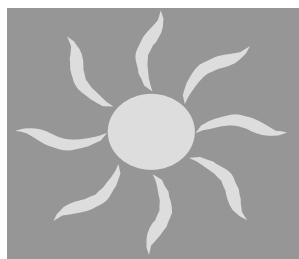


**MINISTRY OF ENVIRONMENT, ENERGY
AND CLIMATE CHANGE**

CLIMATE CHANGE



EMISSIONS INVENTORY

**ANNUAL INVENTORY SUBMISSION UNDER
THE CONVENTION AND THE KYOTO
PROTOCOL FOR GREENHOUSE AND OTHER
GASES FOR THE YEARS 1990-2010**

APRIL 2012

**ANNUAL INVENTORY SUBMISSION
UNDER THE CONVENTION AND
THE KYOTO PROTOCOL
FOR GREENHOUSE AND OTHER GASES
FOR YEARS 1990-2010**

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) and the LULUCF technical consultant), contains estimates of GHG emissions for the period 1990-2010. **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. The recommendations made by the Expert Review Team (ERT) during the Centralized Review of the GHG inventory submitted in 2011, held 29 August to 3 September 2011, have been taken into account as described in the present report.

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.

The compilation of the LULUCF inventory (UNFCCC and Kyoto Protocol) is a responsibility of the General Directorate for the Development and Protection of Forests and Natural Environment (GDDPFNE) of MEECC and is conducted by external consultant.

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 (ElStat), 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. Regarding LULUCF (UNFCCC scope) and Article 3.3 and 3.4 activities (KP LULUCF), the General Directorate for the Development and Protection of Forests of MEECC prepares the NIR and CRF tables for the above mentioned activities, which are incorporated by the inventory team to the NIR and CRF tables submitted to the MEECC Climate team for approval and submission.

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), the technical consultant for LULUCF 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 - 2010 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, but 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 107.23 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 2010, GHG emissions (without *LULUCF*) amounted to 118.29 Mt CO₂ eq showing an increase of 10.27 % compared to base year emissions and of 12.65% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the increase would be 10.43 % (from 102.46 Mt CO₂ eq in 1990 to 115.64 Mt CO₂ eq in 2010).

Carbon dioxide emissions accounted for 82.40% of total GHG emissions in 2010 (without *LULUCF*) and increased by approximately 17.01% from 1990. Methane emissions accounted for 8.28% of total GHG emissions in 2010 and decreased by 5.1% from 1990, while nitrous oxide emissions accounted for 6.22 % of the total GHG emissions in 2010 and decreased by 28.44% from 1990. Finally, F-gases emissions that accounted for 3.1% of total GHG emissions in 2010, increased by 9.02% from 1995 (base year for F-gases).

Table ES.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2000*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
A. GHG emissions per gas (excluding LULUCF)											
CO ₂	83301.00	83016.87	84718.81	84064.68	86339.80	86800.09	88917.19	93763.23	98671.77	98068.26	103210.17
CH ₄	10321.96	10276.63	10387.23	10369.93	10554.04	10580.86	10810.16	10716.54	10950.65	10865.81	10817.83
N ₂ O	10281.00	9978.05	9825.67	8952.02	8767.50	9033.48	9262.34	9042.57	8986.12	8898.09	8571.72
HFC	935.06	1106.82	908.39	1609.35	2150.52	3304.78	3844.18	4138.19	4638.51	5453.41	4345.18
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99
Total	105005.46	104545.70	106004.57	105096.30	107875.68	109776.76	112883.69	117771.93	123383.87	123379.76	127053.98
B. GHG emissions/removals from LULUCF											
CO ₂	-2571.00	-2657.11	-2958.90	-3313.84	-2937.17	-3274.50	-2857.52	-2742.97	-3057.28	-3216.25	-2935.72
CH ₄	26.90	16.76	50.13	39.99	39.20	19.61	15.50	28.31	67.64	6.05	95.19
N ₂ O	2.73	1.70	5.09	4.06	3.98	1.99	1.57	2.87	6.86	0.61	9.66
Total	-2541.37	-2638.65	-2903.68	-3269.80	-2893.99	-3252.89	-2840.46	-2711.79	-2982.78	-3209.58	-2830.87
C. GHG Emissions from International Transport											
CO ₂	10475.30	9478.60	10665.71	12212.33	13251.52	13862.55	12399.31	12343.16	13595.02	12685.32	13857.13
CH ₄	179.14	165.19	188.14	203.36	174.84	180.14	165.31	161.24	129.75	152.92	181.06
N ₂ O	574.83	545.18	646.67	704.95	693.40	767.69	661.37	651.82	597.71	616.43	686.81
Total	11229.27	10188.97	11500.52	13120.64	14119.76	14810.38	13225.99	13156.23	14322.47	13454.67	14725.01

