response by Greece
Agriculture	86. For nitrogen excretion (Nex) from dairy cows, Greece uses the default value for Western European conditions from the Revised 1996 IPCC Guidelines, which is 100 kg nitrogen/cow/year. This value has been used for all years since 1990 despite an increased trend in milk production per dairy cow. The increased feed intake is reflected in the CH ₄ emission estimate for enteric fermentation (see para. 81 above) but not in the estimate for Nex. The default Nex in the Revised 1996 IPCC Guidelines is based on an estimated annual milk production of 4,200 l/cow/year. The average Greek milk production in 2010 was 5,565 l/year. In response to questions raised by the ERT during the review, regarding national data for Nex Greece explained that “there are no published data concerning the nitrogen content in animal feed, i.e. dairy cows, other cattle, sheep and goats and the feed consumption”. The ERT concluded that the use of the IPCC default value may not reflect the situation in Greece and therefore the ERT encourages Greece to estimate country-specific Nex rates, especially for dairy cattle, and report these in its next annual submission.	Done, please see NIR section 6.3.2.
Agriculture	87. Greece uses the default value for Nex for sheep from the Revised 1996 IPCC Guidelines for Mediterranean conditions, with an average of 12 kg/adult sheep/year. For lambs, Greece implemented a reduction factor in accordance with the IPCC good practice guidance. The ERT noted that, in its reporting of ammonia emissions to the EMEP under LRTAP, Greece used a default Nex value of 20 kg/sheep, 67 per cent higher than the IPCC default value. The inconsistencies between inventories for LRTAP and the UNFCCC require additional clarifications to ensure the accuracy of the estimates. In response to a question raised by the ERT during the review, Greece informed the ERT that no country-specific information is published. The ERT encourages Greece to check the applicability of default values or develop national values for Nex for sheep, as this is an important category.	Please see NIR section 6.3.2 a comparison of Nex figures used in Europe. Information provided under LRTAP is planned to be modified in accordance with information used on the compilation of GHG emissions.
Agriculture	88. Greece uses the default manure management type distribution for Mediterranean conditions (Revised IPCC 1996 Guidelines, table 4.7 of the workbook) to estimate the CH ₄ emissions from AWMS of dairy cattle. In its 2012 annual submission, Greece has assumed that all manure of dairy cattle is handled as solid storage. In response to a question raised by the ERT during the review regarding manure handling, Greece explained that deep litter was the main manure type. In the view of the ERT, deep litter may create a large amount of CH ₄ which was not included in the inventory.	A improved approach was utilized on the estimation of manure management type distribution of Dairy Cattle. Please see NIR section 6.3.2.
Agriculture	91. For all years Greece used the same default distribution of AWMS from the Revised 1996 IPCC Guidelines, despite the fact that both Greek (www.statistics.gr) and Eurostat farm structure surveys (http://epp.eurostat.ec.europa.eu) show that agriculture in Greece is switching to larger and more specialized farms. This will, over time, change the way animal manure is handled. The ERT encourages Greece to improve its reporting on AWMS in accordance with data from both Greek and Eurostat farm structure surveys in its next annual submission.	A improved approach was utilized on the estimation of manure management type distribution of Dairy Cattle. Please see NIR section 6.3.2.
Agriculture	92. The sheep population in Greece is divided into two: a nomadic population (10 per cent) and a stationary population (90 per cent). For the inventory it is assumed that all sheep are grazing all year round and that no manure is handled in AWMS, although the majority of the sheep are in stalls. The ERT strongly encourages Greece to investigate this assumption further to avoid a possible underestimation of the emissions from stored manure.	Done, please see NIR section 6.3.2.
Agriculture	93. For poultry, Greece assumes that 28 per cent of the manure is handled as other manure and the remaining 72 per cent is deposited from free-ranging poultry. However, according to the farm structure survey by Eurostat, 46 per cent of the broilers are located on farms larger than 500 livestock units, and the average farm size is 170,000 broilers. The ERT is of the view that it is very unlikely that farms having more than 2,000–5,000 broilers are using free-ranging systems. The ERT therefore recommends that Greece investigate the distribution of AWMS for all animal types in detail and update this in its next annual submission together with all documentation of its national circumstances.	A improved approach was utilized on the estimation of manure management type distribution of poultry based on Country specific data. Please see NIR section 6.3.2.
Waste	115. The total emissions from waste incineration are reported under the waste sector in accordance with the IPCC good practice guidance because the waste incineration in Greece is not used for energy purposes. The ERT noted that waste composting practices have been emerging in the country since 2012 and encourages the Party to estimate and report CH ₄ emissions from composting in its future annual submissions.	Done, please see NIR section 8.5.

Category	Review	Response by Greece
Waste	116. However, the ERT noted that the descriptions in the NIR of the waste and wastewater treatment systems used in the country and their share of the waste are not sufficiently transparent. The ERT recommends that Greece further improve the transparency of the NIR by providing the relevant AD, EFs and other parameters used in the form of tables and flow charts in its next annual submission.	Done, please see NIR, Figure 8.2.2, Chapter 'Other parameters' and Table 8.15.
Waste	117. In Greece there is a well-developed QC system to check the GHG inventory results. In response to questions raised by the ERT during the review, the Party demonstrated the documented cross-check results and protocols for the waste sector categories from its archiving system. Nevertheless, the ERT identified a weakness in the sector-specific QA procedures. The ERT encourages the Party to enhance the QA procedures for key categories in the sector, for example by conducting meetings or conferences involving leading national experts in the waste sector and documenting the results of these discussions in the NIR of its next annual submission.	Meeting have already performed resulted in update activity data for the period 2009-2011.
Waste	120. The recalculation was made on the basis of AD from EL.STAT for industrial and construction/demolition waste disposed at the same landfills as MSW, and amounts of CH ₄ recovered were calculated using the national energy balance data. However, the ERT noted that waste flows in Greece and amounts of waste are not described in the NIR in a transparent manner. In response to questions raised by the ERT during the review, the Party provided the ERT with a clear flow chart of its waste treatment types, including their share of the waste. The ERT recommends that Greece include such a flow chart for the last reported year in the NIR of its next annual submission and provide a table with data on the amounts of disposed waste, by type, for the complete time series in an annex to the NIR.	Done, please see NIR, Figure 8.3 and Table 8.15.
Waste	121. The ERT recommends that Greece improve the transparency of this category by providing a table showing the first order decay method parameters used for calculations, by waste type, in the NIR of its next annual submission.	Done, please see NIR, Table 8.15.

Table 9.11b *Reporting on the outcomes of the 2013 review of Greek GHG inventory*

Category	Review	Response by Greece
Energy	23. The ERT recommends that, in order to improve the transparency of its reporting, Greece provide, in the NIR of its next annual submission, an explanation of how in the energy balance the annual fuel consumption for domestic transport is separated from the consumption for international transport based on the fuel supply data from supplier companies, in order to demonstrate the accuracy of its emission estimates for domestic aviation and navigation.	Please refer to chapter 3.2.2 of the NIR.
Energy	24. The ERT reiterates the recommendation from the previous review report that Greece, in its next annual submission, reallocate emissions from liquid fuels used as feedstock in ammonia production from the energy sector to the corresponding category in the industrial processes sector for the years 1990–1993 and 1995–1998, in order to ensure that its reporting is in line with the IPCC good practice guidance	Please refer to chapter 3.2.4.4.2 of the NIR.
Energy	25. The ERT commends Greece for implementing the recommendation from the previous review report. However, the ERT recommends that Greece improve the description of the recalculations for the whole time series resulting from this change in method as well as the description of the calculation for the fuel consumption ratio of lubricants in road transportation in order to justify the time-series consistency in estimating emissions from this category.	Please refer to chapter 3.2.5.2 and 3.2.5.5 of the NIR. No recalculations have been performed in road transport category related to lubricants in both this and previous submission. For the years 1990–2010 we calculated lubricants emissions by applying a fuel consumption ratio as described in NIR page 114. This calculation was followed for years 1990–2010 in both 2012 and 2013 submission (not for year 2011).
Energy	26. Greece has reported that the planned improvements related to the reconstruction for the whole time series of the fleet population and the composition database for road transportation is ongoing. In addition, the Party expects that measures to reduce the illegal use of fuels and the smuggling of fuels will make the statistical data on energy consumption more reliable. The ERT recommends that Greece complete its improvement plan and reflect any updates in the AD related to this category in its next annual submission.	We would like to mention that every year according to our improvement plan of road transport sector, we try to improve the quality of the GHG inventory of this sector. The emissions of this sector are calculated by a tier 3 method (COPERT) based on a large number of activity data. The method and calculated emissions by the inventory team have been published in peer reviewed scientific journals as: “Twenty year road traffic emissions trend in Greece. Water Air and Soil Pollution, 223 (1) (2012), pp. 305–317”.
Energy	27. The ERT noted inter-annual fluctuations in the consumption of fuel (in TJ) in domestic navigation throughout the time series. For example, the inter-annual changes in fuel consumption in the following years are relatively high: 1994/1995 (–14.4 per cent), 1996/1997 (+21.1 per cent), 1997/1998 (+53.7 per cent), 1999/2000 (–42.1 per cent), 2000/2001 (+35.3 per cent), 2008/2009 (+46.8 per cent) and 2009/2010 (–18.1 per cent). However, the values remained relatively stable for 2010/2011 (an increase since 2010 of 0.3 per cent). The share of GHG emissions from domestic navigation in the transport sector also fluctuated from 9 to 15 per cent throughout the time series, amounting to 11 per cent for 2011. The ERT recommends that Greece explain the cause of this fluctuation.	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.

Category	Review	Response by Greece
Energy	<p>28. Greece reported in the NIR that a tier 1 method and default EF from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines) were used to estimate the CO₂ emissions. The default method from CORINAIR was used for the CH₄ and N₂O emission estimates. In the NIR, Greece explained that the application of a higher tier method was not possible due to the absence of detailed data on the composition of the fleet and the routes performed. Further, Greece stated in the NIR that the possibility of obtaining detailed fleet data for use in the emission estimates is limited. In response to a question raised by the ERT during the review, Greece confirmed that the only variable taken into account in the emission estimates is fuel consumption. The IPCC good practice guidance (page 2.54) indicates a list of several likely sources for the AD and the use of their combination to obtain "a full coverage of shipping activities". The ERT reiterates the recommendation made in the previous review report that Greece start a process aimed at providing, in future annual submissions, a more accurate estimate of CO₂ emissions associated with this category by gathering information on the number of arrivals and departures, destination and fleet composition and, if necessary, take into consideration the experiences of other Parties in gathering these data.</p>	<p>Please refer to chapter 3.2.5.2 and 3.2.5.5 of the NIR. As from this submission (2014), we apply a CS CO₂ EF and NCV. According to the IPCC Good Practice Guidance: "Good practice is to use Tier 1 for CO₂, and Tier 2 for CH₄ and N₂O..... Until the uncertainties in the CH₄ and N₂O emission factors are reduced, more detailed methods will not necessarily reduce uncertainties in the emission estimates." This is the case in our calculations: we apply Tier 1 for CO₂ as well as for CH₄ and N₂O.</p> <p>We would also like to mention that the text that the ERT referred to (page 2.54 of the GPG) includes the following sentences: "Fuel use data <u>may</u> be obtained using several approaches" and "it <u>may</u> be necessary to combine these data sources to get full coverage of shipping activities".</p> <p>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. 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 reliable calculations. Moreover, for the calculation of CO₂ emissions, which is a key category, the total fuel consumption is needed along with the carbon content of the fuel as well as the fraction of fuel left. This is what is done for CO₂.</p>
Energy	<p>29.and recommends that Greece report any progress for the estimates of CH₄ emissions from this category resulted from this bilateral QA exercise in its next annual submission.</p>	<p>Please refer to chapter 3.3.1.4</p>
Industrial processes	<p>Some of the F-gas emissions (octafluoropropane (C₃F₈), perfluorobutane (C₄F₁₀), octafluorocyclobutane (c-C₄F₈), nonafluoro-2-(trifluoromethyl)butane (C₅F₁₂) and perfluorohexane (C₆F₁₄)) from aluminium production for the period 1990–2003 have been reported as "NE", while the notation key "NA" (not applicable) has been reported for the other years of the time series.</p>	<p>The notation key for emissions from fluorocarbons from Aluminium Production have been corrected to NA for all the relevant years.</p>
Industrial processes 2.A.1 - Cement production	<p>Greece explained in the NIR that emissions from non-carbonate carbon have been taken into account only for the recent years of the time series (2008 onwards). The ERT recommends that Greece complete its data collection for the whole time series and reflect the results in the inventory reporting in its next annual submission.</p>	<p>During the 2014 submission emissions from non-carbonate carbon sources (TOC) for the years before 1990-2008 were included and therefore a recalculation, using the overlap methodology, was used. This way the whole time series was updated improving the time-series consistency.</p>

Category	Review	Response by Greece
Industrial processes 2.B.2 - Nitric acid production 2.C.3 - Aluminium Production	The ERT recommends that Greece obtain information on the abatement technologies used for aluminium production and nitric acid production and incorporate that information in its reporting of emissions from those categories in its next annual submission.	In the NIR, Greece explained that for nitric acid production, the abatement system used by the Greek installations to reduce nitrogen oxides (NO _x) emissions is an absorption tower, which does not affect the N ₂ O emissions. However, the Party recognizes that the plants intend to implement some form of abatement technique in the future. For aluminium production, Greece reported in the NIR that the relevant data are obtained directly from the plants and are considered to be confidential. As soon as abatement technologies are installed by the plants the NIR will be updated.
Industrial processes 2.B.1 - Ammonia production	The ERT commends Greece for its efforts to improve the accuracy of the emission estimates for this category and recommends that the Party complete the ongoing work to obtain more accurate data on the amount of liquid fuel used as feedstock and use the updated AD in the emission estimates in its next annual submission.	Emissions from lignite used for ammonia production during years 1990-1991 have been reallocated from the Energy Sector (1A2c) into the Industrial Processes Sector, as one of the two plants operating during these two years used only lignite as fuel. The calculation of the amount of liquid fuel used as feedstock for the missing years is still in progress.
Industrial processes f-gases	Continue to collect the data necessary to estimate potential emissions of F-gases per gas type	Para 4.14.6 of the NIR.
Industrial processes Consumption of halocarbons and SF6 – HFCs	Collect data on HFC emissions from imported foam and provide information on the progress made and results obtained V	Para 4.14.2 of the NIR.
Industrial processes Consumption of halocarbons and SF6 – SF6	Provide additional information on the method used to estimate SF6 emissions	Para 4.15.2 of the NIR.
Agriculture	44. Greece has used provisional data for some AD, including the dairy cattle population and milk yield data. In response to a question raised by the ERT during the review, the Party explained that provisional data have been developed by the agriculture expert of the inventory team in collaboration with the EL.STAT experts following a regression analysis. This approach had to be adopted due to a delay in data delivery by EL.STAT, which was mainly attributed to administrative structural changes carried out by EL.STAT over the last three years. Greece explained that AD for at least two additional years of the time series will be available for use in its next annual submission, provided that the technical difficulties involved in the operation of EL.STAT are resolved. The ERT recommends that Greece obtain actual statistical data, especially for the key categories, for all years of the time series for use in the calculation of the emission estimates in its next annual submission. If this is not feasible, the ERT recommends that Greece provide, in its next annual submission, a more detailed explanation of the provisional data used for the emission estimates, including the methods used to develop those data, in order to improve the transparency of its reporting.	Done, please see NIR section 6.2.2, Chapter 'Methodology for enteric fermentation for the other animals'.

Category	Review	Response by Greece
Agriculture	46. For the estimation of CH ₄ emissions from dairy cattle, Greece used the IPCC tier 2 method. For the methane conversion factor (MCF) the IPCC default value of 0.06 was used and for digestibility of feed the IPCC default value of 60 per cent for Mediterranean conditions was used. However, as already pointed out in the previous review report, the ERT is of the view that this value is too low when compared with the level of Greek milk production. In response to a question raised by the ERT during the review, the Party informed the ERT that Greece is currently investigating information on national feeding conditions which is available in Greek institutes holding specific expertise in these issues (e.g. the Agricultural University of Athens, the Ministry of Rural Development and Food, the Department of Animal Production at the School of Agricultural Technology (Technological Educational Institute of Epirus) and the Office of Rural Development of the Prefecture of Thessaloniki). Greece plans to present the results in the NIR of its next annual submission. The ERT commends Greece for starting the above-mentioned work and recommends that the Party conclude its investigations and develop representative country-specific values for the next annual submission.	Done, please see NIR section 6.2.2, Chapters 'Enteric fermentation of dairy cattle' and 'Enteric fermentation of other cattle'
Agriculture	47. CH ₄ emissions from sheep were calculated using the IPCC tier 2 method. In response to a question raised by the ERT during the review regarding milk production data of sheep, Greece explained that annual official statistics on the total milk production of sheep were used as the basis for the emission estimates and that there are no official data available concerning milk production per ewe for different types of sheep. Average milk production data for domestic sheep (0.22 kg/day) and nomadic sheep (0.20 kg/day), which are based on expert judgement, are used to derive the fractions of the domestic and nomadic sheep populations only. The ERT strongly recommends that Greece provide, in the NIR, a better explanation of the AD used for the inventory in order to improve the transparency of its reporting in the next annual submission. In particular, the ERT recommends that the Party provide a more appropriate explanation for the use of different milk production data, the generation of AD for the nomadic and domestic sheep populations and the input data used for the emission calculations. The ERT also recommends that Greece provide clear references for the data sources for all parameters, presented in formulae and tables of the NIR in its next annual submission.	Done, please see NIR section 6.2.2, Chapters 'Enteric fermentation of sheep'
Agriculture	49. Greece has reported in the NIR that the AD for mineral fertilizer consumption are derived from the Pan-Hellenic Association of Professional Fertilizer Producers & Dealers (PHAPFDP). However, no further information is provided in the NIR on, for example, how the data have been collected, how sales and purchases from non-members of PHAPFDP have been estimated, and how local unregistered imports are treated. The ERT strongly recommends that Greece document in the NIR the completeness of the AD and reiterates the recommendation made in the previous review report that Greece strengthen its arrangements with data providers, primarily with EL.STAT and secondarily with PHAPFDP, with regard to data delivery, including documentation on how the data set has been elaborated.	Please see NIR section 6.5.2 for a reply on this recommendation
Agriculture	51. Greece has applied a country-specific AWMS distribution for cattle and swine for the first time in its 2013 annual submission. In developing the AWMS distribution, assumptions were made based on discussions with experts from the Ministry of Rural Development and Food, the Greek regions with a high population of dairy cattle farms, the Agricultural University of Athens, EL.STAT and the Technological Educational Institute of Thessaloniki. However, the background information used in the expert judgement is not clearly explained in the NIR. In response to a question raised by the ERT during the review, Greece explained that the AWMS distribution based on the data collected since 2000 was applied for the entire time series using the assumption that the same situation occurred for the whole time series (1990–2011). Greece also explained that it is difficult to obtain data for the period 1990–2000 because the information has mostly been collected during the years since 2000. The ERT commends the Party for its efforts to develop a country-specific AWMS distribution and recommends that Greece continue its efforts to further refine the appropriate parameters for the entire time series. The ERT also reiterates the recommendation made in the previous review report that Greece investigate the distribution of AWMS for all animal types in detail and update the information in its next annual submission.	A improved approach was utilized on the estimation of manure management type distribution of cattle, sheep, goats and poultry based on Country specific data. Please see NIR section 6.3.2.

Category	Review	Response by Greece
Agriculture	52. Within the liquid management system for dairy cattle the separation of solids is common practice in Greece. In response to a question raised by the ERT during the review, Greece explained that, according to the expert judgement of the Ministry of Rural Development and Food, about 15 per cent of the amount of volatile solids (VS) excreted by dairy cattle in liquid-solid separation systems is treated by applying liquid practices, which means that it is drifted by the liquid and stored in tanks. The rest is separated and treated according to solid practices. Given that 8 per cent of the total VS excretion of dairy cattle is excreted outside the housings (on pasture/range/paddock) and 40 per cent of the excretion in dairy housings is treated by manure separation, the fraction of VS managed according to liquid practices has been calculated as follows: 92 per cent \times 40 per cent \div 15 per cent = 5.52 per cent, which corresponds to the value provided in CRF table 4.B(a) for liquid systems for dairy cattle. The ERT recommends that Greece include the shares of VS excretion per AWMS, as provided in CRF table 4.B(a), in the NIR of its next annual submission to improve the description of the method used, in particular for the expert judgement, in order to justify the expert judgement used.	Done, please see NIR NIR section 6.3.2.
Agriculture	53. The ERT noted that Greece has reported in CRF table 4.B(a) the AWMS distribution data for 2011 only. The MCF for cattle, swine and sheep has been reported as "NA", "NE" or 0.0 for 2011. For the other years of the time series, 0.0 has been reported for all relevant cells. In response to a question raised by the ERT during the review, Greece explained that a software problem might have occurred and that the data might therefore have been incorrectly inputted. The ERT recommends that Greece identify the cause of this error, correct the software problem, if appropriate, and report the correct data for the entire time series in its next annual submission.	Done, please see related CRF Tables (4.B(a))
Agriculture	53.54. In Greece's inventory, manure separation in dairy cattle husbandry results in different allocations to liquid and solid systems and is therefore reported in CRF table 4.B(a) under CH4 emissions and in CRF table 4.B(b) under N2O emissions from manure management. According to the IPCC good practice guidance (page 4.44), as a rule of thumb, 50 per cent of the N excreted is in the dung and 50 per cent of the N excreted is in the urine. Following the assumption that in liquid-solid separation only 15 per cent of the solids are drifted by the liquid, the resulting share of N treated according to liquid practices has been calculated as follows: 92 per cent \times 40 per cent \div (50 per cent \times 50 per cent \div 15 per cent) = 21.2 per cent, which corresponds to the N fraction provided in CRF table 4.B(b) for liquid systems for dairy cattle. To improve transparency of the inventory, the ERT strongly recommends that Greece improve the description of the method used to derive the AWMS fractions (liquid and solid systems) from manure separation for the estimation of both CH4 and N2O emissions in the relevant subcategories under manure management in the NIR of its next annual submission.	Done, please see NIR section 6.3.2.
Waste	75. Greece carried out category-specific QC procedures for the waste sector, which include the cross-checking of data, a comparison of data with those of other countries and checking the estimates using different calculation tools. During the review, the ERT noted several inconsistencies in the information in the NIR compared with that provided in the CRF tables (see paras. 79 and 81 below) and errors in the NIR (e.g. table 8.2 shows that country-specific EFs are used for the estimation of CH4 and N2O emissions from composting, however the NIR states that IPCC default values are used). The ERT recommends that Greece strengthen its QA/QC procedures to ensure the accuracy and consistency of the information provided in the NIR with that provided in the CRF tables in its future annual submissions.	Errors were corrected while QA/QC procedure is strengthen by adopting more detailed checking of the documents. Please see section 8.2.2, chapters 'Industrial solid waste' and 'Construction and demolition solid waste', section 8.3.1, chapters 'CH4 emissions from industrial wastewater handling' and section
Waste	77. Greece has used a tier 2 first order decay method from the IPCC good practice guidance in its estimation of CH4 emissions from municipal solid waste, industrial waste, construction and demolition waste and sludge disposed in solid waste disposal sites. Country-specific EFs and parameters as well as IPCC default values were used in the estimation of emissions. In the NIR, Greece explained that historical data on construction and demolition waste were estimated using drivers. However, information on these drivers was not provided in the NIR. In response to a question raised by the ERT during the review, Greece explained that the gross domestic product (GDP) was used as a key driver up to 1995, and 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. The ERT recommends that Greece provide an explanation of how historical data on the amount of construction and demolition waste are estimated in its next annual submission.	Information is now provided. Please see section 8.2.2, chapter 'Construction and demolition solid waste'

Category	Review	Response by Greece
Waste	78. Greece reported in the NIR that the fraction of degradable organic carbon dissimilated (DOCf) for sludge disposed at solid waste disposal sites is 40 per cent and that the sewage sludge remains at wastewater treatment facilities under aerobic conditions with negligible CH ₄ production; therefore, a value lower than the default was applied. In response to a question raised by the ERT during the review, Greece explained that there was an error in the NIR and that the default value of 0.6 from the IPCC good practice guidance was used instead of the value 0.4 which was used in the previous annual submissions. The ERT recommends that Greece ensure the accuracy of the information provided in the NIR in its future annual submissions.	Errors were corrected. Please see section 8.2.2, chapters 'Other parameters'
Waste	79. Greece reported in the NIR that emissions from industrial solid waste and from construction and demolition waste disposed in solid waste disposal sites have been reported for the first time in the 2013 annual submission. However, the ERT noted that CH ₄ emissions from construction and demolition waste have been estimated and reported since the 2012 annual submission. In response to a question raised by the ERT during the review, Greece clarified that the emissions from industrial solid waste and from construction and demolition waste disposed in solid waste disposal sites have been reported since the 2012 submission. The ERT recommends that Greece ensure the accuracy of the information provided in the NIR and the consistency with the information provided in the CRF tables in its future annual submissions.	Errors were corrected. Please see section 8.2.2, chapters 'Industrial solid waste' and 'Construction and demolition solid waste'
Waste	80. Greece estimated and reported CH ₄ and N ₂ O emissions from domestic and industrial wastewater handling. CH ₄ emissions from wastewater handling is a key category by both level and trend assessments. The descriptions of the methods and data used are generally transparent. However, the ERT considers that wastewater treatment and discharge pathways, including treatment of the sludge produced from domestic and industrial wastewater handling, are not described in a transparent manner. Therefore, the ERT recommends that Greece provide detailed information on wastewater flows and treatment systems, using figure 5.3 from the IPCC good practice guidance as a guide, in the next annual submission, in order to improve transparency.	Done. Please see section 8.3.2, chapter 'CH ₄ emissions from domestic and commercial wastewater handling'
Waste	81. Greece reported in the NIR that recalculations were performed for CH ₄ and N ₂ O emissions from commercial wastewater handling and CH ₄ emissions from sludge generated in industrial wastewater handling due to the use of country-specific factors. However, no explanation has been provided in the CRF tables on the recalculations for sludge generated in industrial wastewater handling and commercial wastewater. In response to a question raised by the ERT during the review, Greece explained that the recalculations were performed for CH ₄ emissions from domestic wastewater due to the use of updated data on the population for 2010 and for N ₂ O emissions from domestic wastewater handling due to the use of updated data on annual protein consumption for the period 2008–2010 from EL.STAT. The ERT recommends that Greece ensure the accuracy of the information provided in the NIR and the consistency with the information provided in the CRF tables in its future annual submissions.	Errors were corrected. Please see section 8.3.1, chapters 'CH ₄ emissions from industrial wastewater handling'
Waste	82. Greece recalculated CO ₂ , CH ₄ and N ₂ O emissions from waste incineration due to the use of updated AD for 2010. Data on clinical waste incinerated were provided by the Association of Communities and Municipalities of the Attica Region and data on biogenic agricultural residues and industrial chemical waste were provided by EL.STAT. CO ₂ emissions from clinical waste and industrial chemical waste were estimated using the default method from the IPCC good practice guidance together with default and country-specific parameters. The Party did not provide documentation in the NIR on the country-specific EFs used for the CH ₄ and N ₂ O emission estimates. The ERT recommends that Greece provide more information in its next annual submission to improve the transparency of its reporting.	Done. Please see section 8.4.2
LULUCF-General	Provide transparent information on how the annual land-use change matrices have been developed	Done. The necessary information is provided in chapter 7.
	Provide a complete set of annual land-use change matrices for the whole time series.	Done. The necessary information is provided in chapter 7.