Table ES.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2001-2010*

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
A. GHG emissions per gas (excluding LULUCF)										
CO ₂	105569.73	105216.19	109351.32	109635.71	113407.80	111928.39	114442.27	110707.29	104472.44	97468.85
CH ₄	10028.24	10047.00	10073.90	10113.24	10148.37	10189.71	10032.42	9988.42	9731.05	9794.61
N ₂ O	8395.15	8313.59	8236.60	8244.17	7942.56	7728.75	7911.16	7514.51	7058.04	7357.59
HFC	3964.27	4130.47	3930.35	4014.57	4086.28	2229.07	2574.46	2956.54	3356.11	3557.92
PFC	71.16	69.14	72.47	68.99	69.89	66.35	76.22	89.12	69.87	101.61
SF ₆	4.06	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14
Total	128032.61	127780.65	131668.89	132081.14	135661.35	132150.62	135046.45	131263.40	124692.77	118286.73
B. GHG emissions/removals from LULUCF										
CO ₂	-2786.57	-3079.29	-2766.77	-2965.92	-2896.74	-2957.87	-2383.65	-2751.34	-2836.79	-2649.58
CH ₄	15.37	2.49	3.40	8.53	4.90	9.64	167.23	20.26	20.94	7.06
N ₂ O	1.56	0.25	0.35	0.87	0.50	0.98	16.97	2.06	2.13	0.72
Total	-2769.64	-3076.55	-2763.02	-2956.53	-2891.34	-2947.25	-2199.45	-2729.02	-2813.72	-2641.81
C. GHG Emissions from International Transport										
CO ₂	13351.40	12214.71	13150.47	13327.28	11463.77	12661.00	12935.62	12808.67	10909.12	10735.60
CH ₄	184.97	225.09	200.39	234.39	114.04	123.87	158.13	119.77	104.31	16.39
N ₂ O	637.77	679.30	623.84	675.80	413.35	444.07	493.66	414.76	368.40	218.96
Total	14174.15	13119.10	13974.71	14237.47	11991.16	13228.95	13587.42	13343.19	11381.83	10970.96

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2010 are presented in **Table 2.2**.

- ↳ Emissions from *Energy* in 2010 (**Figure 2.1**) accounted for 78.80% of total GHG emissions (without LULUCF) and increased by approximately 20.21% compared to 1990 levels.

The living standards improvement due to the economic growth of the period 1990 – 2008, the important growth of the services sector, the introduction of natural gas in the Greek energy system and the economic recession starting in 2009 represent the basic factors affecting emissions trends from *Energy*.

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 0.9% 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 3.98% 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 1.99% 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 11% in 2010 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.

The majority of GHG emissions (56.0%) in 2010 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 24.7%, 7.3% and 10.6% respectively. The rest 1.5% of total GHG emissions from *Energy* derived from fugitive emissions from fuels. Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an average rate of increase of 2.3%, followed by energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) with a 1.1% and 1.0% average annual rate of increase, respectively. Emissions from manufacturing industries and construction emissions had a mean annual rate of decrease of 1.4%. Finally, fugitive emissions from fuels increased with an average annual rate of 1.5% for the period 1990 – 2010

The substantial increase of GHG emissions from road transport is directly linked to the increase of vehicles fleet but also to the increase of transportation activity. The renewal of the passenger car fleet and the implied improvement of energy efficiency, along with the improvement of public transport means limit the increase of GHG emissions.

- ↳ Emissions from *Industrial Processes* in 2010 accounted for 8.91% of the total emissions (without LULUCF) and increased by approximately 4.37% compared to 1990 levels. The deep decrease in this sector (mainly depicted in the CO₂ emissions) that took place in 2009 is attributed to economic recession, while in 2010 emissions remain at the same low levels. The intense fluctuation observed in the rest years of the time series are highly dependent on the HCFC-22 production until 2006 when the respective production has ceased. In the recent years emissions from the Consumption of Halocarbons and SF₆ have an increasingly important role,

enhanced by the decreased conventional industrial production. Emissions in 2010 show a slight increase, being 2.02% higher than the ones of 2009.