Category	Review	Response by Greece
	Correct the typographical error in the equation for estimating the annual increase in carbon stocks due to biomass growth in new plantations.	Done.
	Provide more information on the QA procedures employed for the LULUCF sector.	Done. The necessary information is provided in chapter 7.
	Collect additional information to determine the areas of conversion of cropland to forest land and cropland to grassland by initial crop type and report the carbon stock changes in mineral soils in the appropriate categories.	Done. The necessary information is provided in chapter 7.
	Provide clarification on its reporting of the carbon stock changes in mineral soils in cropland converted to forest land and cropland converted to grassland and the use of a default transition period of 20 years in the estimation process for carbon stock changes in mineral soils for the land-use conversion categories.	Done. The necessary information is provided in chapter 7.
Forest land remaining forest land – CO₂	Report the carbon stock changes in the dead organic matter and soil carbon pools, or provide evidence transparently substantiating the assertion that the carbon stock changes in the dead organic matter and soil carbon pools are zero.	Done. The necessary information is provided in chapter 7.
	Perform a verification of the results of the carbon stock change method using the IPCC gain–loss method, include the results of this verification, and revise the estimations, if necessary.	Done. The necessary information is provided in chapter 7.
Land converted to forest land – CO₂	Collect the necessary information and estimate the carbon stock changes in dead organic matter in land converted to forest land using higher tier methods.	Done. The necessary information is provided in chapter 7.
	Provide information to substantiate the assumption that there have been no losses due to natural disturbance in land converted to forest land since 1994, or provide revised estimates taking into account the carbon stock losses in the living biomass pool due to natural disturbance.	Done. The necessary information is provided in chapter 7.
Land converted to cropland – N₂O	Estimate and report the N ₂ O emissions from disturbance associated with the conversion of forest land and grassland to cropland.	Done. The necessary information is provided in chapter 7.
	Report the correct numbers for the areas in the CRF tables.	Done. The necessary information is provided in chapter 7.
Land converted to grassland – CO₂	Estimate and report the carbon stock changes in the living biomass for cropland converted to grassland or provide evidence to substantiate the assertion that carbon stock changes in the living biomass pool amount to zero.	Done. The necessary information is provided in chapter 7.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1

10. KP-LULUCF

10.1 General Information

10.1.1 Definition of forest

For reporting purposes under the Kyoto Protocol, 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 in the UNFCCC inventory, in order to maintain coherence and congruence between the two inventories. Greece uses different single minimum values compared to those of FAO in order to ensure consistency with national legislation.

10.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Greece has chosen to elect Forest Management activity under Article 3.4 of the Kyoto Protocol. In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped for Greece in the first commitment period to 330 kt CO₂ per year, or 1650 kt CO₂ for the whole commitment period.

10.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

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 before 31st December 2012. Afforestation / Reforestation category is equivalent to 5.A.2 UNFCCC category (Land converted to Forest land). Forest Management activity under Art. 3.4 is equivalent to 5.A.1 UNFCCC category (Forest land remaining Forest land). 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 5.B.2.1, 5.C.2.1, 5.D.2.1, 5.E.2.1 and 5.F.2.1 (Forest land converted to other land uses).

10.1.4 Precedence conditions and hierarchy among Art. 3.4 activities

Not applicable, as only Forest Management has been elected under Article 3.4.

10.2 Land-related information

10.2.1 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 10.1*. Afforestation / Reforestation data are obtained from the afforestation registry of the Ministry of Environment, Energy and Climate Change (GDPDFNE). 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, Energy and Climate Change. 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, Energy and Climate Change.

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 10.1 *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, Energy and Climate Change	Forest Management information	3.4 FM
The afforestation registry and statistics of the Ministry of Environment, Energy and Climate Change	Afforestation/Reforestation information	3.3 AR
The "Land Use Change Database" of the Ministry of Environment, Energy and Climate Change, which comprise acts of land use change since 1990	Deforestation information	3.3 D

Table 10.2 **NIR 2. Land transition matrix****Table NIR 2. LAND TRANSITION MATRIX**Areas and changes in areas between the previous and the current inventory year ^{(1), (2), (3)}

To current inventory From previous inventory year		Article 3.3 activities		Article 3.4 activities				Other ⁽⁵⁾	Total area at the beginning of the current inventory year ⁽⁶⁾
		Afforestation and Reforestation	Deforestation	Forest Management (if elected)	Cropland Management (if elected)	Grazing Land Management (if elected)	Revegetation (if elected)		
		(kha)							
Article 3.3 activities	Afforestation and Reforestation	33.25	0.00						33.25
	Deforestation		4.54						4.54
Article 3.4 activities	Forest Management (if elected)		NO	1,229.45					1,229.45
	Cropland Management ⁽⁴⁾ (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management ⁽⁴⁾ (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation ⁽⁴⁾ (if elected)	NA			NA	NA	NA		NA
Other ⁽⁵⁾		0.00	0.58	0.00	0.00	0.00	0.00	11,927.92	11,928.50
Total area at the end of the current inventory year		33.25	5.12	1,229.45	0.00	0.00	0.00	11,927.92	13,195.74

⁽¹⁾ This table should be used to report land area and changes in land area subject to the various activities in the inventory year. For each activity it should be used to report area change between the previous year and the current inventory year. For example, the total area of land subject to Forest Management in the year preceding the inventory year, and which was deforested in the inventory year, should be reported in the cell in column of Deforestation and in the row of Forest Management.

⁽²⁾ Some of the transitions in the matrix are not possible and the cells concerned have been shaded.

⁽³⁾ In accordance with section 4.2.3.2 of the IPCC good practice guidance for LULUCF, the value of the reported area subject to the various activities under Article 3.3 and 3.4 for the inventory year should be that on 31 December of that year.

⁽⁴⁾ Lands subject to Cropland Management, Grazing Land Management or Revegetation which, after 2008, are subject to activities other than those under Article 3.3 and 3.4, should still be tracked and reported under Cropland Management, Grazing Land Management or Revegetation, respectively.

⁽⁵⁾ “Other” includes the total area of the country that has not been reported under an Article 3.3 or an elected Article 3.4 activity.

⁽⁶⁾ The value in the cell of row “Total area at the end of the current inventory year” corresponds to the total land area of a country and is constant for all years.

10.2.2 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The reporting method 1 of the GPG LULUCF 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 10.1* present the map and the identification codes of these geographical locations.



Figure 10.1 Map and identification codes for the geographical locations

10.3 Activity-specific information

10.3.1 Methods for carbon stock change and GHG emission and removal estimates

10.3.1.1 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 7. In **Table 10.3**, the activity coverage and other information in regard to activities under Article 3.3 and Article 3.4 are presented.

Table 10.3 *NIR 1. Activity coverage*

TABLE NIR 1. SUMMARY TABLE

Activity coverage and other information relating to activities under Article 3.3 and elected activities under Article 3.4

Activity	Change in carbon pool reported ⁽¹⁾					Greenhouse gas sources reported ⁽²⁾						
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil	Fertilization ⁽³⁾	Drainage of soils under forest management	Disturbance associated with land-use conversion to croplands	Liming	Biomass burning ⁽⁴⁾		
										CO ₂	CH ₄	N ₂ O
Article 3.3 activities	Afforestation and Reforestation	R	R	NR	NR	NR	NO		NO	IE	R	R
	Deforestation	R	R	R	R	R		R	NO	NO	NO	NO
Article 3.4 activities	Forest Management	R	R	NR	NR	NR	NO	NO	NO	IE	R	R
	Cropland Management	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
	Grazing Land Management	NA	NA	NA	NA	NA			NA	NA	NA	NA
	Revegetation	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 or elected activity under Article 3.4. If changes in a carbon pool are not reported, it must be demonstrated in the NIR that this pool is not a net source of greenhouse gases. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the text.

⁽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 or elected activity under Article 3.4. Indicate NA (not applicable) for each activity that is not elected under Article 3.4. Explanation about the use of notation keys should be provided in the text.

⁽³⁾ N₂O emissions from fertilization for Cropland Management, Grazing Land Management and Revegetation should be reported in the Agriculture sector. If a Party is not able to separate fertilizer applied to Forest Land from Agriculture, it may report all N₂O emissions from fertilization in the Agriculture sector.

⁽⁴⁾ If CO₂ emissions from biomass burning are not already included under changes in carbon stocks, they should be reported under biomass burning; this also includes the carbon component of CH₄. Parties that include CO₂ emissions from biomass burning in their carbon stock change estimates should report IE (included elsewhere).

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

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", 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 10.4 *Uncertainty analysis of the KP-LULUCF activities*

Art. 3.3 & 3.4 Activities	Gas	Uncertainty (%)
Afforestation / Reforestation	CO ₂	112.8
Deforestation	CO ₂	51.0
Forest Management	CO ₂	34.0
Forest Management	CH ₄	70.9
Forest Management	N ₂ O	70.9

10.3.1.2 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 include 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 cropland 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 7.2.2.2, 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 7.2.2.2 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 7.14** in section 7. 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 7.3.2.2, while the IPCC default inventory time period was used (T = 20). The results are presented in **Figure 10.2** below:

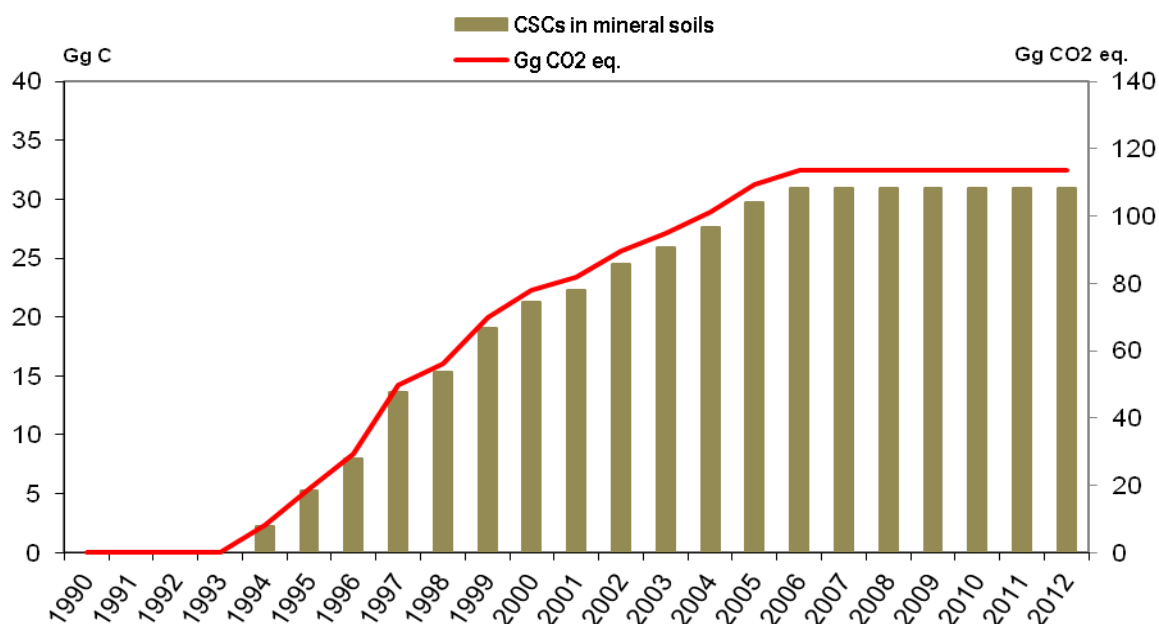


Figure 10.2 Carbon stock changes in mineral soils in the period 1990-2012

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 - 2011. In **Figure 10.3**, 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 are presented.

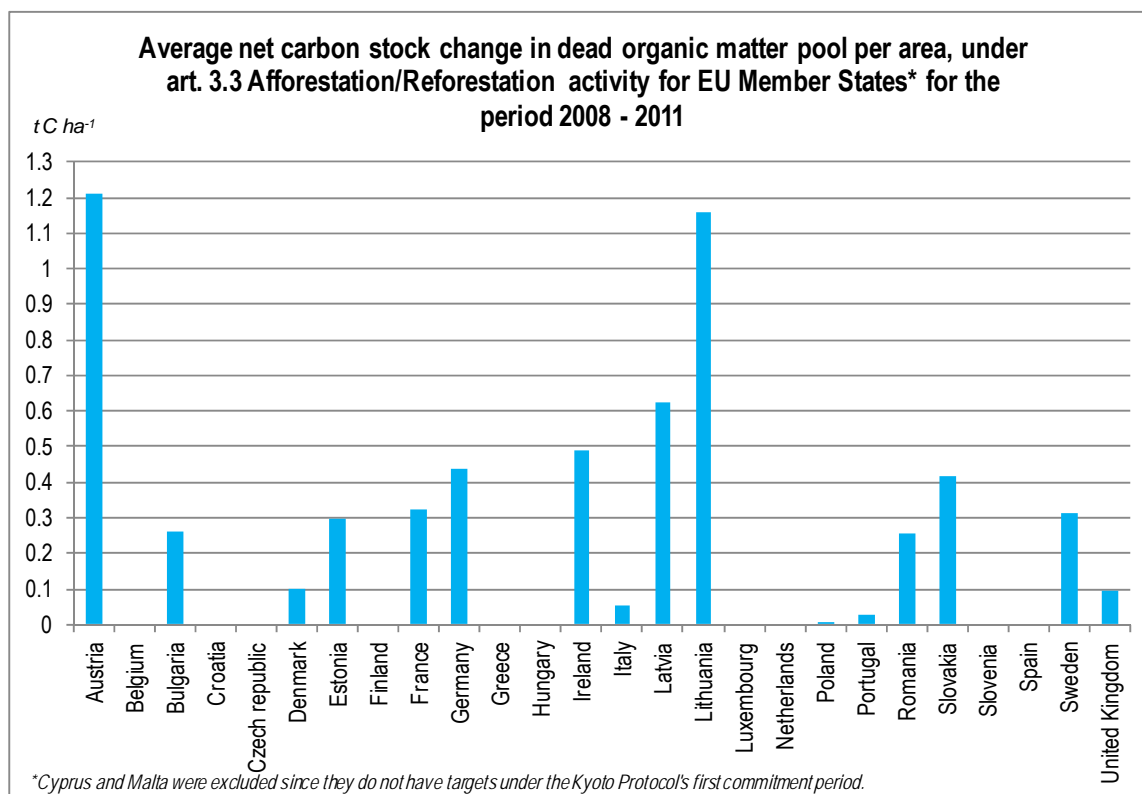


Figure 10.3 *Average net carbon stock changes in DOM pool for art. 3.3 AR activities for EU Member States for the period 2008-2011*

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 practise 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 - 2012. 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, according to the most recent data submitted by the EU Member States, the dead organic matter pool and mineral soils in soil organic matter pool under art. 3.4 Forest Management were net sinks (except for Portugal) during the period 2008 - 2011. In **Figure 10.4**, and **Figure 10.5**, below, the average net carbon stock changes in dead organic matter pool and mineral soils under art. 3.4 Forest Management for each Member State for that period are presented respectively.

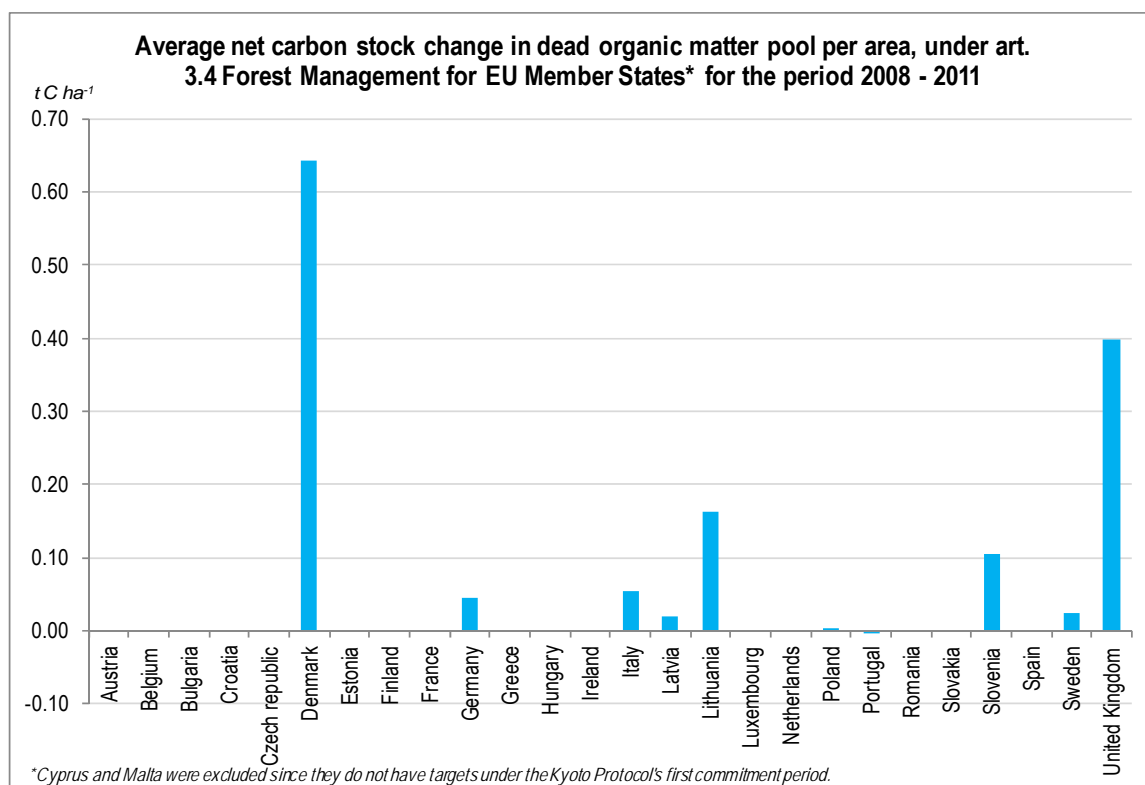


Figure 10.4 **Average net carbon stock changes in DOM pool under art. 3.4 Forest Management for EU Member States for the period 2008-2011**

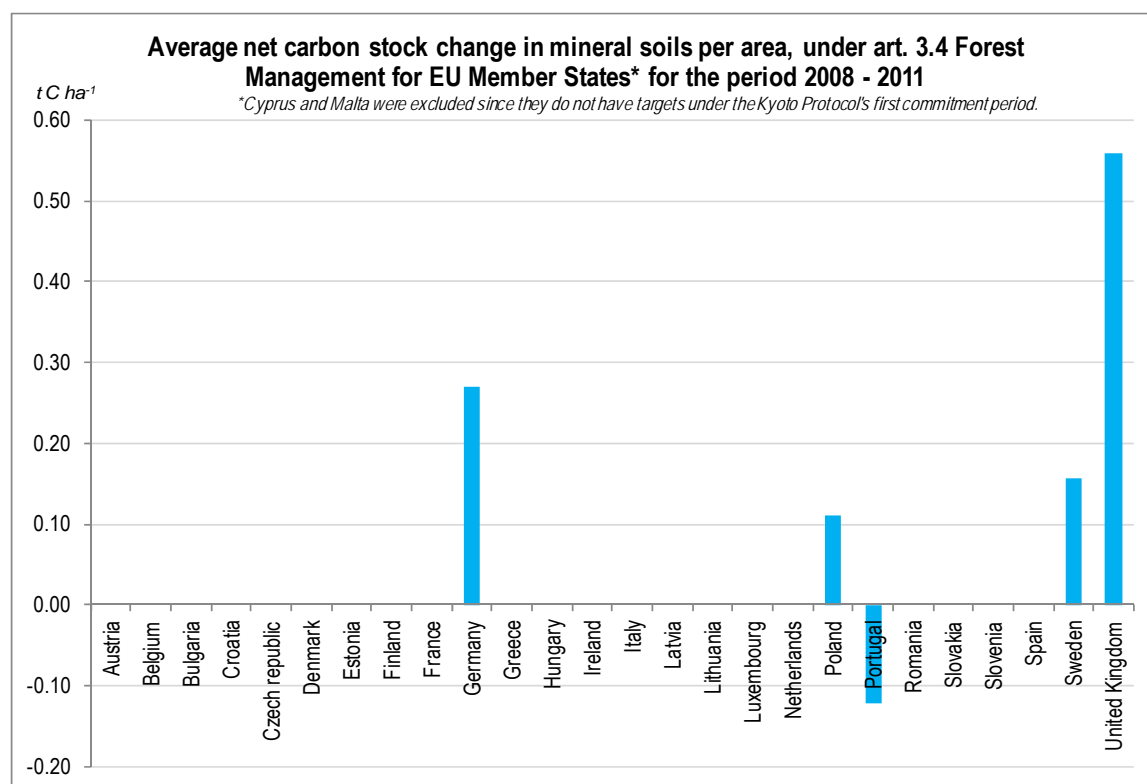


Figure 10.5 Average net carbon stock changes in mineral soils under art. 3.4 Forest Management for EU Member States for the period 2008-2011

References

- Harmon M.E. and Marks B. (2002). Effects of silvicultural practices on carbon stores in Douglas-fir-western hemlock forests in the Pacific Northwest, USA: results from a simulation model. *Canadian Journal of Forest Research*, 32 (5): pp. 863-877.
- Guo L.B. and Gifford R.M., 2002. Soil carbon stocks and land use change: a meta analysis. *Global Change Biology* 8: pp. 345-360
- Johnson D.W., and Curtis P.S. (2001). Effects of forest management on soil C and N storage: meta analysis. *Forest Ecology and Management*, 140: pp. 227-238.
- Liski J., Pussinen A., Pingoud K., Makipaa R., Karjalainen T. (2001). Which rotation length is favourable to carbon sequestration? *Canadian Journal of Forest Research* 31: pp. 2004-2013.
- Polglase P.J., Paul K.I., Khanna P.K., Nyakuengama J.G., O'Connell A.M., Grove T.S., and Battaglia M. , 2000. Change in soil Carbon Following Afforestation or Reforestation. National Carbon Accounting system technical report no. 20 Australian Greenhouse Gas Office, Canberra
- Post, W., Kwon, K., 2000. Soil carbon sequestration and land-use change: processes and potential. *Global Change Biology* 6, 317–328.
- Vesterdal, L., Rosenqvist, L., van der Salm, C., Groenenberg, B.-J., Johansson, M.-B., Hansen, K., 2006. Carbon sequestration in soil and biomass following afforestation: experiences from oak and Norway spruce chronosequences in Denmark, Sweden, and the Netherlands. In: Heil, G., Muys, B., Hansen, K. (Eds.), *Environmental Effects of Afforestation. Field Observations, Modelling and Spatial Decision Support*. Springer, Berlin, p. 999–999.