- ⇒ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.27% of the total emissions) and has increased by 2.54% compared to 1990 level of emissions.
- ⇒ Emissions from *Agriculture* that accounted for 7.85% of total emissions in 2010 (without *LULUCF*), decreased by approximately 19.17% 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 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* (4.17% of the total emissions, without *LULUCF*), decreased by approximately 11.50% from 1990. Greenhouse gases emissions from solid waste disposal on land present an increasing trend, 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.
- ⇒ The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2010. During this period, the *LULUCF* sector offset on average 2.2 % (1.6-3.1%) of the total national emissions (without *LULUCF*). The sink capacity of the *LULUCF* sector fluctuates between 2.2 Mt CO₂ eq. and 3.3 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 1990-2000*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	77538.63	77366.67	79104.68	78750.36	81084.34	81044.63	83263.16	87960.41	92785.54	92284.23	97167.30
Industrial processes	10100.90	10001.75	9876.86	10162.78	10650.25	12307.14	12966.54	13379.13	13985.95	14706.91	13846.85
Solvents	308.34	315.54	314.37	312.95	307.39	299.82	298.22	300.20	300.40	308.73	306.61
Agriculture	11483.24	11322.87	11086.56	10220.26	10035.38	10336.87	10480.53	10334.71	10347.17	10194.17	9956.34
Waste	5574.35	5538.87	5622.11	5649.95	5798.32	5788.29	5875.25	5797.47	5964.81	5885.72	5776.89
Total ¹⁾	105005.46	104545.70	106004.57	105096.30	107875.68	109776.76	112883.69	117771.93	123383.87	123379.76	127053.98
LULUCF	-2541.37	-2638.65	-2903.68	-3269.80	-2893.99	-3252.89	-2840.46	-2711.79	-2982.78	-3209.58	-2830.87
Index per sector											
Energy	100.00	99.78	102.02	101.56	104.57	104.52	107.38	113.44	119.66	119.02	125.31
Industrial processes	100.00	99.02	97.78	100.61	105.44	121.84	128.37	132.45	138.46	145.60	137.09
Solvents	100.00	102.33	101.95	101.49	99.69	97.24	96.72	97.36	97.42	100.13	99.44
Agriculture	100.00	98.60	96.55	89.00	87.39	90.02	91.27	90.00	90.11	88.77	86.70
Waste	100.00	99.36	100.86	101.36	104.02	103.84	105.40	104.00	107.00	105.59	103.63
Total ²⁾	100.00	99.56	100.95	100.09	102.73	104.54	107.50	112.16	117.50	117.50	121.00

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 2001-2010*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Energy	99603.51	99419.00	103379.12	103652.91	106842.82	105592.36	108195.62	104915.56	100491.25	93212.74
Industrial processes	13328.58	13379.86	13299.66	13374.00	13998.88	11754.72	12014.76	11887.28	10262.74	10542.02
Solvents	304.28	305.13	305.93	306.75	309.29	311.92	313.41	314.13	315.60	316.17
Agriculture	9859.75	9828.56	9764.65	9847.87	9555.08	9388.59	9603.27	9223.42	8939.37	9282.22
Waste	4936.49	4848.11	4919.53	4899.62	4955.28	5103.03	4919.39	4923.01	4683.80	4933.57
Total ¹⁾	128032.61	127780.65	131668.89	132081.14	135661.35	132150.62	135046.45	131263.40	124692.77	118286.73
LULUCF	-2769.64	-3076.55	-2763.02	-2956.53	-2891.34	-2947.25	-2199.45	-2729.02	-2813.72	-2641.81
Index per sector										
Energy	128.46	128.22	133.33	133.68	137.79	136.18	139.54	135.31	129.60	120.21
Industrial processes	131.95	132.46	131.67	132.40	138.59	116.37	118.95	117.69	101.60	104.37
Solvents	98.68	98.96	99.22	99.48	100.31	101.16	101.64	101.88	102.36	102.54
Agriculture	85.86	85.59	85.03	85.76	83.21	81.76	83.63	80.32	77.85	80.83
Waste	88.56	86.97	88.25	87.90	88.89	91.54	88.25	88.32	84.02	88.50
Total ²⁾	121.93	121.69	125.39	125.79	129.19	125.85	128.61	125.01	118.75	112.65

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 present report contains also estimates of nitrogen oxides (NO_x), carbon monoxide (CO), non-methane organic volatile compounds (NMVOC) and sulphur dioxide (SO₂) emissions for the period 1990-2010.