10.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

No indirect or natural greenhouse-gas emissions or removals were taken into account. Concerning the elevated CO₂ concentration and the indirect nitrogen deposition, there are no methodologies adopted by the UNFCCC. For Article 3, paragraph 3 activities, the dynamic effect of age is not relevant since all these activities have occurred after 1990. For Article 3, paragraph 4 activities the issue of factoring out was solved during negotiations with the cap for Forest Management.

10.3.1.4 Other methodological issues

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

Following previous ERT's recommendation, Greece has decided to proceed with a verification of the estimates of carbon stock changes in living biomass resulted from the use of the GPG LULUCF 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 5.A.1 UNFCCC category (Forest land remaining Forest land), the results of the verification activity are those reported in section 7.2.2.1.

N₂O emissions from disturbance associated with land-use conversion to Cropland

N₂O emissions as a result of the disturbance associated with land-use conversion (Deforestation) to Cropland are reported in KP-CRF Table 5(KP-II)3. The emissions are calculated according to the methodology described in section 7.3.2.2.

10.4 Article 3.3

10.4.1 Information that demonstrates that activities began on or after 1 January 1990 and before 31 December 2012 and they are directly 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 recently developed Land Use Change Database. This database contains annual statistical data on areas under land use change since 1990 collected from the local Forest Services.

10.4.2 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 of 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.

10.4.3 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.

10.5 Article 3.4

10.5.1 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 36.3% of the total forest land of Greece (high forest).

10.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

These activities were not elected by Greece.

10.6 Other information

10.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

In accordance with the GPG LULUCF, 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 5.B.2.1, 5.C.2.1, 5.D.2.1, 5.E.2.1 and 5.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 5.B.2, 5.C.2, 5.D.2, 5.E.2 and 5.F.2 has been identified as key, and hence Deforestation is not identified as a key category.

Table 10.5 *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

10.7 Information relating to Article 6

Not applicable to Greece.

11. Information on accounting of Kyoto units

11.1 Summary of information reported in the SEF tables

For the information about the national registry on the issue, acquisition, holding, transfer, cancellation, withdrawal and carryover of assigned amount units, removal units, emission reduction units and certified emission reductions during the year 2013 (X-1) the respective software application has been used, which is included in this reporting submission.

11.2 Discrepancies and notifications

No discrepancies identified by the transaction log, was found concerning the completion or termination of the relevant transactions. GR registry has not received any notification (for ICER or tCER) from the Executive Board of the Clean development mechanism (CDM), according to paragraphs 49, 50 and 56 of the annex to decision 5/CMP.1. There are no quantities of ERUs, CERs, tCERs, ICERs, AAUs and RMUs, held in the national registry at the end of that year, that are not valid for use towards compliance with commitments under Article 3, paragraph 1, pursuant to paragraph 43(b) of the annex to decision 13/CMP.1. Moreover, no problems had occurred that caused a discrepancy.

11.3 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 Energy & Climate Change:

<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/>

11.4 Calculation of the commitment period reserve (CPR)

The calculated commitment period reserve for Greece is determined as 100% of GHG emissions of the latest reviewed inventory (ERT of 2013, inventory years 1990-2011) multiplied by 5. Therefore, the commitment period reserve for Greece is **575,225,094 tonnes CO₂ eq** (in the initial report of the 1st CP of KP the CPR was calculated to be 601,802,826 tonnes CO₂ eq).

12. Information on changes in national system

No changes.

13. Information on changes in national registry

The following changes to the national registry of Greece have therefore occurred in 2013

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(a)</p> <p>Change of name or contact</p>	<p>Ms. E. Chatziapostolou (e.hatziapostolou@prv.ypeka.gr), Mr. I. Haralampis (i.haralampis@prv.ypeka.gr)</p> <p>Address: Greek GHG Registry</p> <p>Tim. Vassou 11-13</p> <p>11521 Athens</p> <p>Greece</p> <p>Tel. +30 2106469738</p>
<p>15/CMP.1 annex II.E paragraph 32.(b)</p> <p>Change regarding cooperation arrangement</p>	<p>No change of cooperation arrangement occurred during the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(c)</p> <p>Change to database structure or the capacity of national registry</p>	<p>An updated diagram of the database structure is attached as Annex A.</p> <p>Iteration 5 of the national registry released in January 2013 and Iteration 6 of the national registry released in June 2013 introduces changes in the structure of the database.</p> <p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality.</p> <p>No change was required to the database and application backup plan or to the disaster recovery plan.</p> <p>No change to the capacity of the national registry occurred during the reported period.</p>

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(d)</p> <p>Change regarding conformance to technical standards</p>	<p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality.</p> <p>However, 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 2014 and the successful test report has been attached.</p> <p>No other change in the registry's conformance to the technical standards occurred for the reported period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(e)</p> <p>Change to discrepancies procedures</p>	<p>No change of discrepancies procedures occurred during the reported period.</p>

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(f)</p> <p>Change regarding security</p>	<p>No change of security measures occurred during the reporting period</p>
<p>15/CMP.1 annex II.E paragraph 32.(g)</p> <p>Change to list of publicly available information</p>	<p>The changes to the list of publicly available information that occurred during the reporting period are provided through the link of the Greek Greenhouse Gas Registry in the corresponding web site of the Ministry of Environment Energy & Climate Change:</p> <p>http://www.ypeka.gr/Default.aspx?tabid=775&locale=el-GR&language=en-US (in Greek)</p> <p>http://www.ypeka.gr/Default.aspx?tabid=775&locale=en-US&language=el-GR (in English)</p>
<p>15/CMP.1 annex II.E paragraph 32.(h)</p> <p>Change of Internet address</p>	<p>No change of the registry internet address occurred during the reporting period.</p>
<p>15/CMP.1 annex II.E paragraph 32.(i)</p> <p>Change regarding data integrity measures</p>	<p>No change of data integrity measures occurred during the reporting period.</p>

Reporting Item	Description
<p>15/CMP.1 annex II.E paragraph 32.(j)</p> <p>Change regarding test results</p>	<p>Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality.</p> <p>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. Annex H testing was carried out in February 2014 and the successful test report has been attached.</p>

14. Minimization of adverse impacts in accordance with Article 3, paragraph 14

14.1 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.

14.2 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)

REFERENCES

- Aluminium of Greece, Environmental Study, 2006.
- Carras, G., 1973. "Climatic classification of Greece by Thornwaite", PhD Thesis, Athens
- European Commission, 2001, "Best available techniques – Reference document on the production of iron and steel", European IPPC Bureau
- European Commission, 2001, "Disposal and recycling routes for sewage sludge", Part 3 – Scientific and technical report'.
- European Commission, 2004, "EU energy and transport in figures. Statistical pocketbook 2004", Directorate-General for Energy and Transport
- European Environmental Agency (EEA), 1999, "ReportER User Manual", Technical Report No. 32, Copenhagen
- European Environmental Agency (EEA), 2001, "Joint EMEP/CORINAIR Atmospheric emission inventory guidebook", 3rd edition, Copenhagen
- Fott P., 1999, "Carbon emission factors of coal and lignite: analysis of Czech coal data and comparison to European values", Environmental Science & Policy, 2, pp. 347 - 354
- General Directorate for the Forests and the Natural Environment (GDFNE), 1992, "Results of the First National Forest Census", Ministry for Rural Development and Food, Athens
- General Directorate for the Forests and the Natural Environment (GDFNE), 1994, "Forest Maps of Greece", Volume A (Macedonia-Thraki-Ipiros-Thessalia), Ministry for Rural Development and Food, Athens
- General Directorate for the Forests and the Natural Environment (GDFNE), 2000, "Criteria and Indicators for the Sustainable Forest Management in Greece", Ministry for Rural Development and Food, Athens
- General Directorate for the Forests and the Natural Environment (GDFNE), 2001, "Activities of the Forest Service of the Ministry for Rural Development and Food", Ministry for Rural Development and Food, Athens
- Guo, L. B. and Gifford, R. M., 2002, "Soil Carbon Stocks and Land Use Change: a Meta Analysis", Global Change Biology 8, 345-360
- ICAP, 2000, "Air-conditioning", Market survey, Athens.
- ICAP, 2002, "Air-conditioning", Market survey, Athens.

- ICAP, 2002, "Electric appliances for residential use", Market survey, Athens.
- ICAP, 2005, "Air Conditioning", Market survey, Athens.
- ICAP, 2008, "Air Conditioning", Market survey, Athens.
- ICAP, 2009, "Air-Conditioning", Market survey, Athens.
- ICAP, 2011, "Air-Conditioning", Market survey, Athens.
- ICAP, 2013, "Air-Conditioning", Market survey, Athens.
- ICAP, 2008, "Electrical appliances for residential use", Market survey, Athens.
- ICAP, 2010, "Electrical appliances for residential use", Market survey, Athens.
- Intergovernmental Panel on Climate Change (IPCC), 1997, "Revised 1996 IPCC guidelines for national greenhouse gas inventories – Greenhouse gas inventory reference manual (Vol. 3)", IPCC/OECD/IEA, UK Meteorological Office, Bracknell
- Intergovernmental Panel on Climate Change (IPCC), 2000, "Good practice guidance and uncertainty management in national greenhouse gas inventories", IPCC National Greenhouse Gas Inventories Programme, Institute for Global Environmental Strategies, Japan
- Intergovernmental Panel on Climate Change (IPCC), 2002, "Good practice guidance for Land Use, Land Use Change and Forestry", IPCC National Greenhouse Gas Inventories Programme, Institute for Global Environmental Strategies, Japan
- Intergovernmental Panel on Climate Change (IPCC), 2006, "IPCC Guidelines for National GHG Inventories", IPCC National Greenhouse Gas Inventories Programme, Institute for Global Environmental Strategies, Japan
- International Energy Agency (IEA), "Energy statistics of OECD countries", 1990 – 2002, OECD/IEA, Paris
- International Iron and Steel Institute (IISI), 2001, "Steel statistical yearbook 2001", Committee on Economic Studies, Brussels
- International Iron and Steel Institute (IISI), 2002, "Steel statistical yearbook 2002", Committee on Economic Studies, Brussels
- International Iron and Steel Institute (IISI), 2003, "Steel statistical yearbook 2003", Committee on Economic Studies, Brussels
- Kokkinidis, G., 1989, "Biomass of Greek forests", Athens

- Milios John, 'The greek economy in the 20th century', National Technical University of Athens
- Ministry for Development (MD), "National Energy Balance", 1990 – 2003, Directorate for Energy Policy, Athens
- Ministry for Development (MD), 2004, "Support Actions for the fulfilment of national commitments under the UNFCCC and the Kyoto Protocol", Technical report No. 3 prepared by the National Observatory of Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 1987, "Report on the environmental conditions in Greece – Solid Waste", Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 1998, "National Planning for integrated and alternative treatment of waste", Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 1999, "Planning – Programming of solid waste management projects in national level", Paraskevopoulos – Georgiadis Ltd., Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 2000, "Action Plan for Wastewater Treatment Facilities", Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 2001, "Uncontrolled waste disposal sites in Greece", Department for Solid Waste Management, Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 2001a, "Quantification of targets about sanitary landfill, reported in Directive 31/99/EU", Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), 2001b, "Development of a registry on air emissions, liquid and solid wastes from industry and on air emissions from central heating installations", Final Report, Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), National Observatory of Athens (NOA), 2002, "Climate Change - The Greek Action Plan for the abatement of CO₂ and other GHG emissions (2000 – 2010)", Athens
- Ministry for the Environment, Physical Planning and Public Works (MINENV), National Technical University of Athens (NTUA), 1995, "Climate Change - The Greek Action Plan for the Abatement of CO₂ and Other Greenhouse Gas Emissions", Athens
- Ministry of Agriculture, 1981, 'Tables for the economical analysis of agricultural data', Athens
- National Statistical Service of Greece (NSSG), 1986, "Distribution of the Country's Area by Basic Categories of Land Use ", Athens

- National Statistical Service of Greece (NSSG), 1995, "Distribution of the Country's Area by Basic Categories of Land Use ", Athens
- National Statistical Service of Greece (NSSG), 1995, "Statistical Yearbook of Greece 1992 - 1993", Athens
- National Statistical Service of Greece (NSSG), 1996, "Statistical Yearbook of Greece 1994 - 1995", Athens
- National Statistical Service of Greece (NSSG), 1997, "Statistical Yearbook of Greece 1996", Athens
- National Statistical Service of Greece (NSSG), 1998, "Statistical Yearbook of Greece 1997", Athens
- National Statistical Service of Greece (NSSG), 2000, "Statistical Yearbook of Greece 1999", Athens
- National Statistical Service of Greece (NSSG), 2001, "Statistical Yearbook of Greece 2000", Athens
- National Statistical Service of Greece (NSSG), "Agricultural Statistics of Greece", 1963 – 2001, Athens
- National Statistical Service of Greece (NSSG), "Transport and Communications Statistics", 1990 – 2001, Athens
- National Statistical Service of Greece (NSSG), "Tourist Statistics", 1990 – 2001, Athens
- National Statistical Service of Greece (NSSG), PRODCOM, 1993-2007, Athens
- Hellenic Statistical Authority, PRODCOM 2008-2009, Athens
- Ntziachristos L., Samaras Z., 2000, "COPERT III - Computer programme to calculate emissions from road transport. Methodology and emission factors (Version 2.1)", Technical Report No. 49, European Environmental Agency, Copenhagen
- D. Gkatzoflias, L. Ntziachristos and Z. Samaras (LAT/AUTH)., 2007, "COPERT 4 Computer programme to calculate emissions from road transport - Users Manual", ETC-ACC European Topic Centre on Air and Climate Change
- Panagiotakopoulos, 2002. Sustainable Management of Municipal Solid Waste, Zigos, Thessaloniki (in Greek).

- Papanicolaou C., Kotis T., Foscolos A., Goodarzi F., 2004, "Coals of Greece: a review of properties, uses and future perspectives", *International Journal of Coal Technology*, 58, pp. 147-169.
- Public Power Corporation (PPC), 1994, "Estimation of the CO₂ emission factors for the lignite used by the PPC", Athens
- Soil Science Institute of Athens (SSIA), 2001, "Tenagi Filippon Soil Study", Athens
- Union of Local Authorities in the Prefecture of Attica (ULAPA), 1996, "Environmental impact assessment study for the establishment of a sanitary landfill in South – South-eastern Attica", Athens
- Yassoglou, N. J., 2004. Soil Associations Map of Greece, Agricultural University of Athens
- United Nations Framework Convention on Climate Change (UNFCCC), 2004, "Greece - Report of the individual review of the greenhouse gas inventory submitted in 2004", FCCC/WEB/IRI/2004/GRC
- United Nations Framework Convention on Climate Change (UNFCCC), 2007, "Report of the review of the initial report of Greece", FCCC/IRR/2007/GRC
- United Nations Framework Convention on Climate Change (UNFCCC), 2008, "Report of the individual review of the greenhouse gas inventories of Greece submitted in 2007 and 2008", FCCC/ARR /2008 /GRC
- United Nations Framework Convention on Climate Change (UNFCCC), 2010, "Report of the individual review of the annual submission of Greece submitted in 2009", FCCC/ARR /2009 /GRC
- Vlyssides, G. A., Loizides, M., and Karlis, K. P., 2004 "Integrated strategic approach for reusing olive oil extraction by-products", *Journal of Cleaner Production*, 12(6), pp. 603-611.
- Vlyssides A., Barampouti E.M., Mai S., 2006 "Effect of recirculation of currant-finishing wastewater (CFW) on their energy utilization", *Biomass and Waste to Energy Symposium*, 29 November - 1 December 2006, Venice, Italy.
- Vlyssides A., Barampouti E.M., Mai S., 2007 "Energy utilization and recirculation of currant-finishing wastewater", *Journal of Hazardous Materials*, 145, pp. 506-510
- Vlyssides A., Karlis P., Barampouti E.M., Mai S., 2008 "Effect of recirculation of currant-finishing wastewater (CFW) on its composition", *Bioresource Technology* 99 (5), pp. 1481-1485.
- World Steel Association, 2008, "Sustainability Report of the world steel industry".

ANNEXES

Annex I: Key categories

The IPCC Good Practice Guidance 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 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.

As far as possible, key source categories should receive special consideration in terms of two important inventory aspects.

4. The use of source category-specific good practice methods is preferable, unless resources are unavailable.
5. 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 IPCC Good Practice Guidance (*Tables I.1, I.3 and I.5*), adopting the categorization of sources that is presented in table 7.1 of the IPCC Good Practice Guidance. In the 2010 Centralised Review the ERT has encouraged Greece to explore the possibility of using a finer disaggregation of categories in the next submissions. In answer to that encouragement Greece continues to run the analysis using more disaggregated data in the Energy Sector and in the Agriculture Sector. Tier 1 methodology for the identification of key categories assesses the impacts of various 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 noted that, according to the IPCC GPG 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 1990-2012) 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. The results of the analysis for each year can be viewed in Table 7 of the corresponding CRF excel file.

Table I.1 *Key categories analysis without LULUCF – Level assessment for 2012*

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	35,207.38	41,990.40	37.83	37.83
Road Transportation	CO2	11,742.20	13,594.88	12.25	50.08
Other Sectors: Liquid fuels	CO2	8,006.48	8,120.69	7.32	57.40
Energy Industries: Liquid fuels	CO2	7,683.34	7,367.46	6.64	64.04
Energy Industries: Gaseous fuels	CO2	102.03	5,149.40	4.64	68.68
ODS substitutes	HFC	0.00	3,889.05	3.50	72.18
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	3,717.67	3.35	75.53
Solid waste disposal on land	CH4	2,225.69	3,204.21	2.89	78.42
Cement Production	CO2	5,761.69	3,099.30	2.79	81.21
Indirect N2O from nitrogen used in agr.	N2O	2,818.86	1,783.70	1.61	82.82
Enteric fermentation: Sheep	CH4	1,662.38	1,682.16	1.52	84.33
Navigation	CO2	1,818.34	1,663.95	1.50	85.83
Direct N2O from agr. soils	N2O	2,849.81	1,534.48	1.38	87.22
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,519.55	1.37	88.59
Animal Production	N2O	1,538.95	1,479.83	1.33	89.92
Coal Mining (surface)	CH4	1,095.27	1,328.69	1.20	91.12
Wastewater handling	CH4	3,330.74	1,109.29	1.00	92.12
Other Sectors: Gaseous fuels	CO2	0.00	1,038.34	0.94	93.05
Ferroalloys	CO2	622.23	698.45	0.63	93.68
Enteric fermentation: Other	CH4	661.10	594.63	0.54	94.22
Manure management	N2O	540.72	593.95	0.54	94.75
Enteric fermentation: Non Dairy Cattle	CH4	464.42	553.40	0.50	95.25
Civil Aviation	CO2	319.05	489.75	0.44	95.69
Limestone & Dolomite Use	CO2	582.80	400.48	0.36	96.05
Manure management	CH4	423.37	399.06	0.36	96.41
Wastewater handling	N2O	331.24	382.51	0.34	96.76
Other Chemicals	CO2	0.00	323.29	0.29	97.05
Nitric Acid Production	N2O	1,109.04	307.01	0.28	97.32
Enteric fermentation: Dairy Cattle	CH4	341.79	292.74	0.26	97.59
Aluminium Production	CO2	225.39	270.56	0.24	97.83
Manufacturing Industries & Construction: Solid fuels	CO2	3,524.55	244.44	0.22	98.05
Lime Production	CO2	404.00	208.54	0.19	98.24
Oil, Natural Gas and Other sources	CH4	91.59	198.84	0.18	98.42
Ammonia Production	CO2	652.04	178.73	0.16	98.58
Solvent and other product use	CO2	169.71	162.72	0.15	98.73
Solvent and other product use	N2O	138.63	155.75	0.14	98.87
Energy Industries: Solid fuels	N2O	134.19	153.64	0.14	99.01
Rice Production	CH4	69.10	117.60	0.11	99.11
Road Transportation	N2O	145.27	103.64	0.09	99.20
Other Sectors: Liquid fuels	N2O	349.81	103.03	0.09	99.30
Iron and Steel Production	CO2	92.70	82.99	0.07	99.37
Navigation	N2O	134.53	80.47	0.07	99.44
Railways	CO2	202.69	78.75	0.07	99.52

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Other Sectors: Biomass	CH ₄	76.59	78.53	0.07	99.59
ODS substitutes	PFC	0.00	60.24	0.05	99.64
Road Transportation	CH ₄	100.74	57.30	0.05	99.69
Aluminium Production	PFCs	163.37	50.16	0.05	99.74
Other Sectors: Biomass	N ₂ O	31.80	32.62	0.03	99.77
Field burning of agr.residues	CH ₄	27.06	32.08	0.03	99.80
Energy Industries: Liquid fuels	N ₂ O	19.40	19.30	0.02	99.81
Waste Other	N ₂ O	0.00	18.51	0.02	99.83
Soda Ash Use	CO ₂	33.16	17.02	0.02	99.85
Waste Other	CH ₄	0.00	16.72	0.02	99.86
Other Mineral (Glass)	CO ₂	20.20	15.59	0.01	99.87
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	14.74	0.01	99.89
Field burning of agr.residues	N ₂ O	10.05	12.23	0.01	99.90
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	15.98	12.02	0.01	99.91
Other transportation	CO ₂	0.00	11.15	0.01	99.92
Manufacturing Industries & Construction: Biomass	N ₂ O	9.91	10.01	0.01	99.93
Railways	N ₂ O	24.22	9.61	0.01	99.94
Oil, Natural Gas and Other sources	CO ₂	70.23	8.75	0.01	99.95
Energy Industries: Solid fuels	CH ₄	6.06	6.94	0.01	99.95
Other Sectors: Liquid fuels	CH ₄	7.36	6.92	0.01	99.96
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	0.00	6.79	0.01	99.96
Energy Industries: Liquid fuels	CH ₄	6.57	6.54	0.01	99.97
Civil Aviation	N ₂ O	3.41	5.26	0.00	99.97
SF ₆ from electrical equipment	SF ₆	3.07	5.11	0.00	99.98
Manufacturing Industries & Construction: Biomass	CH ₄	5.03	5.09	0.00	99.98
Waste incineration	CO ₂	0.22	3.23	0.00	99.99
Energy Industries: Gaseous fuels	N ₂ O	0.05	2.90	0.00	99.99
Navigation	CH ₄	2.64	2.69	0.00	99.99
Energy Industries: Gaseous fuels	CH ₄	0.04	1.97	0.00	99.99
Other Sectors: Solid fuels	CO ₂	119.43	1.59	0.00	99.99
Manufacturing Industries & Construction: Solid fuels	N ₂ O	17.74	1.17	0.00	100.00
Manufacturing Industries & Construction: Liquid fuels	CH ₄	3.10	0.95	0.00	100.00
Waste incineration	N ₂ O	0.13	0.74	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.00	0.58	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.00	0.58	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.00	0.39	0.00	100.00
Iron and Steel Production	CH ₄	0.21	0.26	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.00	0.25	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.00	0.22	0.00	100.00
Civil Aviation	CH ₄	0.13	0.20	0.00	100.00
Energy Industries: Biomass	CH ₄	0.00	0.14	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.00	0.11	0.00	100.00
Railways	CH ₄	0.24	0.09	0.00	100.00
Other transportation	N ₂ O	0.00	0.09	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.82	0.05	0.00	100.00
Waste incineration	CH ₄	0.01	0.03	0.00	100.00
Oil, Natural Gas and Other sources	N ₂ O	0.20	0.02	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.71	0.01	0.00	100.00
Other transportation	CH ₄	0.00	0.01	0.00	100.00
Other Sectors: Solid fuels	CH ₄	0.05	0.00	0.00	100.00
Other Chemicals	CH ₄	0.52	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	0.00	100.00
TOTAL			110,985.47	100.00	

Table I.2 Key categories analysis with LULUCF – Level assessment for 2012

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Energy Industries: Solid fuels	CO2	41,990.40	36.74	36.74
Road Transportation	CO2	13,594.88	11.89	48.63
Other Sectors: Liquid fuels	CO2	8,120.69	7.10	55.73
Energy Industries: Liquid fuels	CO2	7,367.46	6.45	62.18
Energy Industries: Gaseous fuels	CO2	5,149.40	4.51	66.68
ODS substitutes	HFC	3,889.05	3.40	70.09
Manufacturing Industries & Construction: Liquid fuels	CO2	3,717.67	3.25	73.34
Solid waste disposal on land	CH4	3,204.21	2.80	76.14
Cement Production	CO2	3,099.30	2.71	78.85
Forest Land remaining Forest Land	CO2	1,841.07	1.61	80.47
Indirect N2O from nitrogen used in agr.	N2O	1,783.70	1.56	82.03
Enteric fermentation: Sheep	CH4	1,682.16	1.47	83.50
Navigation	CO2	1,663.95	1.46	84.95
Direct N2O from agr. soils	N2O	1,534.48	1.34	86.30
Manufacturing Industries & Construction: Gaseous fuels	CO2	1,519.55	1.33	87.62
Animal Production	N2O	1,479.83	1.29	88.92
Coal Mining (surface)	CH4	1,328.69	1.16	90.08
Wastewater handling	CH4	1,109.29	0.97	91.05
Other Sectors: Gaseous fuels	CO2	1,038.34	0.91	91.96
Conversion to Grassland	CO2	916.96	0.80	92.76
Ferroalloys	CO2	698.45	0.61	93.37
Enteric fermentation: Other	CH4	594.63	0.52	93.89
Manure management	N2O	593.95	0.52	94.41
Enteric fermentation: Non Dairy Cattle	CH4	553.40	0.48	94.90
Civil Aviation	CO2	489.75	0.43	95.33
Limestone & Dolomite Use	CO2	400.48	0.35	95.68
Manure management	CH4	399.06	0.35	96.03
Wastewater handling	N2O	382.51	0.33	96.36
Other Chemicals	CO2	323.29	0.28	96.64
Nitric Acid Production	N2O	307.01	0.27	96.91
Enteric fermentation: Dairy Cattle	CH4	292.74	0.26	97.17
Aluminium Production	CO2	270.56	0.24	97.41
Manufacturing Industries & Construction: Solid fuels	CO2	244.44	0.21	97.62
Cropland remaining Cropland	CO2	227.67	0.20	97.82
Lime Production	CO2	208.54	0.18	98.00
Oil, Natural Gas and Other sources	CH4	198.84	0.17	98.17
Ammonia Production	CO2	178.73	0.16	98.33
Solvent and other product use	CO2	162.72	0.14	98.47
Solvent and other product use	N2O	155.75	0.14	98.61
Energy Industries: Solid fuels	N2O	153.64	0.13	98.74
Conversion to Forest Land	CO2	145.24	0.13	98.87
Conversion to Other land	CO2	130.25	0.11	98.98
Rice Production	CH4	117.60	0.10	99.09
Road Transportation	N2O	103.64	0.09	99.18
Other Sectors: Liquid fuels	N2O	103.03	0.09	99.27
Iron and Steel Production	CO2	82.99	0.07	99.34
Navigation	N2O	80.47	0.07	99.41
Railways	CO2	78.75	0.07	99.48
Other Sectors: Biomass	CH4	78.53	0.07	99.55
ODS substitutes	PFC	60.24	0.05	99.60

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Road Transportation	CH ₄	57.30	0.05	99.65
Aluminium Production	PFCs	50.16	0.04	99.70
Other Sectors: Biomass	N ₂ O	32.62	0.03	99.72
Field burning of agr.residues	CH ₄	32.08	0.03	99.75
Conversion to Settlements	CO ₂	24.53	0.02	99.77
Grassland remaining Grassland	CH ₄	19.48	0.02	99.79
Energy Industries: Liquid fuels	N ₂ O	19.30	0.02	99.81
Waste Other	N ₂ O	18.51	0.02	99.82
Soda Ash Use	CO ₂	17.02	0.01	99.84
Waste Other	CH ₄	16.72	0.01	99.85
Other Mineral (Glass)	CO ₂	15.59	0.01	99.87
Manufacturing Industries & Construction: Other Fuels	CO ₂	14.74	0.01	99.88
Field burning of agr.residues	N ₂ O	12.23	0.01	99.89
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	12.02	0.01	99.90
Other transportation	CO ₂	11.15	0.01	99.91
Manufacturing Industries & Construction: Biomass	N ₂ O	10.01	0.01	99.92
Railways	N ₂ O	9.61	0.01	99.93
Oil, Natural Gas and Other sources	CO ₂	8.75	0.01	99.94
Energy Industries: Solid fuels	CH ₄	6.94	0.01	99.94
Other Sectors: Liquid fuels	CH ₄	6.92	0.01	99.95
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	6.79	0.01	99.95
Energy Industries: Liquid fuels	CH ₄	6.54	0.01	99.96
Forest Land remaining Forest Land	CH ₄	6.05	0.01	99.96
Civil Aviation	N ₂ O	5.26	0.00	99.97
SF ₆ from electrical equipment	SF ₆	5.11	0.00	99.97
Manufacturing Industries & Construction: Biomass	CH ₄	5.09	0.00	99.98
Waste incineration	CO ₂	3.23	0.00	99.98
Energy Industries: Gaseous fuels	N ₂ O	2.90	0.00	99.98
Conversion to Wetland	CO ₂	2.87	0.00	99.99
Navigation	CH ₄	2.69	0.00	99.99
Grassland remaining Grassland	N ₂ O	1.98	0.00	99.99
Energy Industries: Gaseous fuels	CH ₄	1.97	0.00	99.99
Other Sectors: Solid fuels	CO ₂	1.59	0.00	99.99
Manufacturing Industries & Construction: Solid fuels	N ₂ O	1.17	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH ₄	0.95	0.00	100.00
Waste incineration	N ₂ O	0.74	0.00	100.00
Forest Land remaining Forest Land	N ₂ O	0.61	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.58	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.58	0.00	100.00
Grassland remaining Grassland	CO ₂	0.40	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.39	0.00	100.00
Conversion to Cropland	CO ₂	0.33	0.00	100.00
Iron and Steel Production	CH ₄	0.26	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.25	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.22	0.00	100.00
Civil Aviation	CH ₄	0.20	0.00	100.00
Energy Industries: Biomass	CH ₄	0.14	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.11	0.00	100.00
Railways	CH ₄	0.09	0.00	100.00
Other transportation	N ₂ O	0.09	0.00	100.00
Conversion to Forest Land	CH ₄	0.06	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.05	0.00	100.00
Conversion to Cropland	N ₂ O	0.03	0.00	100.00

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Waste incineration	CH4	0.03	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.02	0.00	100.00
Other Sectors: Solid fuels	N2O	0.01	0.00	100.00
Conversion to Forest Land	N2O	0.01	0.00	100.00
Other transportation	CH4	0.01	0.00	100.00
Other Sectors: Solid fuels	CH4	0.00	0.00	100.00
Other Chemicals	CH4	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	0.00	0.00	100.00
TOTAL		114,303.00	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 (Base Year)	Cumulative total
Energy Industries: Solid fuels	CO2	35,207.38	33.55	33.55
Road Transportation	CO2	11,742.20	11.19	44.75
Other Sectors: Liquid fuels	CO2	8,006.48	7.63	52.38
Energy Industries: Liquid fuels	CO2	7,683.34	7.32	59.70
Cement Production	CO2	5,761.69	5.49	65.19
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	5.37	70.56
Manufacturing Industries & Construction: Solid fuels	CO2	3,524.55	3.36	73.92
Wastewater handling	CH4	3,330.74	3.17	77.10
Direct N2O from agr. soils	N2O	2,849.81	2.72	79.81
Indirect N2O from nitrogen used in agr.	N2O	2,818.86	2.69	82.50
Solid waste disposal on land	CH4	2,225.69	2.12	84.62
Navigation	CO2	1,818.34	1.73	86.35
Enteric fermentation: Sheep	CH4	1,662.38	1.58	87.94
Animal Production	N2O	1,538.95	1.47	89.40
Nitric Acid Production	N2O	1,109.04	1.06	90.46
Coal Mining (surface)	CH4	1,095.27	1.04	91.50
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.89	92.40
Enteric fermentation: Other	CH4	661.10	0.63	93.03
Ammonia Production	CO2	652.04	0.62	93.65
Ferroalloys	CO2	622.23	0.59	94.24
Limestone & Dolomite Use	CO2	582.80	0.56	94.80
Manure management	N2O	540.72	0.52	95.31
Enteric fermentation: Non Dairy Cattle	CH4	464.42	0.44	95.75
Manure management	CH4	423.37	0.40	96.16
Lime Production	CO2	404.00	0.39	96.54
Other Sectors: Liquid fuels	N2O	349.81	0.33	96.88
Enteric fermentation: Dairy Cattle	CH4	341.79	0.33	97.20
Wastewater handling	N2O	331.24	0.32	97.52
Civil Aviation	CO2	319.05	0.30	97.82
Aluminium Production	CO2	225.39	0.21	98.04
Railways	CO2	202.69	0.19	98.23
Solvent and other product use	CO2	169.71	0.16	98.39
Aluminium Production	PFCs	163.37	0.16	98.55
Road Transportation	N2O	145.27	0.14	98.68
Solvent and other product use	N2O	138.63	0.13	98.82
Navigation	N2O	134.53	0.13	98.95
Energy Industries: Solid fuels	N2O	134.19	0.13	99.07
Other Sectors: Solid fuels	CO2	119.43	0.11	99.19
Energy Industries: Gaseous fuels	CO2	102.03	0.10	99.28
Road Transportation	CH4	100.74	0.10	99.38
Iron and Steel Production	CO2	92.70	0.09	99.47
Oil, Natural Gas and Other sources	CH4	91.59	0.09	99.56
Other Sectors: Biomass	CH4	76.59	0.07	99.63
Oil, Natural Gas and Other sources	CO2	70.23	0.07	99.70
Rice Production	CH4	69.10	0.07	99.76
Soda Ash Use	CO2	33.16	0.03	99.79
Other Sectors: Biomass	N2O	31.80	0.03	99.82
Field burning of agr. residues	CH4	27.06	0.03	99.85
Railways	N2O	24.22	0.02	99.87
Other Mineral (Glass)	CO2	20.20	0.02	99.89
Energy Industries: Liquid fuels	N2O	19.40	0.02	99.91
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	0.02	99.93

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Level Assessment (Base Year)	Cumulative total
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	0.02	99.94
Field burning of agr.residues	N2O	10.05	0.01	99.95
Manufacturing Industries & Construction: Biomass	N2O	9.91	0.01	99.96
Other Sectors: Liquid fuels	CH4	7.36	0.01	99.97
Energy Industries: Liquid fuels	CH4	6.57	0.01	99.97
Energy Industries: Solid fuels	CH4	6.06	0.01	99.98
Manufacturing Industries & Construction: Biomass	CH4	5.03	0.00	99.99
Civil Aviation	N2O	3.41	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	0.00	99.99
SF6 from electrical equipment	SF6	3.07	0.00	99.99
Navigation	CH4	2.64	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.82	0.00	100.00
Other Sectors: Solid fuels	N2O	0.71	0.00	100.00
Other Chemicals	CH4	0.52	0.00	100.00
Railways	CH4	0.24	0.00	100.00
Waste incineration	CO2	0.22	0.00	100.00
Iron and Steel Production	CH4	0.21	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.00	100.00
Civil Aviation	CH4	0.13	0.00	100.00
Waste incineration	N2O	0.13	0.00	100.00
Other Sectors: Solid fuels	CH4	0.05	0.00	100.00
Energy Industries: Gaseous fuels	N2O	0.05	0.00	100.00
Energy Industries: Gaseous fuels	CH4	0.04	0.00	100.00
Waste incineration	CH4	0.01	0.00	100.00
Energy Industries: Biomass	CH4	0.00	0.00	100.00
Energy Industries: Biomass	N2O	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH4	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.00	100.00
Other transportation	CO2	0.00	0.00	100.00
Other transportation	CH4	0.00	0.00	100.00
Other transportation	N2O	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CO2	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CH4	0.00	0.00	100.00
Other Sectors: Gaseous fuels	N2O	0.00	0.00	100.00
Other Chemicals	CO2	0.00	0.00	100.00
ODS substitutes	HFC	0.00	0.00	100.00
ODS substitutes	PFC	0.00	0.00	100.00
Waste Other	CH4	0.00	0.00	100.00
Waste Other	N2O	0.00	0.00	100.00
TOTAL		104,926.55	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	35,207.38	32.80	32.80
Road Transportation	CO2	11,742.20	10.94	43.75
Other Sectors: Liquid fuels	CO2	8,006.48	7.46	51.21
Energy Industries: Liquid fuels	CO2	7,683.34	7.16	58.36
Cement Production	CO2	5,761.69	5.37	63.73
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	5.25	68.99
Manufacturing Industries & Construction: Solid fuels	CO2	3,524.55	3.28	72.27
Wastewater handling	CH4	3,330.74	3.10	75.37
Direct N2O from agr. soils	N2O	2,849.81	2.66	78.03
Indirect N2O from nitrogen used in agr.	N2O	2,818.86	2.63	80.66
Solid waste disposal on land	CH4	2,225.69	2.07	82.73
Navigation	CO2	1,818.34	1.69	84.42
Enteric fermentation: Sheep	CH4	1,662.38	1.55	85.97
Animal Production	N2O	1,538.95	1.43	87.41
Forest Land remaining Forest Land	CO2	1,359.03	1.27	88.67
Nitric Acid Production	N2O	1,109.04	1.03	89.71
Coal Mining (surface)	CH4	1,095.27	1.02	90.73
Cropland remaining Cropland	CO2	981.70	0.91	91.64
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.87	92.51
Enteric fermentation: Other	CH4	661.10	0.62	93.13
Ammonia Production	CO2	652.04	0.61	93.74
Ferroalloys	CO2	622.23	0.58	94.32
Limestone & Dolomite Use	CO2	582.80	0.54	94.86
Manure management	N2O	540.72	0.50	95.36
Enteric fermentation: Non Dairy Cattle	CH4	464.42	0.43	95.80
Manure management	CH4	423.37	0.39	96.19
Lime Production	CO2	404.00	0.38	96.57
Other Sectors: Liquid fuels	N2O	349.81	0.33	96.89
Enteric fermentation: Dairy Cattle	CH4	341.79	0.32	97.21
Wastewater handling	N2O	331.24	0.31	97.52
Civil Aviation	CO2	319.05	0.30	97.82
Aluminium Production	CO2	225.39	0.21	98.03
Railways	CO2	202.69	0.19	98.22
Solvent and other product use	CO2	169.71	0.16	98.37
Aluminium Production	PFCs	163.37	0.15	98.53
Road Transportation	N2O	145.27	0.14	98.66
Solvent and other product use	N2O	138.63	0.13	98.79
Navigation	N2O	134.53	0.13	98.92
Energy Industries: Solid fuels	N2O	134.19	0.13	99.04
Other Sectors: Solid fuels	CO2	119.43	0.11	99.15
Energy Industries: Gaseous fuels	CO2	102.03	0.10	99.25
Road Transportation	CH4	100.74	0.09	99.34
Iron and Steel Production	CO2	92.70	0.09	99.43
Oil, Natural Gas and Other sources	CH4	91.59	0.09	99.51
Other Sectors: Biomass	CH4	76.59	0.07	99.58
Oil, Natural Gas and Other sources	CO2	70.23	0.07	99.65
Rice Production	CH4	69.10	0.06	99.71
Soda Ash Use	CO2	33.16	0.03	99.74
Other Sectors: Biomass	N2O	31.80	0.03	99.77
Field burning of agr. residues	CH4	27.06	0.03	99.80

IPCC source categories	GHG	Base year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Railways	N ₂ O	24.22	0.02	99.82
Conversion to Other land	CO ₂	20.60	0.02	99.84
Other Mineral (Glass)	CO ₂	20.20	0.02	99.86
Energy Industries: Liquid fuels	N ₂ O	19.40	0.02	99.88
Manufacturing Industries & Construction: Solid fuels	N ₂ O	17.74	0.02	99.89
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	15.98	0.01	99.91
Grassland remaining Grassland	CH ₄	14.03	0.01	99.92
Forest Land remaining Forest Land	CH ₄	13.12	0.01	99.93
Field burning of agr.residues	N ₂ O	10.05	0.01	99.94
Manufacturing Industries & Construction: Biomass	N ₂ O	9.91	0.01	99.95
Other Sectors: Liquid fuels	CH ₄	7.36	0.01	99.96
Energy Industries: Liquid fuels	CH ₄	6.57	0.01	99.97
Conversion to Settlements	CO ₂	6.38	0.01	99.97
Energy Industries: Solid fuels	CH ₄	6.06	0.01	99.98
Manufacturing Industries & Construction: Biomass	CH ₄	5.03	0.00	99.98
Civil Aviation	N ₂ O	3.41	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH ₄	3.10	0.00	99.99
SF ₆ from electrical equipment	SF ₆	3.07	0.00	99.99
Navigation	CH ₄	2.64	0.00	99.99
Grassland remaining Grassland	N ₂ O	1.42	0.00	100.00
Forest Land remaining Forest Land	N ₂ O	1.33	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.82	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.71	0.00	100.00
Other Chemicals	CH ₄	0.52	0.00	100.00
Railways	CH ₄	0.24	0.00	100.00
Waste incineration	CO ₂	0.22	0.00	100.00
Iron and Steel Production	CH ₄	0.21	0.00	100.00
Grassland remaining Grassland	CO ₂	0.20	0.00	100.00
Oil, Natural Gas and Other sources	N ₂ O	0.20	0.00	100.00
Civil Aviation	CH ₄	0.13	0.00	100.00
Waste incineration	N ₂ O	0.13	0.00	100.00
Conversion to Cropland	CO ₂	0.07	0.00	100.00
Other Sectors: Solid fuels	CH ₄	0.05	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
Conversion to Grassland	CO ₂	0.03	0.00	100.00
Waste incineration	CH ₄	0.01	0.00	100.00
Conversion 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
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 Chemicals	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
ODS substitutes	HFC	0.00	0.00	100.00
ODS substitutes	PFC	0.00	0.00	100.00
Waste Other	CH ₄	0.00	0.00	100.00
Waste Other	N ₂ O	0.00	0.00	100.00
Conversion to Forest Land	CO ₂	0.00	0.00	100.00
Conversion to Forest Land	CH ₄	0.00	0.00	100.00
Conversion to Forest Land	N ₂ O	0.00	0.00	100.00
Conversion to Wetland	CO ₂	0.00	0.00	100.00
TOTAL		107,324.48	100.00	

Table I.5 Key categories analysis without LULUCF – Trend assessment for 2012

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment	Contribution to trend	Cumulative total
Energy Industries: Gaseous fuels	CO2	102.03	5,149.40	0.04	0.13	0.13
Energy Industries: Solid fuels	CO2	35,207.38	41,990.40	0.04	0.12	0.26
ODS substitutes	HFC	0.00	3,889.05	0.03	0.10	0.36
Manufacturing Industries & Construction: Solid fuels	CO2	3,524.55	244.44	0.03	0.09	0.45
Cement Production	CO2	5,761.69	3,099.30	0.03	0.08	0.53
Wastewater handling	CH4	3,330.74	1,109.29	0.02	0.06	0.60
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	3,717.67	0.02	0.06	0.66
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,519.55	0.01	0.04	0.70
Direct N2O from agr. soils	N2O	2,849.81	1,534.48	0.01	0.04	0.74
Indirect N2O from nitrogen used in agr.	N2O	2,818.86	1,783.70	0.01	0.03	0.77
Road Transportation	CO2	11,742.20	13,594.88	0.01	0.03	0.80
Other Sectors: Gaseous fuels	CO2	0.00	1,038.34	0.01	0.03	0.83
Nitric Acid Production	N2O	1,109.04	307.01	0.01	0.02	0.85
Solid waste disposal on land	CH4	2,225.69	3,204.21	0.01	0.02	0.87
Energy Industries: Liquid fuels	CO2	7,683.34	7,367.46	0.01	0.02	0.89
Ammonia Production	CO2	652.04	178.73	0.00	0.01	0.91
Other Sectors: Liquid fuels	CO2	8,006.48	8,120.69	0.00	0.01	0.92
Other Chemicals	CO2	0.00	323.29	0.00	0.01	0.92
Other Sectors: Liquid fuels	N2O	349.81	103.03	0.00	0.01	0.93
Navigation	CO2	1,818.34	1,663.95	0.00	0.01	0.94
Lime Production	CO2	404.00	208.54	0.00	0.01	0.94
Limestone & Dolomite Use	CO2	582.80	400.48	0.00	0.01	0.95
Coal Mining (surface)	CH4	1,095.27	1,328.69	0.00	0.00	0.96
Animal Production	N2O	1,538.95	1,479.83	0.00	0.00	0.96
Civil Aviation	CO2	319.05	489.75	0.00	0.00	0.96
Railways	CO2	202.69	78.75	0.00	0.00	0.97
Other Sectors: Solid fuels	CO2	119.43	1.59	0.00	0.00	0.97
Aluminium Production	PFCs	163.37	50.16	0.00	0.00	0.97
Oil, Natural Gas and Other sources	CH4	91.59	198.84	0.00	0.00	0.98
Enteric fermentation: Sheep	CH4	1,662.38	1,682.16	0.00	0.00	0.98
Enteric fermentation:Dairy Cattle	CH4	341.79	292.74	0.00	0.00	0.98
Oil, Natural Gas and Other sources	CO2	70.23	8.75	0.00	0.00	0.98
Navigation	N2O	134.53	80.47	0.00	0.00	0.98
Enteric fermentation:Non Dairy Cattle	CH4	464.42	553.40	0.00	0.00	0.99
ODS substitutes	PFC	0.00	60.24	0.00	0.00	0.99
Road Transportation	N2O	145.27	103.64	0.00	0.00	0.99
Manure management	CH4	423.37	399.06	0.00	0.00	0.99
Road Transportation	CH4	100.74	57.30	0.00	0.00	0.99
Rice Production	CH4	69.10	117.60	0.00	0.00	0.99
Ferroalloys	CO2	622.23	698.45	0.00	0.00	0.99
Aluminium Production	CO2	225.39	270.56	0.00	0.00	0.99
Wastewater handling	N2O	331.24	382.51	0.00	0.00	0.99
Manure management	N2O	540.72	593.95	0.00	0.00	1.00
Soda Ash Use	CO2	33.16	17.02	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	1.17	0.00	0.00	1.00
Solvent and other product use	CO2	169.71	162.72	0.00	0.00	1.00
Railways	N2O	24.22	9.61	0.00	0.00	1.00
Iron and Steel Production	CO2	92.70	82.99	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	14.74	0.00	0.00	1.00
Energy Industries: Solid fuels	N2O	134.19	153.64	0.00	0.00	1.00
Other transportation	CO2	0.00	11.15	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
Solvent and other product use	N2O	138.63	155.75	0.00	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	6.79	0.00	0.00	1.00
Other Mineral (Glass)	CO2	20.20	15.59	0.00	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	12.02	0.00	0.00	1.00
Field burning of agr.residues	CH4	27.06	32.08	0.00	0.00	1.00
Waste incineration	CO2	0.22	3.23	0.00	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	2.90	0.00	0.00	1.00
Other Sectors: Biomass	CH4	76.59	78.53	0.00	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	0.95	0.00	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.97	0.00	0.00	1.00
SF6 from electrical equipment	SF6	3.07	5.11	0.00	0.00	1.00
Civil Aviation	N2O	3.41	5.26	0.00	0.00	1.00
Field burning of agr.residues	N2O	10.05	12.23	0.00	0.00	1.00
Energy Industries: Liquid fuels	N2O	19.40	19.30	0.00	0.00	1.00
Waste Other	N2O	0.00	18.51	0.00	0.00	1.00
Other Sectors: Biomass	N2O	31.80	32.62	0.00	0.00	1.00
Waste Other	CH4	0.00	16.72	0.00	0.00	1.00
Other Sectors: Liquid fuels	CH4	7.36	6.92	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.82	0.05	0.00	0.00	1.00
Other Sectors: Solid fuels	N2O	0.71	0.01	0.00	0.00	1.00
Waste incineration	N2O	0.13	0.74	0.00	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.58	0.00	0.00	1.00
Manufacturing Industries & Construction:Gaseous fuels	CH4	0.00	0.58	0.00	0.00	1.00
Energy Industries: Solid fuels	CH4	6.06	6.94	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.91	10.01	0.00	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.57	6.54	0.00	0.00	1.00
Other Sectors:Gaseous fuels	CH4	0.00	0.39	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.03	5.09	0.00	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.25	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.22	0.00	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.20	0.02	0.00	0.00	1.00
Railways	CH4	0.24	0.09	0.00	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.14	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.11	0.00	0.00	1.00
Navigation	CH4	2.64	2.69	0.00	0.00	1.00
Other transportation	N2O	0.00	0.09	0.00	0.00	1.00
Civil Aviation	CH4	0.13	0.20	0.00	0.00	1.00
Other Sectors: Solid fuels	CH4	0.05	0.00	0.00	0.00	1.00
Iron and Steel Production	CH4	0.21	0.26	0.00	0.00	1.00
Waste incineration	CH4	0.01	0.03	0.00	0.00	1.00
Other transportation	CH4	0.00	0.01	0.00	0.00	1.00
Enteric fermentation: Other	CH4	661.10	594.63	0.00	0.00	1.00
Other Chemicals	CH4	0.52	0.00	0.00	0.00	1.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	0.00	0.00	1.00
TOTAL		104,926.55	110,985.47	0.32	1.00	