The key features of emissions trends for indirect greenhouse gases and SO₂ are the following:

- ↪ NO_x emissions decreased by 2.36% from 1990 to 2010. Energy sector accounts for the high majority of emissions (99.26%). 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 46.77% of total NO_x emissions in 2010). Emissions from *Industrial processes* decreased by 45.23% 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 62.84% from 1990 to 2010 and as a result total CO emissions in 2010 decreased by 53.35%. Emissions from industrial processes in 2010 decreased by 1.87% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2010 emissions from *LULUCF* accounted for 1.27% of total CO emissions (incl *LULUCF*), and are by 34.97% lower than emissions of 1990.
- ↪ NMVOC emissions decreased by 31.48% from 1990 to 2010. Emissions from transport (25.83% of total NMVOC emissions in 2010), decreased by 65.76% compared to 1990 levels, while emissions from *Energy* decreased by 42.46% from 1990 to 2010. The significant increase of NMVOC emissions from *Industrial processes* (approximately 24.90% from 1990 to 2010) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 4.10% compared to 1990 levels.
- ↪ SO₂ emissions decreased by 44.28% from 1990 to 2010. Emissions from energy, which is the main source of SO₂ emissions in Greece (98.14 % of total SO₂ emissions for 2010), decreased with a mean annual rate of decrease of 2.21% for the period 1990 – 2010. 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 87.48% for the period 1990 – 2010. Emissions from *Industrial processes* decreased by 41% 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.

The compilation of the LULUCF inventory (UNFCCC and Kyoto Protocol) is a responsibility of the General Directorate for the Development and Protection of Forests and Natural Environment (GDDPFNE) of MEECC and is conducted by external consultant.

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” and modified accordingly. 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.