Table I.6 *Key categories analysis with LULUCF – Trend assessment for 2012*

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
Energy Industries: Gaseous fuels	CO2	102.03	5,149.40	0.04434	0.13	0.13
Energy Industries: Solid fuels	CO2	35,207.38	41,990.40	0.04336	0.12	0.25
ODS substitutes	HFC	0.00	3,889.05	0.03420	0.10	0.34
Manufacturing Industries & Construction: Solid fuels	CO2	3,524.55	244.44	0.03047	0.09	0.43
Cement Production	CO2	5,761.69	3,099.30	0.02608	0.07	0.50
Wastewater handling	CH4	3,330.74	1,109.29	0.02107	0.06	0.56
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	3,717.67	0.01949	0.06	0.62
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,519.55	0.01336	0.04	0.66
Direct N2O from agr. soils	N2O	2,849.81	1,534.48	0.01288	0.04	0.69
Road Transportation	CO2	11,742.20	13,594.88	0.01086	0.03	0.72
Indirect N2O from nitrogen used in agr.	N2O	2,818.86	1,783.70	0.01041	0.03	0.75
Other Sectors: Gaseous fuels	CO2	0.00	1,038.34	0.00913	0.03	0.78
Conversion to Grassland	CO2	0.03	-916.96	0.00806	0.02	0.80
Solid waste disposal on land	CH4	2,225.69	3,204.21	0.00758	0.02	0.82
Nitric Acid Production	N2O	1,109.04	307.01	0.00757	0.02	0.84
Cropland remaining Cropland	CO2	-981.70	-227.67	0.00708	0.02	0.86
Energy Industries: Liquid fuels	CO2	7,683.34	7,367.46	0.00633	0.02	0.88
Ammonia Production	CO2	652.04	178.73	0.00446	0.01	0.89
Forest Land remaining Forest Land	CO2	-1,359.03	-1,841.07	0.00361	0.01	0.90
Other Chemicals	CO2	0.00	323.29	0.00284	0.01	0.91
Other Sectors: Liquid fuels	CO2	8,006.48	8,120.69	0.00270	0.01	0.92
Other Sectors: Liquid fuels	N2O	349.81	103.03	0.00233	0.01	0.93
Navigation	CO2	1,818.34	1,663.95	0.00220	0.01	0.93
Lime Production	CO2	404.00	208.54	0.00191	0.01	0.94
Limestone & Dolomite Use	CO2	582.80	400.48	0.00187	0.01	0.94
Coal Mining (surface)	CH4	1,095.27	1,328.69	0.00155	0.00	0.95
Civil Aviation	CO2	319.05	489.75	0.00135	0.00	0.95
Conversion to Forest Land	CO2	0.00	-145.24	0.00128	0.00	0.96
Animal Production	N2O	1,538.95	1,479.83	0.00123	0.00	0.96
Railways	CO2	202.69	78.75	0.00118	0.00	0.96
Other Sectors: Solid fuels	CO2	119.43	1.59	0.00109	0.00	0.97
Aluminium Production	PFCs	163.37	50.16	0.00107	0.00	0.97
Conversion to Other land	CO2	20.60	130.25	0.00095	0.00	0.97
Oil, Natural Gas and Other sources	CH4	91.59	198.84	0.00090	0.00	0.97
Enteric fermentation: Other	CH4	661.10	594.63	0.00089	0.00	0.98
Enteric fermentation: Sheep	CH4	1,662.38	1,682.16	0.00059	0.00	0.98
Enteric fermentation:Dairy Cattle	CH4	341.79	292.74	0.00059	0.00	0.98
Oil, Natural Gas and Other sources	CO2	70.23	8.75	0.00057	0.00	0.98
Enteric fermentation:Non Dairy Cattle	CH4	464.42	553.40	0.00057	0.00	0.98
Navigation	N2O	134.53	80.47	0.00054	0.00	0.98
ODS substitutes	PFC	0.00	60.24	0.00053	0.00	0.99
Road Transportation	N2O	145.27	103.64	0.00043	0.00	0.99
Road Transportation	CH4	100.74	57.30	0.00043	0.00	0.99
Manure management	CH4	423.37	399.06	0.00041	0.00	0.99
Rice Production	CH4	69.10	117.60	0.00039	0.00	0.99
Ferroalloys	CO2	622.23	698.45	0.00038	0.00	0.99
Wastewater handling	N2O	331.24	382.51	0.00030	0.00	0.99
Aluminium Production	CO2	225.39	270.56	0.00029	0.00	0.99
Manure management	N2O	540.72	593.95	0.00022	0.00	0.99
Waste Other	N2O	0.00	18.51	0.00016	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
Soda Ash Use	CO2	33.16	17.02	0.00016	0.00	0.99
Conversion to Settlements	CO2	6.38	24.53	0.00016	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	1.17	0.00015	0.00	1.00
Waste Other	CH4	0.00	16.72	0.00015	0.00	1.00
Solvent and other product use	CO2	169.71	162.72	0.00014	0.00	1.00
Railways	N2O	24.22	9.61	0.00014	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	14.74	0.00013	0.00	1.00
Iron and Steel Production	CO2	92.70	82.99	0.00013	0.00	1.00
Energy Industries: Solid fuels	N2O	134.19	153.64	0.00011	0.00	1.00
Other transportation	CO2	0.00	11.15	0.00010	0.00	1.00
Solvent and other product use	N2O	138.63	155.75	0.00009	0.00	1.00
Forest Land remaining Forest Land	CH4	13.12	6.05	0.00007	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	6.79	0.00006	0.00	1.00
Other Mineral (Glass)	CO2	20.20	15.59	0.00005	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	12.02	0.00004	0.00	1.00
Grassland remaining Grassland	CH4	14.03	19.48	0.00004	0.00	1.00
Field burning of agr.residues	CH4	27.06	32.08	0.00003	0.00	1.00
Waste incineration	CO2	0.22	3.23	0.00003	0.00	1.00
Conversion to Wetland	CO2	0.00	2.87	0.00003	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	2.90	0.00003	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	0.95	0.00002	0.00	1.00
Other Sectors: Biomass	CH4	76.59	78.53	0.00002	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.97	0.00002	0.00	1.00
SF6 from electrical equipment	SF6	3.07	5.11	0.00002	0.00	1.00
Civil Aviation	N2O	3.41	5.26	0.00001	0.00	1.00
Field burning of agr.residues	N2O	10.05	12.23	0.00001	0.00	1.00
Energy Industries: Liquid fuels	N2O	19.40	19.30	0.00001	0.00	1.00
Other Sectors: Biomass	N2O	31.80	32.62	0.00001	0.00	1.00
Other Sectors: Liquid fuels	CH4	7.36	6.92	0.00001	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.82	0.05	0.00001	0.00	1.00
Forest Land remaining Forest Land	N2O	1.33	0.61	0.00001	0.00	1.00
Other Sectors: Solid fuels	N2O	0.71	0.01	0.00001	0.00	1.00
Waste incineration	N2O	0.13	0.74	0.00001	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.58	0.00001	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	CH4	0.00	0.58	0.00001	0.00	1.00
Energy Industries: Solid fuels	CH4	6.06	6.94	0.00000	0.00	1.00
Grassland remaining Grassland	N2O	1.42	1.98	0.00000	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.91	10.01	0.00000	0.00	1.00
Other Sectors: Gaseous fuels	CH4	0.00	0.39	0.00000	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.57	6.54	0.00000	0.00	1.00
Conversion to Cropland	CO2	0.07	0.33	0.00000	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.25	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.22	0.00000	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.03	5.09	0.00000	0.00	1.00
Grassland remaining Grassland	CO2	0.20	0.40	0.00000	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.20	0.02	0.00000	0.00	1.00
Railways	CH4	0.24	0.09	0.00000	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.14	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.11	0.00000	0.00	1.00
Other transportation	N2O	0.00	0.09	0.00000	0.00	1.00
Navigation	CH4	2.64	2.69	0.00000	0.00	1.00
Civil Aviation	CH4	0.13	0.20	0.00000	0.00	1.00
Conversion to Forest Land	CH4	0.00	0.06	0.00000	0.00	1.00
Iron and Steel Production	CH4	0.21	0.26	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
Conversion to Cropland	N ₂ O	0.00	0.03	0.00000	0.00	1.00
Waste incineration	CH ₄	0.01	0.03	0.00000	0.00	1.00
Conversion to Forest Land	N ₂ O	0.00	0.01	0.00000	0.00	1.00
Other transportation	CH ₄	0.00	0.01	0.00000	0.00	1.00
Other Sectors: Solid fuels	CH ₄	0.05	0.00	0.00000	0.00	1.00
Other Chemicals	CH ₄	0.52	0.00	0.00000	0.00	1.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	0.00000	0.00	1.00
TOTAL		102,643.01	108,041.14	0.35	1.00	

The results of the key categories analysis for the year 2012 are summed up in **Table I.7**.

Table I.7 *Source Category Analysis Summary for 2012*

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		
Civil Aviation	CO2	YES	Level	T2
Civil Aviation	CH4	NO		
Civil Aviation	N2O	NO		
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	YES	Trend	T2
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, Trend	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	YES	Trend	CS
Limestone & Dolomite Use	CO2	YES	Trend	CS, T1
Soda Ash Use	CO2	NO		
Other Mineral (Glass)	CO2	NO		
Other Chemicals	CO2	YES	Trend	T1
Other Chemicals	CH4	NO		
Nitric Acid Production	N2O	YES	Trend	D
Ammonia Production	CO2	YES	Trend	T1a
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		
HFC-23 Emissions from HCFC-22 Manufacture	HFC	NO		
ODS substitutes	HFC	YES	Level, Trend	CS, T2
ODS substitutes	PFC	NO		
SF6 from electrical equipment	SF6	NO		
AGRICULTURE				
Enteric fermentation: Dairy Cattle	CH4	NO		
Enteric fermentation: Non Dairy Cattle	CH4	YES	Level	T2
Enteric fermentation: Sheep	CH4	YES	Level	T2
Enteric fermentation: Other	CH4	YES	Level	T1
Manure management	CH4	NO		
Manure management	N2O	YES	Level	T2
Field burning of agr. residues	CH4	NO		
Field burning of agr. residues	N2O	NO		
Direct N2O from agr. soils	N2O	YES	Level, Trend	T1, T1a, T1b
Animal Production	N2O	YES	Level	D
Indirect N2O from nitrogen used in agr.	N2O	YES	Level, Trend	T1a
Rice Production	CH4	NO		
WASTE				
Solid waste disposal on land	CH4	YES	Level, Trend	T2
Wastewater handling	CH4	YES	Level, Trend	CS, D
Wastewater handling	N2O	NO		
Waste incineration	CO2	NO		
Waste incineration	CH4	NO		
Waste incineration	N2O	NO		
Waste Other	CH4	NO		
Waste Other	N2O	NO		
LULUCF				
Forest Land remaining Forest Land	CO2	YES	Level, Trend	T2

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
Forest Land remaining Forest Land	CH4	NO		
Forest Land remaining Forest Land	N2O	NO		
Cropland remaining Cropland	CO2	YES	Trend	T1, T2
Grassland remaining Grassland	CO2	NO		
Grassland remaining Grassland	CH4	NO		
Grassland remaining Grassland	N2O	NO		
Conversion to Forest Land	CO2	NO		
Conversion to Forest Land	CH4	NO		
Conversion to Forest Land	N2O	NO		
Conversion to Cropland	CO2	NO		
Conversion to Cropland	N2O	NO		
Conversion to Grassland	CO2	YES	Level, Trend	T1, T2
Conversion to Wetland	CO2	NO		
Conversion to Settlements	CO2	NO		
Conversion to Other land	CO2	NO		

Finally in **Table I.8** the Table NIR.3 as contained in the annex to decision 6/CMP.3 can be found

Table I.8 *Table NIR.3 for year 2012*

Key Categories of Emissions and Removals	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION		COMMENTS
		Associated LULUCF category	Category contribution > than the smallest UNFCCC key category	
Forest Management	CO2	Forest land remaining forest land	Yes	Level assessment & Trend assessment

Annex II: Detailed discussion of methodology and data for estimating CO₂ and other GHG emissions from fossil fuel combustion

General discussion

The calculation of GHG emissions from the energy sector is performed by the application of a Tier 2 methodology based on IPCC guidelines, according to which the allocation of energy consumption by sector, fuel and technology is required. Emissions are then estimated multiplying the consumption per fuel and technology 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. We also capitalize on them to estimate CH₄ and N₂O emission factors per sector and fuel, by using the IPCC default emission factors per technology and fuel type (tier 2 methodology with IPCC default emission factors). Thus, the emission factors for methane and nitrous oxide are differentiated per technology, while the emission factors for carbon dioxide are differentiated mainly per 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).

Table II.1 presents the correspondence between the sectors of the energy balance (as it is compiled by the MEECC based on the joint questionnaires of IEA and EUROSTAT), the CORINAIR activities and the IPCC source categories. In **Tables II.2 – II.6** information from the national energy balance on lignite, natural gas, heavy fuel oil, diesel, and gasoline is presented.

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, naptha, 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 - 2012. 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 number of plants where EU ETS data is used for each CRF subsector are presented in **Table II.7**. The ranges of NCVs, oxidation factors and carbon contents derived from the EU ETS reporting for the different subsectors are presented in **Table II.8**. The methodological tier levels for the plants where data is used from EU ETS reporting are presented in **Table II.9**.

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 MEECC 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

A typical composition of the refinery gas of greek plants is presented in **Table II.10**.

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.

The NCV and EF of alternative fuels used in cement plants in 2010 are presented in **Table II.11**.

Finally, in **Table II.12** the EFs of non-CO₂ GHG, which were used in the inventory, are presented.

Table II.1 *Correspondence between IPCC source categories, energy balance sectors and CORINAIR activities*

Energy balance sectors	IPCC source categories	CORINAIR activities
Production	Reference approach	
Imports	Reference approach	
Exports	Reference approach	
International marine bunkers	Reference approach /Bunkers	080404 – International marine bunkers
Stock changes	Reference approach	
TRANSFORMATION		
Electricity plants	1.A.1a	0101 – Public power / steam turbines, gas turbines, stationary engines
CHP plants	1.A.2a – 1.A.2f	
Heat plants	1.A.1a	
ENERGY SECTOR		
Petroleum refineries	1.A.1b	0103 – Petroleum refining plants
Oil and gas extraction	1.A.1c	010504 – Coal mining. oil/gas extraction, pipeline compressors / gas turbines
		010503 – Coal mining. oil/gas extraction, pipeline compressors / boilers
INDUSTRY		
Iron and steel	1.A.2a	030302 – Reheating furnaces 030303 – Grey iron foundries
Chemical industry	1.A.2c	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
<i>of which: Feedstocks</i>	Non-energy uses	
Non-ferrous metals	1.A.2b	0301 – Industry / Combustion in boilers, gas turbines and stationary engines 030322 – Alumina production 030311 – Cement 030312 – Lime
Non-metallic minerals	1.A.2f	030315 – Glass (container glass) 030319 – Bricks and tiles 0301 – Industry / Combustion in boilers, gas turbines and stationary engines
Transport equipment	1.A.2f	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
Machinery	1.A.2f	
Mining	1.A.2f	
Food and tobacco	1.A.2e	
Paper. pulp	1.A.2d	
Wood and wood products	1.A.2f	
Construction	1.A.2f	
Textile and leather	1.A.2f	
Non-specified	1.A.2f	
TRANSPORT		
International civil aviation	Reference approach/Bunkers	080502 and 080504 – International airport/cruise traffic
Domestic air	1.A.3a	080501 and 080503 – Domestic airport/cruise traffic
Road	1.A.3b	07 (except 0707 and 0708) – Road transport per type of vehicle
Rail	1.A.3c	0802 – Diesel and gasoline machinery in railways

Energy balance sectors	IPCC source categories	CORINAIR activities
Internal navigation	1.A.3d	080402 – National sea traffic within EMEP area
OTHER SECTORS		
Agriculture	1.A.4c	0203 – Combustion plants in agriculture 0806 – Diesel and gasoline machinery in agriculture
Comm. and public. services	1.A.4a	0201 – Commercial and institutional plants
Residential	1.A.4b	0202 – Residential plants
Non-specified	1.A.4c	0203 – Plants in agriculture 0806 – Diesel and gasoline machinery in agriculture
NON-ENERGY USE	Non-energy use	

Table II.2 *Energy balance of lignite (in kt) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Primary production	51,896	52,695	55,051	54,817	56,672	57,662	59,781	58,844	60,884	62,051	63,887	66,344	70,468	68,299	70,041	69,398	64,787	66,308	65,720	64,893	56,520	58,666	62,956
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	13	30	34	111	137
Exports	0	0	14	0	0	0	0	22	6	21	21	0	0	0	0	0	0	0	0	0	0	0	0
Stock changes	157	-1,144	-544	366	1,301	-700	-1,629	-197	-254	-1,083	698	911	-1,750	1,770	814	698	-189	59	-1,101	290	1150	1,211	-1,165
DOMESTIC SUPPLY	52,053	51,551	54,493	55,183	57,973	56,962	58,152	58,625	60,624	60,947	64,564	67,255	68,718	70,069	70,855	70,096	64,598	66,373	64,632	65,213	57,704	59,978	61,910
Transfers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Statistical differences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
TRANSFORMATION	50,881	50,616	53,993	54,501	57,463	56,431	57,511	58,098	60,160	60,637	64,100	67,005	68,562	69,874	70,655	69,840	64,222	66,056	64,296	65,165	57,656	59,868	61,907
Electricity plants	50,531	50,265	53,790	54,323	57,249	56,240	57,354	53,129	55,207	55,429	59,811	62,541	64,019	59,270	60,602	55,953	48,862	52,715	48,170	51,439	41,619	42,770	43,337
CHP plants ²⁴	0	0	0	0	0	0	0	4,800	4,820	5,084	4,053	4,199	4,198	10,185	9,631	13,476	15,094	13,153	16,087	13,726	16,037	17,098	18,570
BKB plants	350	351	203	178	214	191	157	169	133	124	236	265	345	419	422	411	266	188	39	0	0	0	0
FINAL CONSUMPTION	1,172	935	500	682	510	531	641	527	464	310	464	250	156	195	199	256	376	317	336	48	48	110	3
INDUSTRY	515	432	379	552	406	408	503	418	362	235	381	172	156	195	195	224	345	313	304	29	22	66	0
Iron and steel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical industry	199	94	7	85	58	62	60	57	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-ferrous metals ²⁵	299	318	359	445	333	342	439	359	355	233	379	170	156	195	195	224	345	313	304	29	22	66	0
Non-metallic minerals	17	20	13	22	15	4	4	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0
TRANSPORT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER SECTORS	78	125	121	130	104	123	138	109	102	75	83	78	0	0	4	32	31	4	32	19	26	44	3
Agriculture	19	25	33	40	30	40	45	30	30	48	53	50	0	0	0	20	30	0	0	0	0	0	0
Commercial and public	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	59	100	88	90	74	83	93	79	72	27	30	28	0	0	1	12	1	4	32	19	26	35	3
Non-specified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
NON-ENERGY USE	579	378	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

²⁴ Fuel consumption in CHP plants is included in electricity plants.²⁵ Accounted in Industrial Processes sector.

Table II.3 *Energy balance of natural gas in TJ (GCV) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Primary production	6,426	6,348	5,866	4,326	2,213	2,041	2,154	2,088	1,874	117	1,968	1,870	1,973	1,442	1,337	851	1,209	1,026	681	545	354	299	321
Imports	0	0	0	0	0	0	357	6,017	32,111	56,575	78,551	77,680	81,622	93,138	101,125	108,495	126,604	155,138	163,122	137,833	150,292	184,847	170,908
Stock changes	0	0	0	0	0	0	-218	-150	-238	-32	-1,224	-1,255	192	-319	1,220	141	-11	336	-697	-169	-177	-357	-868
DOMESTIC SUPPLY	6,426	6,348	5,866	4,326	2,213	2,041	2,293	7,955	33,747	56,660	79,295	78,295	83,787	94,261	103,682	109,487	127,802	156,500	163,106	138,209	150,469	184,789	170,361
Transfers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Statistical differences	0	0	0	0	0	0	0	0	0	-65	19	0	0	18	-220	-112	81	1,432	-1,226	1540	117	3619	3661
TRANSFORMATION	840	826	725	707	691	649	765	3,266	16,398	40,311	59,553	58,848	62,699	69,017	74,390	74,679	87,877	114,104	116,078	84,511	95,857	111,198	103,109
1Electricity plants	0	0	0	0	0	0	0	2,125	15,852	39,705	58,138	57,628	61,175	68,015	73,782	73,858	87,060	113,520	112,666	76,900	88,265	103,352	95,802
CHP plants ²⁶	840	826	725	707	691	649	765	1,141	546	606	1,415	1,220	1,524	1,002	608	821	817	584	3,412	7,611	7,592	7846	7307
ENERGY SECTOR	1,090	1,226	1,056	986	1,260	1,216	1,200	1,183	1,328	59	1,552	1,420	1,516	1,407	1,662	1,360	1,413	1,354	1,485	1,240	862	919	904
Oil and gas extraction	1,090	1,226	1,056	986	1,260	1,216	1,200	1,183	1,328	59	1,552	1,420	1,516	1,407	1,662	1,261	1,413	1,354	1,485	1,240	862	919	904
Distribution losses	0	0	0	0	0	0	0	94	40	36	568	466	27	64	235	331	393	305	224	1,090	812	742	894
FINAL CONSUMPTION	4,496	4,296	4,085	2,633	262	176	328	3,412	15,981	16,319	17,603	17,561	19,545	23,755	27,615	33,229	38,038	39,305	46,545	49,828	52,806	68,311	62,133
INDUSTRY SECTOR	0	0	0	0	0	0	161	1,544	5,996	8,842	11,341	13,672	14,376	15,281	17,336	19,801	20,690	19,012	21,100	18,988	17,377	25,825	23,650
Iron and steel	0	0	0	0	0	0	0	115	1,326	2,302	2,572	2,956	3,069	2,751	3,057	3,252	3,166	3,639	3,475	2,932	2,850	2,863	2,479
Chemical industry	0	0	0	0	0	0	0	0	147	372	347	405	778	1,001	1,332	2,462	2,006	1,838	1,970	2,117	2,082	2,099	1,980
Non-ferrous metals	0	0	0	0	0	0	0	0	260	1,215	1,830	1,651	1,858	2,407	2,510	2,946	2,372	2,649	2,772	2,607	2,973	3,001	10,077
Non-metallic minerals	0	0	0	0	0	0	0	99	1,217	1,319	1,820	2,997	3,145	2,773	3,078	3,198	4,316	3,887	3,867	3,559	2,800	2,408	1,603
Transport equipment	0	0	0	0	0	0	0	9	74	62	46	81	55	66	68	0	0	0	0	0	0	0	0
Machinery	0	0	0	0	0	0	0	0	0	0	0	81	91	0	27	75	87	139	140	140	143	141	132
Mining and Quarrying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213	0	0	0	0	0
Food and tobacco	0	0	0	0	0	0	161	1,174	1,811	2,475	2,925	2,441	2,520	3,191	3,818	5,074	5,840	3,425	3,872	4,687	3,805	3,230	3,559
Paper, pulp	0	0	0	0	0	0	0	67	423	297	561	891	1,151	1,289	1,445	1,245	1,557	1,393	1,572	1,581	1,449	1,505	1,156
Wood and wood products	0	0	0	0	0	0	0	0	0	0	0	0	0	1	26	35	28	41	38	32	42	149	173
Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textile and leather	0	0	0	0	0	0	0	80	733	800	999	1,377	1,253	1,399	1,382	896	817	1,027	2,754	783	699	612	536

²⁶ Fuel consumption in CHP plants is added to the respective industrial sectors

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Non-specified	0	0	0	0	0	0	0	0	5	0	241	792	456	403	593	618	501	761	640	550	534	9,817	1,955
TRANSPORT	0	0	0	0	0	0	0	0	0	0	0	325	557	567	537	629	670	815	977	685	658	695	685
Road transport	0	0	0	0	0	0	0	0	0	0	0	284	449	495	493	552	582	667	660	685	658	695	685
Pipeline transport	0	0	0	0	0	0	0	0	0	0	0	41	108	72	44	77	88	148	317	16	0	0	0
OTHER SECTOR	0	0	0	0	0	0	0	0	618	526	626	810	1,243	2,157	3,636	6,840	10,648	13,099	15,645	18,643	18,309	23,856	20,855
Commercial and public	0	0	0	0	0	0	0	0	618	345	400	567	845	1,287	2,024	3,434	4,168	4,883	5,992	6,737	6,464	7,666	6,419
Residential	0	0	0	0	0	0	0	0	0	181	226	243	398	870	1,612	3,406	6,480	8,216	9,653	11,906	11,845	16,189	14,436
NON-ENERGY USE	4,496	4,296	4,085	2,633	262	176	167	1,868	9,367	6,951	5,636	2,754	3,369	5,750	6,106	5,959	6,030	6,379	8,823	11,512	16,462	17,935	16,943

Table II.4 *Energy balance of heavy fuel oil (in kt) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production	5,596	5,374	5,284	4,419	5,308	6,061	7,424	7,149	6,959	6,326	7,510	7,361	7,188	7,456	7,095	6,956	6,953	7,116	6,008	5,959	5,878	5,053	5,111
Imports	2,233	1,806	2,040	1,955	1,342	733	151	435	411	298	174	169	36	184	171	264	389	677	2,304	1,845	1,558	1,852	1,603
Exports	2,026	1,217	1,710	654	832	616	1,032	696	196	280	220	255	564	649	748	604	835	979	1,301	1,583	2,172	2,165	2,731
International marine bunkers	2,063	1,846	2,052	2,444	2,557	2,641	2,399	2,413	2,798	2,452	2,898	2,933	2,624	2,757	2,809	2,542	2,761	2,860	2,815	2,359	2,444	2,535	2,064
Stock changes	-80	-223	121	196	204	81	-72	7	-41	45	-32	25	-66	-36	159	-47	16	-261	219	-191	48	-42	-77
DOMESTIC SUPPLY	2,906	3,025	2,993	2,831	2,756	2,943	2,985	2,993	3,007	2,997	2,807	2,757	2,701	2,642	2,625	2,641	2,841	2,762	2,792	2,439	1,805	1,526	1,589
Transfers	-733	-404	-287	-445	-453	-579	-653	-1,135	-1,125	-716	-1,392	-1,324	-1,050	-1,360	-955	-1,006	-465	-629	-1,257	-834	-691	-409	0
Statistical differences	-245	186	143	-14	-17	-178	139	60	-117	-89	-37	-72	-38	-68	-128	-62	-26	-163	-82	-24	-55	-94	85
TRANSFORMATION	1,455	1,608	1,564	1,665	1,619	1,755	1,645	1,580	1,513	1,609	1,661	1,558	1,536	1,522	1,405	1,601	1,631	1,581	1,795	1,347	965	919	935
Electricity plants	1,421	1,559	1,506	1,598	1,561	1,697	1,590	1,541	1,483	1,585	1,634	1,539	1,516	1,513	1,398	1,595	1,624	1,576	1,727	1,334	958	916	932
CHP plants ²⁷	34	49	58	67	58	58	55	39	30	24	27	19	20	9	7	6	7	5	68	13	7	3	3
ENERGY SECTOR	266	279	260	210	273	274	295	294	320	313	372	358	397	351	416	442	482	465	448	422	427	322	452
Petroleum refineries	266	279	260	210	273	274	295	294	320	313	372	358	397	351	416	442	482	465	448	422	427	322	452
FINAL CONSUMPTION	1,451	1,417	1,429	1,166	1,137	1,188	1,340	1,413	1,494	1,388	1,146	1,199	1,165	1,120	1,220	1,040	1,210	1,181	997	1,092	840	607	654
INDUSTRY	1,152	1,107	1,096	910	841	899	1,067	1,045	928	769	882	830	847	778	801	667	791	772	653	427	378	341	189
Iron and steel	101	96	97	86	78	47	21	16	18	8	18	19	20	17	13	4	5	5	4	3	3	1	15
Chemical industry	92	45	43	26	24	29	106	124	159	81	87	82	82	74	110	106	123	120	99	65	58	55	0
Non-ferrous metals	185	157	161	157	144	142	162	185	151	211	214	216	227	224	235	177	198	193	166	100	89	81	0
1Non-metallic minerals	159	174	188	177	165	179	178	182	94	67	89	86	86	78	132	138	157	153	130	92	81	77	5
Transport equipment	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	4	4	3	2	2	1	0
Machinery	0	0	0	0	0	0	13	13	13	12	15	15	15	10	7	6	7	7	6	5	4	2	2
Mining	22	21	23	21	20	50	67	52	42	42	43	43	45	3	3	3	4	4	3	2	2	1	35
Food and tobacco	241	250	255	257	240	235	249	224	236	181	208	187	188	205	164	104	125	122	102	67	59	54	54
Paper, pulp	84	81	80	71	65	59	77	85	66	66	81	66	67	64	47	42	47	46	38	24	21	17	14
Wood and wood products	0	3	2	2	2	4	3	1	2	2	2	2	2	2	2	2	3	3	3	2	2	1	0
Construction	0	27	26	22	21	50	20	17	21	18	30	30	35	30	25	28	32	31	27	19	17	15	6
Textile and leather	111	93	108	91	82	88	140	137	101	79	92	81	77	68	60	54	46	42	36	22	19	16	4

²⁷ Fuel consumption in CHP plants is added to the respective industrial sectors

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Non-specified	157	160	113	0	0	16	29	7	23	0	0	0	0	0	0	0	40	42	36	24	21	20	54
TRANSPORT	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359	350	292	630	462	266	352
Internal navigation	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359	350	292	630	462	266	352
OTHER SECTORS	62	79	78	55	40	21	28	28	28	28	28	34	35	36	44	47	60	59	52	35	0	0	0
Agriculture	0	20	21	15	15	10	15	15	15	15	15	18	18	19	21	23	31	30	30	20	0	0	0
Commercial and public	13	20	19	15	10	11	13	13	13	13	13	16	17	17	23	24	29	29	22	15	0	0	0
Residential	36	35	38	25	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-specified	13	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-ENERGY USE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table II.5 *Energy balance of diesel (in kt) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production	3,663	3,289	3,786	3,259	3,723	3,987	4,760	5,144	5,544	4,866	5,647	5,452	5,624	6,053	5,369	5,653	6,503	6,656	6,593	6,529	6,932	5,776	7,816
Imports	2,303	2,474	2,042	2,370	2,198	2,293	2,788	2,292	2,539	2,738	2,013	2,435	2,993	3,003	3,672	3,757	3,594	2,629	2,598	3,137	2,505	2,892	1,416
Exports	556	496	509	201	267	342	493	185	284	586	576	794	891	1,102	1,164	1,480	2,311	2,307	2,087	3,018	2,997	3,075	4,735
International marine bunkers	510	514	657	718	801	966	776	771	758	706	750	612	549	497	472	384	398	365	339	318	344	306	264
Stock changes	-169	162	99	-51	-32	67	-166	-133	-468	419	108	35	-251	129	-204	-271	-204	178	-180	353	-84	328	223
DOMESTIC SUPPLY	4,731	4,915	4,761	4,634	4,821	4,868	5,559	5,680	5,981	6,085	6,234	6,605	6,962	7,587	7,340	7,415	7,157	6,823	6,663	6,484	6,012	5,539	4,485
Transfers	0	0	0	-25	0	-171	-554	-667	-592	-646	-208	89	36	1	141	140	-20	32	78	-199	0	0	0
Statistical differences	7	-23	-47	-150	-2	-176	-177	-158	-244	-83	-98	-61	-16	-214	254	-59	-449	-453	-291	-270	-24	-596	16
TRANSFORMATION	315	319	339	287	272	305	381	367	371	336	382	376	465	499	452	429	438	514	425	347	324	301	289
Electricity plants	314	312	338	287	272	305	381	367	371	336	382	376	465	499	448	424	427	507	415	399	308	284	271
CHP plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	11	7	10	8	16	16	18
ENERGY SECTOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	26	27	26	23	0	0	0
FINAL CONSUMPTION	4,409	4,619	4,469	4,497	4,551	4,739	5,355	5,471	5,854	5,832	5,950	6,290	6,513	7,302	6,634	7,023	7,142	6,735	6,503	6,384	5,712	5,834	4,180
INDUSTRY SECTOR	354	319	290	296	320	457	490	500	525	560	504	500	500	550	227	439	486	435	419	345	291	191	253
Iron and steel	41	20	20	26	28	18	5	11	12	20	13	13	15	17	1	1	1	1	1	1	1	0	4
Chemical industry	15	12	11	11	12	8	5	3	9	10	9	9	9	9	9	10	10	9	9	9	8	3	1
Non-ferrous metals	0	25	24	25	27	38	28	13	21	23	23	23	20	23	1	2	2	2	2	2	2	1	5
Non-metallic minerals	49	30	31	31	34	48	36	40	49	53	49	48	42	48	3	4	4	4	4	4	3	1	10
Transport equipment	0	2	2	2	2	12	12	7	15	17	16	15	15	16	15	17	18	18	17	17	15	8	5
Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mining	43	32	31	32	35	49	43	45	41	42	41	40	40	45	38	40	41	37	36	29	26	17	25
Food and tobacco	33	35	33	39	42	59	45	37	49	53	51	51	50	52	22	23	23	21	20	17	15	9	15
Paper, pulp	12	11	10	14	15	8	5	10	9	10	10	10	10	14	2	3	3	3	3	3	3	1	0
Wood and wood products	0	0	0	0	0	0	2	2	2	3	2	1	1	1	0	0	0	0	0	0	0	0	0
Construction	0	1	1	1	1	1	75	94	118	126	130	130	135	140	131	140	142	127	122	130	110	72	46
Textile and leather	17	16	15	20	22	18	10	3	5	8	10	10	7	8	5	5	4	3	3	3	3	1	0

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Non-specified	144	135	112	95	102	198	224	235	195	195	150	150	156	177	0	194	238	210	202	130	105	78	141
TRANSPORT	1,761	1,955	1,952	1,986	1,978	1,988	1,985	2,010	2,245	2,217	2,193	2,280	2,295	2,441	2,406	2,423	2,598	2,666	2,575	3,117	2,824	2,477	1,884
Road	1,362	1,549	1,557	1,588	1,601	1,660	1,711	1,732	1,851	1,888	1,890	1,895	1,925	2,100	2,058	2,055	2,199	2,309	2,230	2,813	2,533	2,205	1,671
Rail	63	49	47	48	52	43	45	42	42	40	40	40	40	40	40	40	41	37	36	30	20	15	25
Internal navigation	336	357	348	350	325	285	229	236	352	289	263	345	330	301	308	328	358	320	309	274	271	257	188
OTHER SECTORS	2,294	2,345	2,227	2,215	2,253	2,294	2,880	2,961	3,084	3,055	3,253	3,510	3,718	4,311	4,001	4,161	4,058	3,634	3,509	2,922	2,597	3,166	2,043
Agriculture	820	888	822	802	808	750	761	760	760	760	760	770	850	929	786	806	845	757	731	575	511	489	59
Commercial and public	145	167	155	150	160	165	200	192	195	195	203	270	278	300	285	365	371	332	321	233	207	187	227
Residential	1,292	1,290	1,250	1,263	1,285	1,379	1,919	2,009	2,129	2,100	2,290	2,470	2,590	3,082	2,930	2,990	2,842	2,545	2,457	2,144	1,879	2,490	1,757
Non-specified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON-ENERGY USE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table II.6 *Energy balance of gasoline (in kt) for the period 1990 – 2012*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production	3,379	3,128	3,581	3,445	3,543	3,545	3,383	3,607	3,671	3,205	3,758	3,770	3,802	3,653	3,629	4,058	4,327	4,318	4,251	4,075	4,407	3804	4,592
Imports	213	162	345	242	98	217	180	45	152	477	415	116	514	749	1,059	1,023	1,002	609	629	936	371	563	380
Exports	1,097	884	1,238	1,077	1,094	881	780	556	645	653	1,011	678	809	942	1,216	1,261	1,351	1,373	1,081	1,152	1,372	1385	2,382
Stock changes	-45	59	-171	11	141	34	-4	-115	-69	169	-27	3	-122	53	11	1	-259	59	-32	192	-46	102	11
DOMESTIC SUPPLY	2,423	2,501	2,582	2,644	2,695	2,774	2,940	3,035	3,156	3,215	3,280	3,385	3,543	3,685	3,763	3,918	3,959	4,137	4,059	4,070	3,705	3220	2,940
Transfers	0	0	0	0	0	0	42	4	28	17	22	167	153	166	121	99	140	76	161	27	410	136	178
Statistical differences	27	-36	-65	-23	-7	141	-119	-50	-19	0	-123	-7	-5	-6	-159	2	-100	-448	-131	8	65	-117	-161
TRANSFORMATION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ENERGY SECTOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FINAL CONSUMPTION	2,423	2,501	2,582	2,644	2,695	2,774	2,940	3,035	3,156	3,215	3,280	3,385	3,543	3,685	3,763	3,918	3,959	4,137	4,059	4,070	3,705	3337	2940
<i>INDUSTRY</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
<i>TRANSPORT</i>	<i>2,373</i>	<i>2,447</i>	<i>2,532</i>	<i>2,594</i>	<i>2,645</i>	<i>2,724</i>	<i>2,890</i>	<i>2,985</i>	<i>3,106</i>	<i>3,165</i>	<i>3,230</i>	<i>3,336</i>	<i>3,493</i>	<i>3,650</i>	<i>3,730</i>	<i>3,888</i>	<i>3,931</i>	<i>4,108</i>	<i>4,031</i>	<i>4,042</i>	<i>3,680</i>	<i>3328</i>	<i>2841</i>
Road transport	2,373	2,447	2,532	2,594	2,645	2,724	2,890	2,985	3,106	3,165	3,230	3,336	3,493	3,650	3,730	3,888	3,931	4,108	4,031	4,042	3,680	3328	2841
OTHER SECTORS	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28	29	28	28	25	9	98
Agriculture	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28	29	28	28	25	9	98
Non specified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NON ENERGY USE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table II.7 *Number of plants where EU ETS data is used for each CRF subsector*

Source Category	No of ETS plants	Comment
1A1a	33	Only some small plants that use HFO, diesel and NG are not subjected to ETS scheme.
1A1b	4	This CRF category consists of these 4 plants.
1A1c	1	This CRF category consists of this 1 plant.
1A2a	5	Some small plants are not subjected to ETS scheme.
1A2b	1	This CRF category consists of this 1 plant.
1A2c		Some data from refineries' ETS reports are used in the calculations of emissions from this CRF category.
1A2d	14	The energy consumption derived from national energy balance is used in this CRF category. The energy consumption from ETS reports is used for QA/QC checks. EFs from ETS report are used.
1A2e	5	The ETS reports of these 5 sugar production plants are used supplementary to the national energy balance data for the calculations of emissions from this CRF category.
1A2f	1 glass 45 ceramics 19 lime 8 cement	Data from the ETS reports from these 73 plants, as AD, EF and NCV are used in the calculations of emissions of this CRF category. However, this category includes other types of industries, too. Thus, these ETS reports are used in combination with national energy balance.

Table II.8 *Ranges of NCVs, oxidation factors and carbon contents derived from the EU ETS reporting for the different subsectors*

Souce category	Fuel	NCV (TJ/kt or NM3) Weighted average	OF Weighted average	EF (tCO ₂ /TJ) Weighted average
1A1a	NG	3.72E-05	99.50%	55.1678
	lignite	5.4966	98%	124.8685
	HFO	76.28	99%	40.73
	diesel	71.33	99%	43.13
1A1b	Ref gas	48.81	99%	56.10
	petcoke	32.33		99.84
	LPG	47.31	99%	62.54
	HFO	40.41	99%	77.20
	NG	3.69E-05	100%	56.06
1A1c	NG domestic (kavala)	0.0000474	99.50%	58.55
	NG domestic (prinos)	0.0000514	99.50%	59.53
	NG imported	0.0000366	99.50%	55.16
1A2f	lignite	8.025	98%	99.18
	coal	25.13	98%	95.94
	petcoke	32.01		94.02
	alternative fuels	24.65		25.81

Table II.9 *The methodological tier levels for the plants where data is used from EU ETS reporting*

Source category	Fuel	NCV (TJ/kt or NM3) Weighted average	OF Weighted average	EF (tCO ₂ /TJ) Weighted average
1A1a	NG	4	3	2
	lignite	3	2a	2
1A1b	Ref gas	4	3	2
	petcoke	1		
1A1c	NG domestic (kavala)	3	2a	1
	NG domestic (prinos)	3	2a	1
	NG imported	3	2a	1
1A2f	lignite	3		
	coal	3	3	1
	petcoke	3	3	1
	alternative fuels	2	3	1

Table II.10 *A typical composition of the refinery gas of greek plants*

Component	wt%
H2	5,0
C1	5,4
C2	25,8
C3	33,8
iC4	7,6
nC4	13,3
iC5	2,4
nC5	2,2
C6	3,4
C2=	0,0
C3=	0,1
C4=	0,0
N2	0,8
CO	0,1
CO2	0,1
	100,0

Table II.11 *NCV and EF of alternative fuels used in cement plants*

Alternative fuel type	TJ/t	tCO ₂ /TJ
Scrap tires	0.02996	82.74
Sludges	0.01562	96.04
Soap waste oil	0.01194	74.87
Dry sludge from WWT	0.01337	91.72
Cable coating scrap	0.02819	91,84
Liners of scrap tires	0.02819	91.84
Cotton seed	0.02031	90.60

Table II.12 Non-CO2 GHG EFs

CRG category			CH4 (kg/TJ)	N2O (kg/TJ)
1A1a		Lignite	1	1,5
		BKB	1	1,5
		Heavy fuel oil	3	0,6
		Diesel	3	0,6
		Natural gas	1	0,1
1A1b		Refinery Gas	3	0,6
		LPG	3	0,6
		Heavy Fuel Oil	3	0,6
		Low S Heavy fuel oil	3	0,6
		Petrocoke	3	0,6
		Diesel	3	0,6
1A1c		Natural gas	1	0,1
1A2a		Heavy fuel oil	3	0,6
		Low S Heavy fuel oil	3	0,6
		Diesel	3	0,6
		Natural gas	1	0,1
1A2b	Alumina production			
		Heavy fuel oil (low S)	3	0,3
	boilers			
		Bituminous Coal	1	1,5
		Lignite	1	1,5
		Oven and Gas Coke	1	1,5
		Pat Fuel and BKB	1	1,5

CRG category			CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
		LPG	0,9	4
		Diesel	0,2	0,4
		Heavy Fuel Oil	3	0,3
		Low S Heavy Fuel Oil	3	0,3
		Natural Gas	1	1
1A2c		LPG	0,9	4
		Diesel	0,2	0,4
		Heavy Fuel Oil	3	0,3
		Low S Heavy fuel oil	3	0,3
		Natural Gas	1	1
1A2d		LPG	0,9	4
		Diesel	0,2	0,4
		Heavy Fuel Oil	3	0,3
		Low S Heavy fuel oil	3	0,3
		Natural Gas	1	1
1A2e		Oven and Gas Coke	1	1,5
		LPG	0,9	4
		Diesel	0,2	0,4
		Heavy Fuel Oil	3	0,3
		Low S Heavy fuel oil	3	0,3
		Natural Gas	1	1
		Solid Biomass	30	4
1A2f	Cement production			
		Bituminous coal	1	1,5
		Petroleum coke	1	0,6

CRG category			CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
		Heavy fuel oil	3	0,6
		Alternative fuels	14,60	2,11
	Lime production			
		Heavy fuel oil	3	0,6
		Diesel	1	0,6
		Solid Biomass	30	4
		Petroleum coke	1	0,6
	Ceramics production			
		Heavy fuel oil	3	0,6
		LPG	1	0,1
		Solid Biomass	30	4
		Natural gas	1	0,1
		Petroleum coke	1	0,6
	Glass production			
		Heavy fuel oil	3	0,6
		LPG	1	0,1
		Natural gas	1	0,1
	Boilers			
		Oven and Gas Coke		
		LPG	0,9	4
		Kerosene	3	0,6
		Diesel	0,2	0,4
		Heavy Fuel Oil	3	0,6
		Low S Heavy fuel oil	3	0,6
		Natural Gas	1	0,1
		Solid Biomass	30	4
1A4a		Diesel	3	0,6
		Heavy Fuel Oil	3	0,6

CRG category			CH ₄ (kg/TJ)	N ₂ O (kg/TJ)
		Low S Heavy fuel oil	3	0,6
		Natural Gas	1	0,1
1A4b		Diesel	3	0,6
		Natural Gas	1	0,1
		Bituminous Coal	1	1,5
		Lignite	1	1,5
		LPG	1	0,1
		Kerosene	3	0,6
		Solid Biomass	320	9
1A4c	Boilers			
		Lignite	1	1,5
		Diesel	3	0,6
		Heavy Fuel Oil	3	0,6
		Low S Heavy fuel oil	3	0,6
		Solid Biomass	320	9
	Off-road machinery			
		Motor Gasoline	2	2
		Diesel	170	1290

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* and *III.2*).

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 and therefore it is presented separately in *Table III.1*.

The application of the reference approach for each year is presented hereafter (Tables 1.A(b) of the Common Reporting Format).

Table III.1 *Net calorific value of lignite (in TJ/kt) for the period 1990 - 2012*

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

Table III.2 Reference approach for 2012

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit)	NCV/ GCV ⁽¹⁾	Apparent consumption (TJ)	Carbon emission factor (t C/TJ)	Carbon content (Gg C)	Carbon stored (Gg C)	Net carbon emissions (Gg C)	Fraction of carbon oxidized	Actual CO ₂ emissions (Gg CO ₂)	
Liquid Fossil	Primary Fuels	Crude Oil	kt	94.00	20,978.00	258.00		337.00	20,477.00	42.75	NCV	875,391.75	20.00	17,507.84	NA	17,507.84	0.99	63,553.44	
		Orimulsion		NA	NA	NA		NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	
		Natural Gas Liquids		7.85	NA	NA		NA	7.85	41.56	NCV	326.25	17.20	5.61	NA	5.61	0.99	20.37	
	Secondary Fuels	Gasoline	kt		380.00	2,382.00	NA	-172.00	-1,830.00	43.96	NCV	-80,446.80	18.90	-1,520.44	NA	-1,520.44	0.99	-5,519.21	
		Jet Kerosene	kt		138.00	828.00	798.00	6.00	-1,494.00	44.59	NCV	-66,617.46	19.46	-1,296.41	NA	-1,296.41	0.99	-4,705.97	
		Other Kerosene			0.00	0.00	NA	-2.00	2.00	44.75	NCV	89.50	19.60	1.75	NA	1.75	0.99	6.37	
		Shale Oil			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	
		Gas / Diesel Oil	kt		1,416.00	4,735.00	264.00	-207.00	-3,376.00	43.00	NCV	-145,168.00	20.20	-2,932.39	NO	-2,932.39	0.99	-10,644.59	
		Residual Fuel Oil	kt		1,603.00	2,731.00	2,064.00	162.00	-3,354.00	40.19	NCV	-134,797.26	21.10	-2,844.22	NA	-2,844.22	0.99	-10,324.53	
		Liquefied Petroleum Gas (LPG)	kt		53.00	216.00		-12.00	-151.00	47.31	NCV	-7,143.81	17.20	-122.87	NO	-122.87	0.99	-446.03	
		Ethane			NA	NA		NA	NA	NA	NCV	NA	NA	NA	NO	NA,NO	NA	NA,NO	
		Naphtha	kt		137.00	555.00		20.00	-438.00	45.01	NCV	-19,714.38	20.00	-394.29	43.97	-438.26	0.99	-1,590.88	
		Bitumen	kt		17.00	173.00		-3.00	-153.00	40.19	NCV	-6,149.07	20.00	-122.98	79.58	-202.56	0.99	-735.28	
		Lubricants	kt		17.00	162.00	8.00	32.00	-185.00	40.19	NCV	-7,435.15	20.00	-148.70	12.06	-160.76	0.99	-583.56	
		Petroleum Coke	kt		906.00	117.00		169.00	620.00	32.37	NCV	20,071.53	25.76	516.95	49.22	467.73	0.99	1,697.86	
		Refinery Feedstocks	kt		1,887.00	66.00		49.00	1,772.00	41.32	NCV	73,215.50	20.00	1,464.31	NA	1,464.31	0.99	5,315.45	
		Other Oil				44.00	154.00		75.00	-185.00	40.19	NCV	-7,435.15	20.00	-148.70	65.91	-214.61	0.99	-779.05
Other Liquid Fossil											NA		NA	NA	NA		NA		
Other non-specified				NA	NA	NA	NA	NA	NA	NCV			NA	NA	NA	NA	NA		
Liquid Fossil Totals											494,187.44		9,965.44	250.74	9,714.70		35,264.37		
Solid Fossil	Primary Fuels	Anthracite ⁽²⁾			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	
		Coking Coal			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NO	NA,NO	NA	NA,NO	
		Other Bituminous Coal	kt		NA	276.00	9.00	NA	-84.00	351.00	25.03	NCV	8,784.53	26.80	235.45	178.44	57.01	0.98	204.85
		Sub-bituminous Coal			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Lignite	kt	62,956.00	137.00	18.00		1,165.00	61,910.00	5.34	NCV	330,414.03	35.37	11,685.65	0.00	11,685.65	0.98	41,990.43	
		Oil Shale			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Peat			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
	Secondary Fuels	BKB ⁽³⁾ and Patent Fuel			NA	NA	NA	0.00	NA	0.00	NCV	NA	NA	0.00	NA	NA	NA	0.98	NA
		Coke Oven/Gas Coke	kt			2.02	NA		NA	2.02	27.84	NCV	56.30	29.50	1.66	NA	1.66	0.98	5.97
		Other Solid Fossil											NA		NA	NA	NA		NA
Other non-specified				NA	NA	NA	NA	NA	NA	NCV			NA	NA	NA	NA	NA		
Solid Fossil Totals												339,254.86		11,922.76	178.44	11,744.32		42,201.25	
Gaseous Fossil	Natural Gas (Dry)	TJ	288.90	153,817.20	NA		4,076.10	150,030.00	1.00	NCV	150,030.00	15.16	2,274.93	136.21	2,138.73	1.00	7,802.78		
Other Gaseous Fossil											NA		NA	NA	NA	NA	NA		
Other non-specified				NA	NA	NA	NA	NA	NA	NCV			NA	NA	NA	NA	NA		
Gaseous Fossil Totals												150,030.00		2,274.93	136.21	2,138.73		7,802.78	
Total												983,472.30		24,163.14	565.40	23,597.75		85,268.40	
Biomass total												5,434,850.00		105,986.44	NA	105,986.44		384,731.80	
	Solid Biomass			0.00	0.00	NA		NA	NA	0.00	NCV	NA	0.00	NA	NA	NA	0.00	NA	
	Liquid Biomass	kt	137,000.00	18,000.00	12,000.00		NA	143,000.00	37.98	NCV	5,431,140.00	19.50	105,929.67	NA	105,929.67	0.99	384,524.71		
	Gas Biomass	TJ	3,710.00	NA	NA		NA	3,710.00	1.00	NCV	3,710.00	15.30	56.76	NA	56.76	1.00	207.09		

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 20/CP.7).