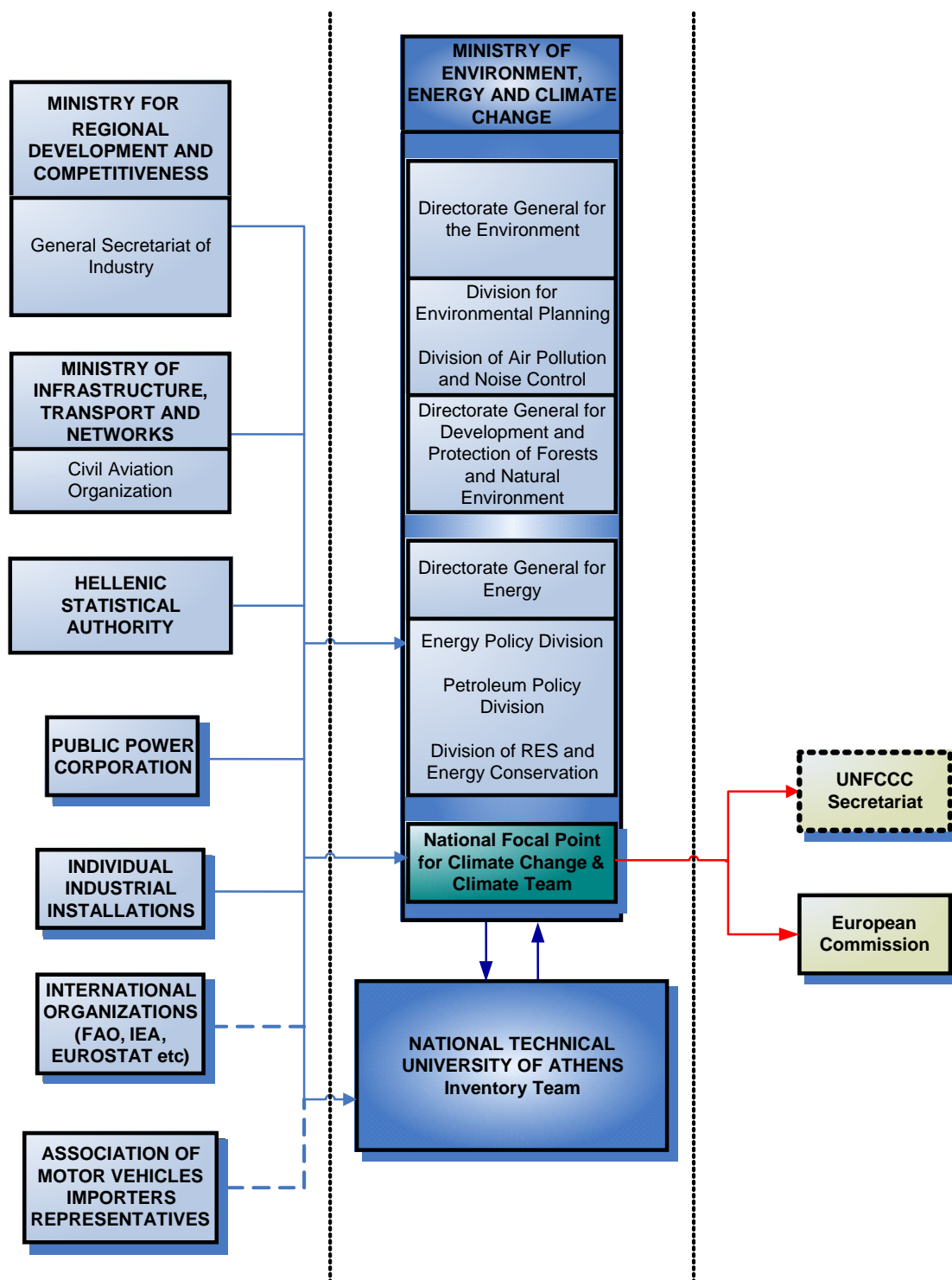


Figure 1.1 *Organizational Structure of the National Inventory System*

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.

Furthermore, for expanding the overseeing role of MEECC in the inventory process, the supervision of QA/QC system is performed by the QA/QC responsible, an expert from the National Center for the Environment and Sustainable Development (NCESD), which is supervised by MEECC. The QA/QC responsible is not involved in the day-to-day inventory preparation and

compilation. In co-operation with the scientific responsible of NTUA team and the NTUA inventory sector experts, he is responsible for the sound performance of the QA/QC system.

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, and Waste.
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
Address: National Technical University of Athens, School of Chemical Engineering,
Heroon Polytechniou 9, Zografos, 157 80 Athens, Greece.
E-mail: ziomas@chemeng.ntua.gr
Tel: +30 210 772 2358
FAX: +30 210 772 3155
2. Ioannis Sempas (Sebos)
Chemical Engineer, MBA, PhD
E-mail: isebos@mail.ntua.gr
Tel: +30 210 772 3240
FAX: +30 210 772 3155
3. Athina Progiou
Dr Mechanical Engineer
E-mail: athenaproyou@axonenviro.gr
Tel: +30 210 8223083
Fax: +30 210 8238604
4. Spyridoula Ntemiri
Chemical Engineer, PhD
E-mail: spyrdem@chemeng.ntua.gr
Tel: +30 210 772 3149
FAX: +30 210 772 3155
5. Leonidas Kallinikos
Chemical Engineer, PhD
E-mail: leokalls@central.ntua.gr
Tel: +30 210 772 3240
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: Konstantinos Chatzigianakis, Ioannis Macheras, Argyro Zerva, Chrysoula Karakosta) 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)
 - emissions / removals from LULUCF activities (UNFCCC scope), along with emissions / removals from activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol (KP). The above-mentioned KP activities are afforestation, reforestation and deforestation, which are mandatory according to Article 3.3, along with the elected one forest land management, according to Article 3.4. (General Directorate for the Development and Protection of Forests and Natural Environment). Moreover, the General Directorate for the Development and Protection of Forests prepares the NIR and CRF tables for the above mentioned activities (UNFCCC and KP LULUCF), which are incorporated by the inventory

team to the NIR and CRF tables submitted to the MEECC Climate team for approval and submission.

- 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).

1.2.2.4 Technical consultant for LULUCF

The compilation of the LULUCF inventory (UNFCCC and KP LULUCF) is a responsibility of the General Directorate for the Development and Protection of Forests and Natural Environment (GDDPFNE) of MEECC and is conducted by external consultant. The technical consultant for LULUCF prepares the NIR and CRF tables for the above mentioned activities (UNFCCC and KP LULUCF), which are incorporated by the NTUA team to the NIR and CRF tables submitted to the MEECC Climate team for approval and submission.