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 IPCC Good Practice Guidance. 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

$$A_{i,g} = \frac{0,01 \cdot E_{i,g,t} + \sum_{i,g} E_{i,g,t} - \left(0,01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0} \right)}{0,01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0}} \cdot 100 - \frac{\sum_{i,g} E_{i,g,t} - \sum_{i,g} E_{i,g,0}}{\sum_{i,g} E_{i,g,0}} \cdot 100$$

$$B_{i,g} = \frac{E_{i,g,t}}{\sum_{i,g} E_{i,g,0}}$$

$$TREF_{i,g} = A_{i,g} \cdot u_{EF,i,g}$$

$$TRAD_i = B_{i,g} \cdot u_{AD,i} \cdot \sqrt{2}$$

$$U_{TR} = \sqrt{\sum_{i,g} TREF_{i,g}^2 + TRAD_{i,g}^2}$$

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 GPG LULUCF and data provider
Conversion to Forest Land	CO ₂	Conservative expert judgement based on suggestions by GPG LULUCF.	The respective EF uncertainty was combined based on suggestions by GPG LULUCF.
Cropland remaining Cropland	CO ₂	The respective AD uncertainty was combined based on suggestions by GPG LULUCF.	The respective EF uncertainty was combined based on suggestions by GPG LULUCF.
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 GPG LULUCF	Suggested default value by GPG LULUCF

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 GPG LULUCF	Suggested default value by GPG LULUCF
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
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
1A 1,2,4	Stationary Combustion - solid fuels	CO ₂	38,851.35	42,236.44	3	3	4.2	1.6	0.0108	0.4025	0.03	1.71	1.71
1A 1,2,4	Stationary Combustion - liquid fuels	CO ₂	21,327.77	19,205.81	3	3	4.2	0.7	-0.0319	0.1830	-0.10	0.78	0.78
1A 1,2,4	Stationary Combustion - gaseous fuels	CO ₂	102.03	7,707.29	3	2	3.6	0.3	0.0724	0.0735	0.14	0.31	0.34
1A2	Stationary Combustion - Other fuels	CO ₂	0.00	14.74	3	3	4.2	0.0	0.0001	0.0001	0.00	0.00	0.00
1A3	Road transport	CO ₂	11,742.20	13,594.88	5	5	7.1	0.9	0.0112	0.1296	0.06	0.92	0.92
1A3	Navigation	CO ₂	1,818.34	1,663.95	5	5	7.1	0.1	-0.0025	0.0159	-0.01	0.11	0.11
1A3	Civil Aviation	CO ₂	319.05	489.75	5	5	7.1	0.0	0.0015	0.0047	0.01	0.03	0.03
1A3	Railway	CO ₂	202.69	78.75	5	5	7.1	0.0	-0.0013	0.0008	-0.01	0.01	0.01
1A3	Other transportation	CO ₂	0.00	11.15	5	5	7.1	0.0	0.0001	0.0001	0.00	0.00	0.00
1B	Oil and Natural gas	CO ₂	70.23	8.75	5	300	300.0	0.0	-0.0006	0.0001	-0.19	0.00	0.19
2A1	Cement Production	CO ₂	5,761.69	3,099.30	2	2	2.8	0.1	-0.0285	0.0295	-0.06	0.08	0.10
2A2	Lime Production	CO ₂	404.00	208.54	5	6	7.8	0.0	-0.0021	0.0020	-0.01	0.01	0.02
2A3	Limestone & Dolomite Use	CO ₂	582.80	400.48	10	5	11.2	0.0	-0.0021	0.0038	-0.01	0.05	0.05
2A42	Soda Ash Production and Use	CO ₂	33.16	17.02	10	5	11.2	0.0	-0.0002	0.0002	0.00	0.00	0.00
2A7	Other Mineral (Glass)	CO ₂	20.20	15.59	5	3	5.8	0.0	-0.0001	0.0001	0.00	0.00	0.00
2B1	Ammonia Production	CO ₂	652.04	178.73	3	6	6.7	0.0	-0.0049	0.0017	-0.03	0.01	0.03
2.B.5	Other Chemicals (Hydrogen Production)	CO ₂	0.00	323.29	3	3	4.2	0.0	0.0031	0.0031	0.01	0.01	0.02
2C1	Iron and Steel Production	CO ₂	92.70	82.99	5	5	7.1	0.0	-0.0001	0.0008	0.00	0.01	0.01
2C2	Ferroalloys	CO ₂	622.23	698.45	7	7	9.9	0.1	0.0004	0.0067	0.00	0.07	0.07
2C3	Aluminium Production	CO ₂	225.39	270.56	2	2	2.8	0.0	0.0003	0.0026	0.00	0.01	0.01
3	Solvent and other product use	CO ₂	169.71	162.72	5	300	300.0	0.4	-0.0002	0.0016	-0.05	0.01	0.05

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
6C	Waste incineration	CO ₂	0.22	3.23	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CO ₂	82,997.81	90,472.39									
1A 1,2,4	Stationary Combustion - all fuels	CH ₄	105.62	108.21	3	100	100.0	0.1	0.0000	0.0010	0.00	0.00	0.01
1A3	Road transport	CH ₄	100.74	57.30	4	40	40.2	0.0	-0.0005	0.0005	-0.02	0.00	0.02
1A3	Navigation	CH ₄	2.64	2.69	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH ₄	0.13	0.20	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Railway	CH ₄	0.24	0.09	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Other transportation	CH ₄	0.00	0.01	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	CH ₄	91.59	198.84	5	300	300.0	0.5	0.0010	0.0019	0.29	0.01	0.29
1B	Coal Mining	CH ₄	1,095.27	1,328.69	2	300	300.0	3.6	0.0016	0.0127	0.49	0.04	0.49
2B5	Other Chemicals (Organic chemicals production)	CH ₄	0.52	0.00	5	5	7.1	0.0	0.0000	0.0000	0.00	0.00	0.00
2C1	Iron and Steel Production	CH ₄	0.21	0.26	5	4	6.4	0.0	0.0000	0.0000	0.00	0.00	0.00
4A	Enteric fermentation	CH ₄	3,129.68	3,122.92	5	30	30.4	0.9	-0.0018	0.0298	-0.05	0.21	0.22
4B	Manure management	CH ₄	423.37	399.06	5	50	50.2	0.2	-0.0005	0.0038	-0.02	0.03	0.04
4C	Rice cultivation	CH ₄	69.10	117.60	2	40	40.0	0.0	0.0004	0.0011	0.02	0.00	0.02
4F	Field burning of agr. residues	CH ₄	27.06	32.08	20	20	28.3	0.0	0.0000	0.0003	0.00	0.01	0.01
6A1	MSW (Managed solid waste disposal)	CH ₄	63.02	941.71	20	40	44.7	0.4	0.0083	0.0090	0.33	0.25	0.42
6A2	MSW (Unmanaged solid waste disposal)	CH ₄	1,910.60	1,500.95	20	72	74.7	1.0	-0.0050	0.0143	-0.36	0.40	0.54
6A3	Industrial waste (Managed Waste Disposal on Land)	CH ₄	1.34	37.95	20	40	44.7	0.015	0.0003	0.0004	0.01	0.01	0.02
6A3	Industrial waste (Unmanaged Waste Disposal on Land)	CH ₄	38.15	29.66	20	72	74.7	0.020	-0.0001	0.0003	-0.01	0.01	0.01
6A3	Construction and Demolition Waste (Managed Waste Disposal on Land)	CH ₄	5.33	208.35	20	40	44.7	0.1	0.0019	0.0020	0.08	0.06	0.10

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
6A3	Construction and Demolition Waste (Unmanaged Waste Disposal on Land)	CH ₄	194.28	235.02	20	72	74.7	0.2	0.0003	0.0022	0.02	0.06	0.07
6A3	Municipal Sludge Disposal on Land	CH ₄	12.97	250.57	20	40	44.7	0.1	0.0023	0.0024	0.09	0.07	0.11
6B	Wastewater handling	CH ₄	3,330.74	1,109.29	30	100	104.4	1.0	-0.0230	0.0106	-2.30	0.45	2.34
6C	Waste incineration	CH ₄	0.01	0.03	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
6D	Composting	CH ₄	0.00	16.72	20	100	102.0	0.0	0.0002	0.0002	0.02	0.00	0.02
		Total CH ₄	10,602.58	9,698.20									
1A1,2,4	Stationary Combustion - all fuels	N ₂ O	579.58	342.53	3	300	300.0	0.9	-0.0026	0.0033	-0.77	0.01	0.77
1A3	Road transport	N ₂ O	145.27	103.64	5	50	50.2	0.0	-0.0005	0.0010	-0.02	0.01	0.02
1A3	Navigation	N ₂ O	134.53	80.47	5	300	300.0	0.2	-0.0006	0.0008	-0.18	0.01	0.18
1A3	Civil Aviation	N ₂ O	3.41	5.26	5	300	300.0	0.0	0.0000	0.0001	0.00	0.00	0.00
1A3	Railway	N ₂ O	24.22	9.61	5	300	300.0	0.0	-0.0002	0.0001	-0.05	0.00	0.05
1A3	Other transportation	N ₂ O	0.00	0.09	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	N ₂ O	0.20	0.02	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N ₂ O	1,109.04	307.01	2	20	20.1	0.1	-0.0083	0.0029	-0.17	0.01	0.17
3	Solvent and other product use	N ₂ O	138.63	155.75	5	300	300.0	0.4	0.0001	0.0015	0.03	0.01	0.03
4B	Manure management	N ₂ O	540.72	593.95	50	100	111.8	0.6	0.0002	0.0057	0.02	0.40	0.40
4D	Agricultural soils - direct emissions	N ₂ O	2,849.81	1,534.48	20	400	400.5	5.5	-0.0141	0.0146	-5.64	0.41	5.66
4D	Agricultural soils - indirect emissions	N ₂ O	2,818.86	1,783.70	20	50	53.9	0.9	-0.0114	0.0170	-0.57	0.48	0.75
4D	Animal Production	N ₂ O	1,538.95	1,479.83	50	100	111.8	1.5	-0.0014	0.0141	-0.14	1.00	1.01
4F	Field burning of agr. residues	N ₂ O	10.05	12.23	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
6B	Wastewater handling	N ₂ O	331.24	382.51	5	10	11.2	0.0	0.0003	0.0036	0.00	0.03	0.03
6C	Waste incineration	N ₂ O	0.13	0.74	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
6D	Composting		0.00	18.51	20	100	102.0	0.0	0.0002	0.0002	0.02	0.00	0.02
		Total N ₂ O	10,224.65	6,810.34									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	50	50	70.7	0.0	-0.0095	0.0000	-0.47	0.00	0.47
2F1	Refrigeration and Air Conditioning Equipment	HFC	0.00	3,777.24	100	150	180.3	6.1	0.0361	0.0361	5.41	5.10	7.44
2F2	Foam Blowing	HFC	0.00	32.73	40	50	64.0	0.0	0.0003	0.0003	0.02	0.02	0.02
2F3	Fire Extinguishers	HFC	0.00	38.33	60	10	60.8	0.0	0.0004	0.0004	0.00	0.03	0.03
2F4	Aerosols/MDIs	HFC	0.00	40.75	15	5	15.8	0.0	0.0004	0.0004	0.00	0.01	0.01
		Total HFC	935.06	3,889.05									
2C	PFC from Aluminium	PFC	163.37	50.16	3	6	6.7	0.0	-0.0012	0.0005	-0.01	0.00	0.01
2F1	Refrigeration and Air Conditioning Equipment	PFC	0.00	60.24	100	150	180.3	0.1	0.0006	0.0006	0.09	0.08	0.12
2F	SF ₆ from electrical equipment	SF ₆	3.07	5.11	50	20	53.9	0.0	0.0000	0.0000	0.00	0.00	3.07
TOTAL			104,656.72	110,784.38				9.65					10.03

Table IV.3 *Uncertainty analysis with LULUCF*

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
1A 1,2,4	Stationary Combustion - solid fuels	CO ₂	38,851.35	42,236.44	3	3	4.2	1.7	0.0130	0.4115	0.04	1.75	1.75
1A 1,2,4	Stationary Combustion - liquid fuels	CO ₂	21,327.77	19,205.81	3	3	4.2	0.8	-0.0315	0.1871	-0.09	0.79	0.80
1A 1,2,4	Stationary Combustion - gaseous fuels	CO ₂	102.03	7,707.29	3	2	3.6	0.3	0.0740	0.0751	0.15	0.32	0.35
1A2	Stationary Combustion - Other fuels	CO ₂	0.00	14.74	3	3	4.2	0.0	0.0001	0.0001	0.00	0.00	0.00
1A3	Road transport	CO ₂	11,742.20	13,594.88	5	5	7.1	0.9	0.0120	0.1324	0.06	0.94	0.94
1A3	Navigation	CO ₂	1,818.34	1,663.95	5	5	7.1	0.1	-0.0024	0.0162	-0.01	0.11	0.12
1A3	Civil Aviation	CO ₂	319.05	489.75	5	5	7.1	0.0	0.0015	0.0048	0.01	0.03	0.03
1A3	Railway	CO ₂	202.69	78.75	5	5	7.1	0.0	-0.0013	0.0008	-0.01	0.01	0.01
1A3	Other transportation	CO ₂	0.00	11.15	5	5	7.1	0.0	0.0001	0.0001	0.00	0.00	0.00
1B	Oil and Natural gas	CO ₂	70.23	8.75	5	300	300.0	0.0	-0.0006	0.0001	-0.19	0.00	0.19
2A1	Cement Production	CO ₂	5,761.69	3,099.30	2	2	2.8	0.1	-0.0289	0.0302	-0.06	0.09	0.10
2A2	Lime Production	CO ₂	404.00	208.54	5	6	7.8	0.0	-0.0021	0.0020	-0.01	0.01	0.02
2A3	Limestone & Dolomite Use	CO ₂	582.80	400.48	10	5	11.2	0.0	-0.0021	0.0039	-0.01	0.06	0.06
2A42	Soda Ash Production and Use	CO ₂	33.16	17.02	10	5	11.2	0.0	-0.0002	0.0002	0.00	0.00	0.00
2A7	Other Mineral (Glass)	CO ₂	20.20	15.59	5	3	5.8	0.0	-0.0001	0.0002	0.00	0.00	0.00
2B1	Ammonia Production	CO ₂	652.04	178.73	3	6	6.7	0.0	-0.0049	0.0017	-0.03	0.01	0.03
2.B.5	Other Chemicals (Hydrogen Production)	CO ₂	0.00	323.29	3	3	4.2	0.0	0.0031	0.0031	0.01	0.01	0.02
2C1	Iron and Steel Production	CO ₂	92.70	82.99	5	5	7.1	0.0	-0.0001	0.0008	0.00	0.01	0.01
2C2	Ferroalloys	CO ₂	622.23	698.45	7	7	9.9	0.1	0.0004	0.0068	0.00	0.07	0.07
2C3	Aluminium Production	CO ₂	225.39	270.56	2	2	2.8	0.0	0.0003	0.0026	0.00	0.01	0.01
3	Solvent and other product use	CO ₂	169.71	162.72	5	300	300.0	0.5	-0.0002	0.0016	-0.05	0.01	0.05

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
5.A.1	Forest Land remaining Forest Land	CO ₂	-1,359.03	-1,841.07	5	34	34.0	-0.6	-0.0040	-0.0179	-0.13	-0.13	0.18
5.A.2	Conversion to Forest Land	CO ₂	0.00	-145.24	5	113	112.8	-0.2	-0.0014	-0.0014	-0.16	-0.01	0.16
5.B.1	Cropland remaining Cropland	CO ₂	-981.70	-227.67	12	53	54.0	-0.1	0.0078	-0.0022	0.41	-0.04	0.41
5.B.2	Conversion to Cropland	CO ₂	0.07	0.33	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.1	Grassland remaining Grassland	CO ₂	0.20	0.40	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.2	Conversion to Grassland	CO ₂	0.03	-916.96	10	50	51.0	-0.4	-0.0089	-0.0089	-0.45	-0.13	0.46
5.D.2	Land converted to Wetlands	CO ₂	0.00	2.87	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.E.2	Conversion to Settlements	CO ₂	6.38	24.53	10	50	51.0	0.0	0.0002	0.0002	0.01	0.00	0.01
5.F.2	Conversion to Other Land	CO ₂	20.60	130.25	10	50	51.0	0.1	0.0011	0.0013	0.05	0.02	0.06
6C	Waste incineration	CO ₂	0.22	3.23	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
Total CO ₂			80,684.36	87,499.84									
1A 1,2,4	Stationary Combustion - all fuels	CH ₄	105.62	108.21	3	100	100.0	0.1	0.0000	0.0011	0.00	0.00	0.01
1A3	Road transport	CH ₄	100.74	57.30	4	40	40.2	0.0	-0.0005	0.0006	-0.02	0.00	0.02
1A3	Navigation	CH ₄	2.64	2.69	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH ₄	0.13	0.20	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Railway	CH ₄	0.24	0.09	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Other transportation	CH ₄	0.00	0.01	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	CH ₄	91.59	198.84	5	300	300.0	0.6	0.0010	0.0019	0.30	0.01	0.30
1B	Coal Mining	CH ₄	1,095.27	1,328.69	2	300	300.0	3.7	0.0017	0.0129	0.51	0.04	0.52
2B5	Other Chemicals (Organic chemicals production)	CH ₄	0.52	0.00	5	5	7.1	0.0	0.0000	0.0000	0.00	0.00	0.00
2C1	Iron and Steel Production	CH ₄	0.21	0.26	5	4	6.4	0.0	0.0000	0.0000	0.00	0.00	0.00
4A	Enteric fermentation	CH ₄	3,129.68	3,122.92	5	30	30.4	0.9	-0.0017	0.0304	-0.05	0.22	0.22
4B	Manure management	CH ₄	423.37	399.06	5	50	50.2	0.2	-0.0005	0.0039	-0.02	0.03	0.04
4C	Rice cultivation	CH ₄	69.10	117.60	2	40	40.0	0.0	0.0004	0.0011	0.02	0.00	0.02

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
4F	Field burning of agr. residues	CH ₄	27.06	32.08	20	20	28.3	0.0	0.0000	0.0003	0.00	0.01	0.01
5.A.1	Forest Land remaining Forest Land	CH ₄	13.12	6.05	11	70	70.9	0.0	-0.0001	0.0001	-0.01	0.00	0.01
5.A.2	Conversion to Forest Land	CH ₄	0.00	0.06	11	70	70.9	0.0	0.0000	0.0000	0.00	0.00	0.00
5.B.2	Conversion to Cropland	CH ₄	0.00	0.00	11	70	70.9	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.1	Grassland remaining Grassland	CH ₄	14.03	19.48	10	70	70.7	0.0	0.0000	0.0002	0.00	0.00	0.00
6A1	MSW (Managed solid waste disposal)	CH ₄	63.02	941.71	20	40	44.7	0.4	0.0085	0.0092	0.34	0.26	0.43
6A2	MSW (Unmanaged solid waste disposal)	CH ₄	1,910.60	1,500.95	20	72	74.7	1.0	-0.0050	0.0146	-0.36	0.41	0.55
6A3	Industrial waste (Managed Waste Disposal on Land)	CH ₄	1.34	37.95	20	40	44.7	0.0	0.0004	0.0004	0.01	0.01	0.02
6A3	Industrial waste (Unmanaged Waste Disposal on Land)	CH ₄	38.15	29.66	20	72	74.7	0.0	-0.0001	0.0003	-0.01	0.01	0.01
6A3	Construction and Demolition Waste (Managed Waste Disposal on Land)	CH ₄	5.33	208.35	20	40	44.7	0.1	0.0020	0.0020	0.08	0.06	0.10
6A3	Construction and Demolition Waste (Unmanaged Waste Disposal on Land)	CH ₄	194.28	235.02	20	72	74.7	0.2	0.0003	0.0023	0.02	0.06	0.07
6A3	Municipal Sludge Disposal on Land	CH ₄	12.97	250.57	20	40	44.7	0.1	0.0023	0.0024	0.09	0.07	0.12
6B	Wastewater handling	CH ₄	3,330.74	1,109.29	30	100	104.4	1.1	-0.0233	0.0108	-2.33	0.46	2.38
6C	Waste incineration	CH ₄	0.01	0.03	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
6D	Composting	CH ₄	0.00	16.72	20	100	102.0	0.0	0.0002	0.0002	0.02	0.00	0.02
		Total CH ₄	10,629.74	9,723.78									
1A1,2,4	Stationary Combustion - all fuels	N ₂ O	579.58	342.53	3	300	300.0	1.0	-0.0026	0.0033	-0.78	0.01	0.78
1A3	Road transport	N ₂ O	145.27	103.64	5	50	50.2	0.0	-0.0005	0.0010	-0.02	0.01	0.03

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
1A3	Navigation	N ₂ O	134.53	80.47	5	300	300.0	0.2	-0.0006	0.0008	-0.18	0.01	0.18
1A3	Civil Aviation	N ₂ O	3.41	5.26	5	300	300.0	0.0	0.0000	0.0001	0.00	0.00	0.00
1A3	Railway	N ₂ O	24.22	9.61	5	300	300.0	0.0	-0.0002	0.0001	-0.05	0.00	0.05
1A3	Other transportation	N ₂ O	0.00	0.09	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	N ₂ O	0.20	0.02	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N ₂ O	1,109.04	307.01	2	20	20.1	0.1	-0.0084	0.0030	-0.17	0.01	0.17
3	Solvent and other product use	N ₂ O	138.63	155.75	5	300	300.0	0.4	0.0001	0.0015	0.03	0.01	0.03
4B	Manure management	N ₂ O	540.72	593.95	50	100	111.8	0.6	0.0002	0.0058	0.02	0.41	0.41
4D	Agricultural soils - direct emissions	N ₂ O	2,849.81	1,534.48	20	400	400.5	5.7	-0.0143	0.0149	-5.71	0.42	5.72
4D	Agricultural soils - indirect emissions	N ₂ O	2,818.86	1,783.70	20	50	53.9	0.9	-0.0115	0.0174	-0.58	0.49	0.76
4D	Animal Production	N ₂ O	1,538.95	1,479.83	50	100	111.8	1.5	-0.0014	0.0144	-0.14	1.02	1.03
4F	Field burning of agr. residues	N ₂ O	10.05	12.23	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
5.A.1	Forest Land remaining Forest Land	N ₂ O	1.33	0.61	11	70	70.9	0.0	0.0000	0.0000	0.00	0.00	0.00
5.A.2	Conversion to Forest Land	N ₂ O	0.00	0.01	11	70	70.9	0.0	0.0000	0.0000	0.00	0.00	0.00
5.B.2	Conversion to Cropland	N ₂ O	0.00	0.03	11	70	70.9	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.1	Grassland remaining Grassland	N ₂ O	1.42	1.98	10	70	70.7	0.0	0.0000	0.0000	0.00	0.00	0.00
6B	Wastewater handling	N ₂ O	331.24	382.51	5	10	11.2	0.0	0.0003	0.0037	0.00	0.03	0.03
6C	Waste incineration	N ₂ O	0.13	0.74	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
6D	Composting	N ₂ O	0.00	18.51	20	100	102.0	0.0	0.0002	0.0002	0.02	0.01	0.02
		Total N ₂ O	10,227.41	6,812.97									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	50	50	70.7	0.0	-0.0096	0.0000	-0.48	0.00	0.48
2F1	Refrigeration and Air Conditioning Equipment	HFC	0.00	3,777.24	100	150	180.3	6.3	0.0369	0.0369	5.53	5.22	7.61
2F2	Foam Blowing	HFC	0.00	32.73	40	50	64.0	0.0	0.0003	0.0003	0.02	0.02	0.02

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
2F3	Fire Extinguishers	HFC	0.00	38.33	60	10	60.8	0.0	0.0004	0.0004	0.00	0.03	0.03
2F4	Aerosols/MDIs	HFC	0.00	40.75	15	5	15.8	0.0	0.0004	0.0004	0.00	0.01	0.01
		Total HFC	935.06	3,889.05									
2C	PFC from Aluminium	PFC	163.37	50.16	3	6	6.7	0.0	-0.0012	0.0005	-0.01	0.00	0.01
5F1	Refrigeration and Air Conditioning Equipment	PFC	0.00	60.24	100	150	180.3	0.1	0.0006	0.0006	0.09	0.08	0.12
2F	SF6 from electrical equipment	SF6	3.07	5.11	50	20	53.9	0.0	0.0000	0.0000	0.00	0.00	0.00
TOTAL			102,643.01	108,041.14				9.944					10.239

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 2012 decreased by 20.63% compared to 1990 levels, with an average annual rate of decrease estimated at 0.94% for the period 1990 - 2012. Emissions of NO_x derive by 99.07% from the energy sector and especially from transport, which is responsible for the 39.02% of total NO_x emissions. In **Table V.1** NO_x emissions by source category for the period 1990 – 2012 are presented.