The technical consultant contracted for LULUCF inventory is :

1. Babis (Charalampos) Petsikos, Forester
E-mail: babis@amegilla.gr
Tel: +30 2251020994
FAX: +30 2251020994

The technical consultant has acknowledged the supportive work of:

1. Michael Karatzas, Forester – Environmental Engineer
E-mail: michael@amegilla.gr
Tel: +30 2251020994
FAX: +30 2251020994
2. Christina Zografou, Environmentalist
E-mail: christina@amegilla.gr
Tel: +30 2251020994
FAX: +30 2251020994

In this framework, the technical consultant for LULUCF has the following responsibilities / tasks to fulfil for the GHG inventory preparation:

1. Data collection (activity data and emission factors) for LULUCF activities.
2. Reliability check of input data through the comparison of the same or similar data from alternative data sources and
3. Time-series assessment in order to identify changes that cannot be explained.
4. Selection of the appropriate methodologies according to IPCC guidelines, preparation of GHG emissions estimates by applying the methodologies and models having been selected.
5. Data processing and archiving.
6. Assessment of the consistency of the methodologies applied, inventory improvement – recalculations.
7. Reliability check of results.
8. Uncertainty estimation of the LULUCF sector.

9. Preparation of Common Reporting Format (CRF) tables.
10. Preparation of LULUCF part of the National Inventory Report (NIR).
11. Implementing the QA/QC procedures under the supervision of MEECC.

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. Regarding LULUCF (UNFCCC scope) and Article 3.3 and 3.4 activities (KP LULUCF), the General Directorate for the Development and Protection of Forests of MEECC prepares the NIR and CRF tables for the above mentioned activities, which are incorporated by the inventory team to the NIR and CRF tables submitted to the MEECC Climate team for approval and submission.

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), the technical consultant for LULUCF 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.

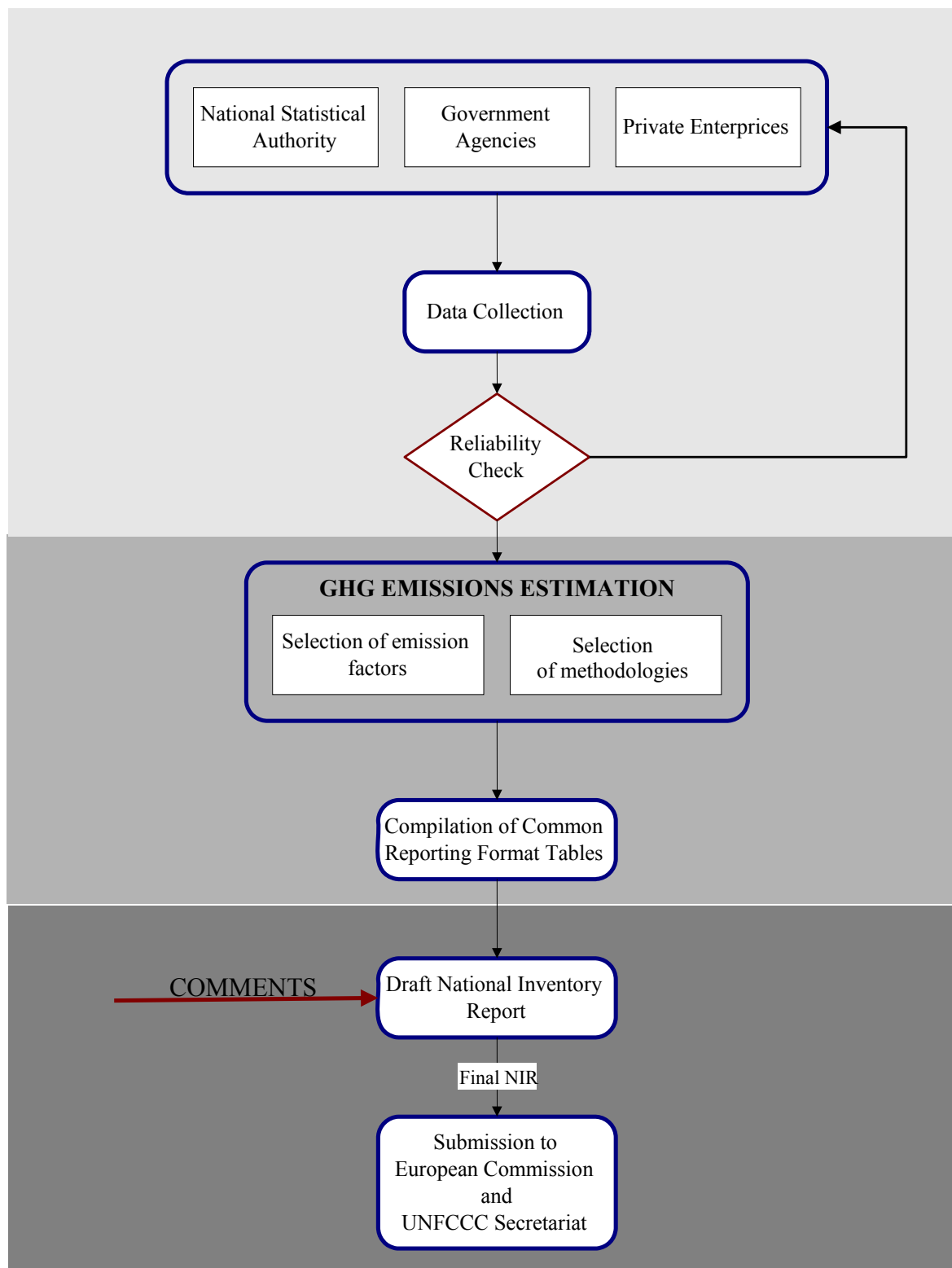


Figure 1.2 *GHG emissions inventory preparation process in Greece*

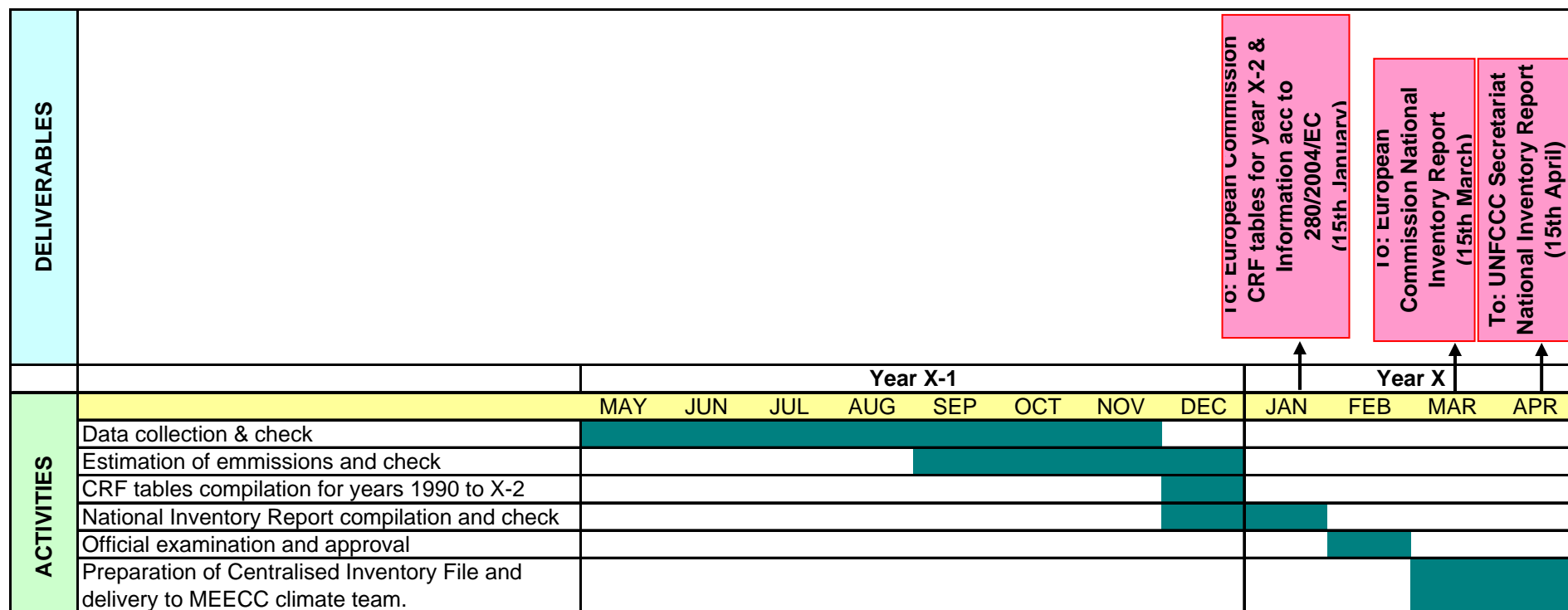


Figure 1.3 *Timetable for the preparation and submission of GHG emissions/removals inventory in Greece*