- ✎ The calculation of NO_x emissions from *Energy* (area sources) is based emission factors per source, fuel type and technology suggested by CORINAIR. For point sources, measurement data from the relative plants were used.
- ✎ In the sector *Industrial processes*, the emissions factors for ammonia iron and steel and aluminium production are the default ones, provided by the EMEP/EEA Inventory Guidebook 2009. NO_x emission factor for nitric acid production is based on NO_x measurements taking place in the sole industrial plant producing nitric acid in Greece.
- ✎ Emissions estimates for field burning of agricultural residues and of forest and grassland conversion are calculated by using the emission factors suggested by the IPCC Guidelines and the CORINAIR methodology (grassland conversion).

Carbon monoxide

Emissions of carbon monoxide in 2012 decreased by 59.69% approximately compared to 1990 levels, with an average annual rate of decrease estimated at 2.71% for the period 1990 – 2012. CO emissions derive by 85.91% from the energy sector and especially from transport, which is responsible for the 56.83% of total CO emissions. In **Table V.2** CO emissions by source category for the period 1990 – 2012 are presented.

- ✎ The calculation of CO emissions from *Energy* is based on emission factors per source, fuel type and technology suggested by CORINAIR.
- ✎ In the sector *Industrial processes*, the emission factor for glass (100 kg/kt) derives from CORINAIR, while for ammonia, steel and aluminium production the updated EMEP/EEA Inventory Guidebook 2009 values have been used.
- ✎ Emissions estimates for field burning of agricultural residues and of forest and grassland conversion are calculated by using the emission factors suggested by the IPCC Guidelines and the CORINAIR methodology (grassland conversion).

Non-methane volatile organic compounds

NMVOC emissions decreased by 43.59% in 2012 compared to 1990, with an average annual rate of decrease estimated at 1.98%. NMVOC emissions derive by 55.64% from the energy sector and especially from transport, which is responsible for the 24.34% of total NMVOC emissions. In **Table V.3** NMVOC emissions by source category for the period 1990 – 2012 are presented.

- ✎ For the calculation of NMVOC emissions from *Energy* the emission factors per source, fuel type and technology suggested by CORINAIR were used.
- ✎ In the sector *Industrial processes*, the NMVOC emission factor for the production of glass (4500 gr/t), as well as the emission factors for organic chemicals, food and drinks, are those suggested by the IPCC Good Practice Guidance. NMVOC emission factor for asphalt uses is provided by the 1996 IPCC Guidelines. The values for ammonia and steel production is provided by the EMEP/EEA Inventory Guidebook 2009.
- ✎ NMVOC emission factors for the Solvents and other products use have been already presented in Chapter 5 of the present inventory.

Sulphur dioxide

Sulphur dioxide emissions in 2012 decreased by 48.56% compared to 1990 levels, with an average annual rate of decrease estimated at 2.21% for the period 1990 - 2012. SO₂ emissions derive by 98.33% from the energy sector and mainly from the energy industries, which are responsible for the 77.31% of total SO₂ emissions. In **Table V.4** SO₂ emissions by source category for the period 1990 – 2012 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 88.76% was observed for the period 1990 – 2012. Emissions from Industrial processes decreased by 52.321% in 2012 compared to 1990, due to the decrease of sulphuric acid industrial production

The calculation of SO₂ emissions from the energy sector is based on the sulphur content of the fuel. Measurement data were used for the case of electricity production plants. In the sector *Industrial processes*, the SO₂ emission factors for the production of cement (300 gr/t), ammonia (30 gr/t) are those suggested by the IPCC Guidelines, while emission factors for glass (1700 gr/t) from CORINAIR. Aluminium and ferroalloys emission factors derive from the EMEP/EEA Inventory Guidebook 2009. Finally the EFs for sulphuric acid production (3800 gr/t) is based on data from the relevant industries.

Table V.1 *NOx emissions (in kt) by source category. for the period 1990 – 2012*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
TOTAL	326.2	335.9	342.7	340.2	348.8	329.1	333.0	346.7	369.8	367.6	360.4	382.3	383.2	393.4	399.0	416.6	412.8	416.1	392.4	379.8	319.5	296.2	258.9
Energy	323.2	332.8	339.7	337.3	345.9	326.5	330.4	343.9	366.7	365.2	356.9	379.9	380.8	391.0	396.5	414.2	410.6	411.9	389.8	377.4	317.2	293.7	256.5
Fuel combustion	322.9	332.4	339.3	336.7	345.5	326.0	330.0	343.5	366.3	364.7	356.4	379.5	380.3	390.5	396.1	413.8	410.0	411.2	389.1	376.6	316.9	293.2	255.9
Energy industries	73.6	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	116.7	118.2
Industry	22.2	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
Transport	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
Other sectors	46.6	48.3	45.1	43.9	44.1	41.3	43.1	43.2	43.4	43.4	43.8	44.8	48.7	53.6	46.5	48.8	48.8	44.0	42.2	33.9	30.3	32.7	20.4
Fugitive emissions	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.6	0.7	0.7	0.7	0.4	0.5	0.6
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
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
Ammonia production	0.3	0.3	0.2	0.1	0.0	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
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
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
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
Agriculture	1.2	1.6	1.3	1.3	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.2	1.3	1.3	1.2	1.2	1.4	1.4	1.4	1.4	1.4
Field burning of agricultural residues	1.2	1.6	1.3	1.3	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.2	1.3	1.3	1.2	1.2	1.4	1.4	1.4	1.4	1.4
LULUCF	0.3	0.2	0.6	0.5	0.5	0.2	0.2	0.3	0.8	0.1	1.1	0.2	0.0	0.0	0.1	0.1	0.1	2.0	0.2	0.2	0.1	0.1	0.3
Forest and grassland conversion	0.3	0.2	0.6	0.5	0.5	0.2	0.2	0.3	0.8	0.1	1.1	0.2	0.0	0.0	0.1	0.1	0.1	2.0	0.2	0.2	0.1	0.1	0.3

Table V.2 CO emissions (in kt) by source category. for the period 1990 – 2012

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
TOTAL	1142.9	1124.2	1094.1	1085.4	1062.8	961.4	954.0	957.1	975.1	955.8	961.2	918.0	856.3	811.9	810.6	721.6	740.1	750.8	630.0	599.8	527.7	497.0	460.7
Energy	1084.7	1059.1	1022.1	1019.6	996.0	905.5	900.6	897.5	898.9	904.7	870.5	859.9	803.4	760.7	753.8	665.5	684.3	629.3	565.0	540.8	475.0	437.0	395.8
Fuel combustion	1084.5	1058.9	1021.9	1019.3	995.8	905.2	900.4	897.3	898.7	904.4	870.2	859.6	803.1	760.4	753.5	665.3	684.0	628.9	564.6	540.4	474.8	436.8	395.5
Energy industries	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
Industry	9.5	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
Transport	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
Other sectors	161.0	165.9	176.0	168.1	160.8	158.2	160.4	156.7	153.9	162.7	173.0	163.7	147.0	126.4	130.2	101.0	108.6	113.9	102.2	100.0	94.8	87.9	80.3
Fugitive emissions	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.2	0.2	0.3
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	23.0	23.1	23.5	23.9	24.1	24.4	24.0	19.1	19.7	23.3	22.2
Glass production	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	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ammonia production	0.002	0.002	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
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
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
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	0.2
Agriculture	27.1	37.9	30.9	29.5	32.2	30.3	29.7	30.0	28.1	27.6	29.2	29.9	28.9	26.7	29.8	30.1	27.6	26.9	32.4	31.1	30.5	31.6	32.1
Field burning of agricultural residues	27.1	37.9	30.9	29.5	32.2	30.3	29.7	30.0	28.1	27.6	29.2	29.9	28.9	26.7	29.8	30.1	27.6	26.9	32.4	31.1	30.5	31.6	32.1
LULUCF	11.3	7.0	21.0	16.8	16.4	8.2	6.5	11.9	28.4	2.5	40.0	6.4	1.0	1.4	3.6	2.1	4.0	70.1	8.5	8.8	2.6	5.1	10.7
Forest and grassland conversion	11.3	7.0	21.0	16.8	16.4	8.2	6.5	11.9	28.4	2.5	40.0	6.4	1.0	1.4	3.6	2.1	4.0	70.1	8.5	8.8	2.6	5.1	10.7

Table V.3 NMVOC emissions (in kt) by source category, for the period 1990 – 2012

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
TOTAL	269.2	271.3	268.7	267.9	266.2	259.6	260.2	261.7	267.2	270.0	265.8	262.9	258.1	245.7	245.9	221.3	231.1	220.1	228.1	212.4	184.8	158.6	151.8
Energy	187.1	185.5	182.4	181.4	180.3	171.1	171.5	172.1	173.2	172.7	163.4	161.1	154.2	148.9	143.5	134.5	134.1	129.3	119.3	114.6	98.4	89.8	84.5
Fuel combustion	164.8	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	102.7	100.8	94.4	85.6	81.1	67.6	61.7	53.9
<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
<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
<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
<i>Other sectors</i>	15.7	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	12.0	12.7	12.6	11.5	10.5	9.8	10.0	8.1
Fugitive emissions	22.2	21.6	22.8	22.0	23.4	25.3	25.9	26.5	27.4	26.5	28.6	28.3	29.2	30.0	29.0	31.8	33.2	34.9	33.7	33.5	30.9	28.1	30.6
Industrial processes	25.5	27.5	28.8	30.3	31.6	36.9	37.7	38.2	42.6	43.6	49.1	49.5	51.4	44.1	49.7	33.8	43.4	36.9	54.8	43.6	32.1	14.4	12.7
Asphalt roofing	0.83	0.91	0.96	1.02	1.03	1.22	1.24	1.25	1.41	1.44	1.66	1.69	1.76	1.50	1.69	1.13	1.48	1.24	1.91	1.52	1.10	0.47	0.40
Road paving with asphalt	22.4	24.4	25.8	27.3	27.7	32.8	33.2	33.6	37.8	38.8	44.5	45.4	47.2	40.3	45.4	30.3	39.7	33.2	51.4	40.8	29.5	12.6	10.9
Glass production	0.61	0.56	0.44	0.45	0.49	0.53	0.57	0.61	0.65	0.69	0.73	0.76	0.77	0.66	0.62	0.58	0.46	0.52	0.52	0.42	0.51	0.39	0.52
Ammonia production	0.03	0.02	0.02	0.01	NO	0.01	0.01	0.01	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	0.01
Organic chemicals production	0.94	0.92	0.94	0.97	1.72	1.75	1.94	2.03	2.03	1.90	1.50	0.90	0.87	0.89	1.11	0.99	0.90	1.03	NA	NA	NA	NA	NA
Steel production	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.06	0.08	0.08	0.09	0.11	0.11	0.12	0.11	0.09	0.08	0.09	0.06
Paper and pulp	0.15	0.12	0.12	0.07	0.07	0.11	0.10	0.09	0.10	0.10	0.11	0.10	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10
Food - Drinks	0.52	0.53	0.53	0.47	0.48	0.52	0.56	0.55	0.58	0.59	0.59	0.61	0.59	0.55	0.66	0.61	0.63	0.66	0.70	0.65	0.78	0.78	0.74
Solvents and other products use	56.6	58.3	57.5	56.2	54.3	51.6	51.1	51.4	51.4	53.8	53.2	52.3	52.5	52.6	52.7	53.1	53.7	53.9	54.0	54.2	54.3	54.4	54.7

Table V.4 *SO₂ emissions (in kt) by source category, for the period 1990 – 2012*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
TOTAL	476	517	534	531	522	540	530	529	536	555	496	504	515	553	548	541	533	538	445	426	265	262	245
Energy	467	509	527	524	515	532	522	521	528	547	488	496	508	546	540	532	527	531	439	421	260	258	241
Fuel combustion	461	502	518	514	508	525	516	514	520	538	479	489	498	536	533	523	516	519	426	407	254	250	230
<i>Energy industries</i>	299	341	362	373	382	407	387	379	378	405	371	372	383	422	414	414	402	406	366	334	202	198	189
<i>Industry</i>	94	91	90	78	66	71	80	80	71	59	69	67	69	64	63	57	58	62	19	12	12	11	11
<i>Transport</i>	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	34.1	35.1	25.4
<i>Other sectors</i>	28.5	30.7	26.2	24.6	17.6	15.1	19.4	17.5	18.1	17.5	18.8	20.4	20.6	23.7	23.3	24.1	24.9	22.3	18.3	15.1	5.2	5.6	5.0
Fugitive emissions	6.5	7.4	8.3	9.4	6.8	6.9	5.8	6.4	8.3	8.4	9.0	7.8	9.2	9.5	7.4	8.4	10.8	12.6	12.5	13.3	6.7	8.3	10.5
Industrial processes	8.6	8.1	7.2	6.8	7.2	8.0	8.0	8.3	8.3	8.4	7.6	7.5	7.6	7.6	7.7	9.1	6.7	6.7	6.4	4.9	5.1	4.2	4.1
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
Glass production	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2
Ammonia production	0.01	0.01	0.01	0.00	NO	0.00	0.00	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
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	3.5	1.2	1.2	1.1	0.9	1.2	1.1	0.5
Iron and Steel production	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.07	0.06	0.07	0.08	0.11	0.10	0.12	0.14	0.14	0.15	0.15	0.12	0.11	0.12	0.07
Ferroalloys Production	0.28	0.29	0.28	0.20	0.29	0.31	0.32	0.32	0.27	0.24	0.31	0.32	0.35	0.32	0.33	0.35	0.32	0.33	0.29	0.15	0.25	0.33	0.34
Aluminium production	0.90	0.91	0.92	0.89	0.83	0.79	0.79	0.80	0.88	0.96	0.98	0.97	0.98	1.00	1.00	0.99	0.99	1.00	0.98	0.78	0.82	0.99	0.99
Pulp and paper	0.27	0.22	0.23	0.13	0.13	0.20	0.18	0.17	0.18	0.18	0.21	0.20	0.18	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.19	0.20

Annex VI: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded for the annual inventory submission and also for the KP-LULUCF inventory

Table VI shows sources of GHGs that are not estimated in the Greek GHG inventory, and the reasons for those sources being omitted. This table is taken from the CRF; “Table9(a)”.

Table VI *Assessment of Completeness*

Sources and sinks not estimated (NE)			
GHG	Sector	Source/sink category	Explanation
Carbon	5 LULUCF	5.A.2.2 Grassland converted to Forest Land	Lack of AD
Carbon	5 LULUCF	5.E.1 5.E.1 Settlements remaining Settlements	Parties do not have to prepare estimates of emissions and removals from Settlements remaining Settlements
Carbon	5 LULUCF	5.A.2.2 Grassland converted to Forest Land	Lack of AD
Carbon	5 LULUCF	5.D.1 5.D.1 Wetlands remaining Wetlands	Parties do not have to prepare estimates of emissions and removals from Wetlands remaining Wetlands
Carbon	5 LULUCF	5.E.1 5.E.1 Settlements remaining Settlements	Parties do not have to prepare estimates of emissions and removals from Settlements remaining Settlements
Carbon	5 LULUCF	5.E.2.2 Cropland converted to Settlements	
Carbon	5 LULUCF	5.A.2.2 Grassland converted to Forest Land	Lack of AD
Carbon	5 LULUCF	5.B.1 5.B.1 Cropland remaining Cropland	Tier 1 approach has been used on the basis of documentation provided in the NIR/section 7.3
CH ₄	1 Energy	1.B.2.D Geothermal	Lack of background information and methodological approach
CH ₄	4 Agriculture	4.D.1 Direct Soil Emissions	There has not been any method for the estimation of CH ₄ emissions from this source.
CH ₄	4 Agriculture	4.D.3 Indirect Emissions	There has not been any method for the estimation of CH ₄ emissions from this source.
CH ₄	5 LULUCF	5.D.2 5.D.2 Land converted to Wetlands	Parties do not have to prepare estimates of non-CO ₂ emissions from lands converted to Wetlands
CO ₂	1 Energy	1.B.2.D Geothermal	Lack of background information and methodological approach
CO ₂	2 Industrial Processes	2.A.5 Asphalt Roofing	Not available methodology in the IPCC guidelines.
CO ₂	2 Industrial Processes	2.A.6 Road Paving with Asphalt	Not available methodology in the IPCC

			guidelines.
CO2	2 Industrial Processes	2.B.5 Organic chemicals production	No method in the IPCC Guidelines
HFCs	2 Industrial Processes	2.F.1 Refrigeration and Air Conditioning Equipment	Lack of AD for potential emissions.
HFCs	2 Industrial Processes	2.F.2 Foam Blowing	Lack of activity data
HFCs	2 Industrial Processes	2.F.3 Fire Extinguishers	Lack of AD for potential emissions.
HFCs	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD for potential emissions.
N2O	1 Energy	1.B.2.D Geothermal	Lack of background information and methodological approach
N2O	5 LULUCF	5.D.2 5.D.2 Land converted to Wetlands	Parties do not have to prepare estimates of non-CO2 emissions from lands converted to Wetlands
SF6	2 Industrial Processes	2.F.8 Electrical Equipment	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P2.1 In bulk	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P2.2 In products	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P3.1 In bulk	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P3.2 In products	Lack of AD for

			potenti al emissi ons.
SF6	2 Industrial Processes	2.F.P4 Destroyed amount	Lack of AD for potenti al emissi ons.

Sources and sinks reported elsewhere (IE) ¹				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
Carbon	Managed	5.A.1 - Carbon stock change	5.A.1 - Carbon stock change	Losses are included in Gains owing to the application of the Method 2 of the GPG LULUCF
Carbon	5.D.2.1 Forest Land converted to Wetlands	5.D.2.1. - Forest land converted to Wetlands	5.D.2.1. - Forest land converted to Wetlands	Carbon stock changes in dead organic matter are included in carbon stock changes in soils, due to the methodology applied (Appendix 3a.3 GPG LULUCF)
Carbon	5.D.2.3 Grassland converted to Wetlands	5.D.2.3. - Grassland converted to Wetlands	5.D.2.3. - Grassland converted to Wetlands	Carbon stock changes in dead organic matter are included in carbon stock changes in soils, due to the methodology applied (Appendix 3a.3 GPG LULUCF)
CH4	1.B.1.A.2.2 Post-Mining Activities	Post mining activities	Mining activities	Good Practice Guidance, p.2.75
CH4	1.B.1.B Solid Fuel Transformation		Emissions from this sub-source category are assumed to be negligible, as the gas content of surface coal are typically very low. Emissions can be viewed as being accommodated within the surface emission factor of mining activities.	
CH4	1.B.2.B.5.1 at industrial plants and power stations		Included in category 1.B.2.B.3 & 4	
CH4	1.B.2.B.5.2 in residential and commercial sectors		Included in category 1.B.2.B.3 & 4	
CH4	6.A.2.2 shallow (<5 m)	Unmanaged Waste Disposal on Land - Uncategorized SWDS		
CH4	6.B.2.1 Domestic and Commercial (w/o human sewage)	Domestic and commercial wastewater handling	Solid waste disposal on land	Sludge from domestic wastewater handling is landfilled on managed waste disposal sites
CH4	1.AA.2.B Non-Ferrous Metals	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).
CH4	1.AA.3.B Road Transportation		CH4 and N2O emissions are calculated with COPERT and are	CH4 and N2O emissions are calculated with COPERT and are

Sources and sinks reported elsewhere (IE) ¹				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
			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. Therefore, the CH ₄ and N ₂ O emissions are incorporated in the total emissions amount for each gas of gasoline, diesel and LPG.	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. Therefore, the CH ₄ and N ₂ O emissions are incorporated in the total emissions amount for each gas of gasoline, diesel and LPG.
CH ₄	Other non-specified		For confidentiality reasons, military fuel use is not reported separately but included under the relevant categories in the energy sector.	
CH ₄	Municipal Sludge Disposal on Land	Municipal sludge disposal on land		
CO ₂	1.B.2.A.4 Refining / Storage		Included in fuel combustion sector.	
CO ₂	1.B.2.B.5.1 at industrial plants and power stations		Included in category 1.B.2.B.3 & 4	
CO ₂	1.B.2.B.5.2 in residential and commercial sectors		Included in category 1.B.2.B.3 & 4	
CO ₂	1.AA.1.B Petroleum Refining	The emissions from H ₂ production from NG were reallocated to the IP sector.	The emissions from H ₂ production from NG were reallocated to the IP sector.	The emissions from H ₂ production from NG were reallocated to the IP sector.
CO ₂	1.AA.2.B Non-Ferrous Metals	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).
CO ₂	SO ₂ scrubbing	Reallocated to IP 2.A.3 category.	Reallocated to IP 2.A.3 category.	Reallocated to IP 2.A.3 category.
CO ₂	Other non-specified		For confidentiality reasons, military fuel use is not reported separately but included under the relevant categories in the energy sector.	
CO ₂	5.A.1 Forest Land remaining Forest Land	5.A.1. - 5(V) - Biomass Burning - Wildfires	5.A.1. Carbon stock change	CO ₂ emissions due to wildfires in forest land remaining forest land are included in table 5.A.1., Carbon stock change in living biomass, Gains
N ₂ O	6.B.1 Industrial Wastewater			Emissions from sludge are reported in Industrial wastewater/wastewater
N ₂ O	6.B.2.1 Domestic and	IE		N ₂ O emissions are

Sources and sinks reported elsewhere (IE) ¹				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
	Commercial (w/o human sewage)			reported in Human sewage
N2O	1.AA.2.B Non-Ferrous Metals	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).	Reallocation from Energy to IP sector (as non-energy use of fuels).
N2O	1.AA.3.B Road Transportation		CH4 and N2O 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. Therefore, the CH4 and N2O emissions are incorporated in the total emissions amount for each gas of gasoline, diesel and LPG.	CH4 and N2O 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. Therefore, the CH4 and N2O emissions are incorporated in the total emissions amount for each gas of gasoline, diesel and LPG.
N2O	Other non-specified		For confidentiality reasons, military fuel use is not reported separately but included under the relevant categories in the energy sector.	