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	NA, T1, T1a	NA,PS	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				

	CO2		CH4		N2O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
D. Agricultural soils			NA	NA	D,T1,T1a,T1b	CS,D		
F. Field burning of agricultural residues			D	D	D	D		
5. Land Use, Land Use Change and Forestry								
A. Forest land	T1,T2	CS,D	T1	D	T1	D		
B. Cropland	T1,T2	CS,D	NA	NA	NA	NA		
C. Grassland	T2	CS	T1	D	T1	D		
D. Wetlands	T2, NA	CS, NA	NA	NA	NA	NA		
E. Settlements	T2	CS	NA	NA	NA	NA		
F. Other Land	T2	CS	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	T1	D	NA	NA	NA	NA		
KP.A.2. Deforestation	T2	CS	NA	NA	NA	NA		
KP.B.1. Forest Management	T2	CS	T1	CS, D	T1	CS, 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 2005-2010 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 2010 are presented in **Table 1.4**. There are important differences compared to the results of the analysis

presented in the previous submissions. These differences refer to the number and the identity of the key categories and are closely connected to the breaking up of larger categories in the Energy and the Agriculture Sectors, following the suggestions of the ERT during the 2010 centralised review.

Twelve key source categories are found in the energy sector and six in the IP sector in 2010 (without *LULUCF*).

Table 1.4 *Key categories for the Greek inventory system without LULUCF for 2010*

Source categories	Gas	Criteria
Energy		
Energy industries – Solid fuels	CO ₂	Level, Trend
Energy industries – Liquid fuels	CO ₂	Level, Trend
Energy industries – Gaseous fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO ₂	Level, 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 – Aviation	CO ₂	Level, Trend
Coal mining and handling	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Lime production	CO ₂	Trend
Limestone and dolomite use	CO ₂	Trend
Nitric acid production	N ₂ O	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, Trend
Enteric fermentation – Other	CH ₄	Level
Agricultural soils – Direct emissions	N ₂ O	Level, Trend
Agricultural soils – Animal production	N ₂ O	Level, Trend
Agricultural soils – Indirect emissions	N ₂ O	Level, Trend
Waste		
Solid waste disposal on land	CH ₄	Level, Trend
Wastewater handling	CH ₄	Level, Trend

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 2010 are presented in **Table 1.5** (see Annex I for an analytic presentation of calculations). The comparison of the results of the

analysis with and without *LULUCF* reveals no major differences in the source categories identified (apart from the categories from the *LULUCF* sector).

In the analysis including *LULUCF* twelve categories from the Energy Sector and seven from the IP Sector have been identified as key.

Table 1.5 *Key categories for the Greek inventory system with LULUCF for 2010*

Source categories	Gas	Criteria
Energy		
Energy industries – Solid fuels	CO ₂	Level
Energy industries– Liquid fuels	CO ₂	Level, Trend
Energy industries – Gaseous fuels	CO ₂	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO ₂	Level, 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 – Aviation	CO ₂	Level, Trend
Coal mining and handling	CH ₄	Level
Other Sectors - Liquid fuels	CO ₂	Level, Trend
Other Sectors – Gaseous fuels	CO ₂	Level, Trend
Industrial processes		
Cement production	CO ₂	Level, Trend
Lime production	CO ₂	Trend
Limestone and dolomite use	CO ₂	Level, Trend
Nitric acid production	N ₂ O	Trend
Other chemicals	CO ₂	Trend
Ferroalloys production	CO ₂	Level
Ozone depleting substances substitutes	F-gases	Level, Trend
Agriculture		
Enteric fermentation – Non dairy cattle	CH ₄	Level
Enteric fermentation – Sheep	CH ₄	Level, Trend
Enteric fermentation – Other	CH ₄	Level
Agricultural soils – Direct emissions	N ₂ O	Level, Trend
Agricultural soils – Animal production	N ₂ O	Level, Trend
Agricultural soils – Indirect emissions	N ₂ O	Level, Trend
Waste		
Solid waste disposal on land	CH ₄	Level, Trend
Wastewater handling	CH ₄	Level, Trend
LULUCF		
Forest land remaining forest land	CO ₂	Level, Trend
Cropland remaining cropland	CO ₂	Trend
Conversion to forestland	CO ₂	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. Afforestation/ Reforestation 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			
Afforestation / Reforestation	CO ₂	Trend	Land converted to Forest Land
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.

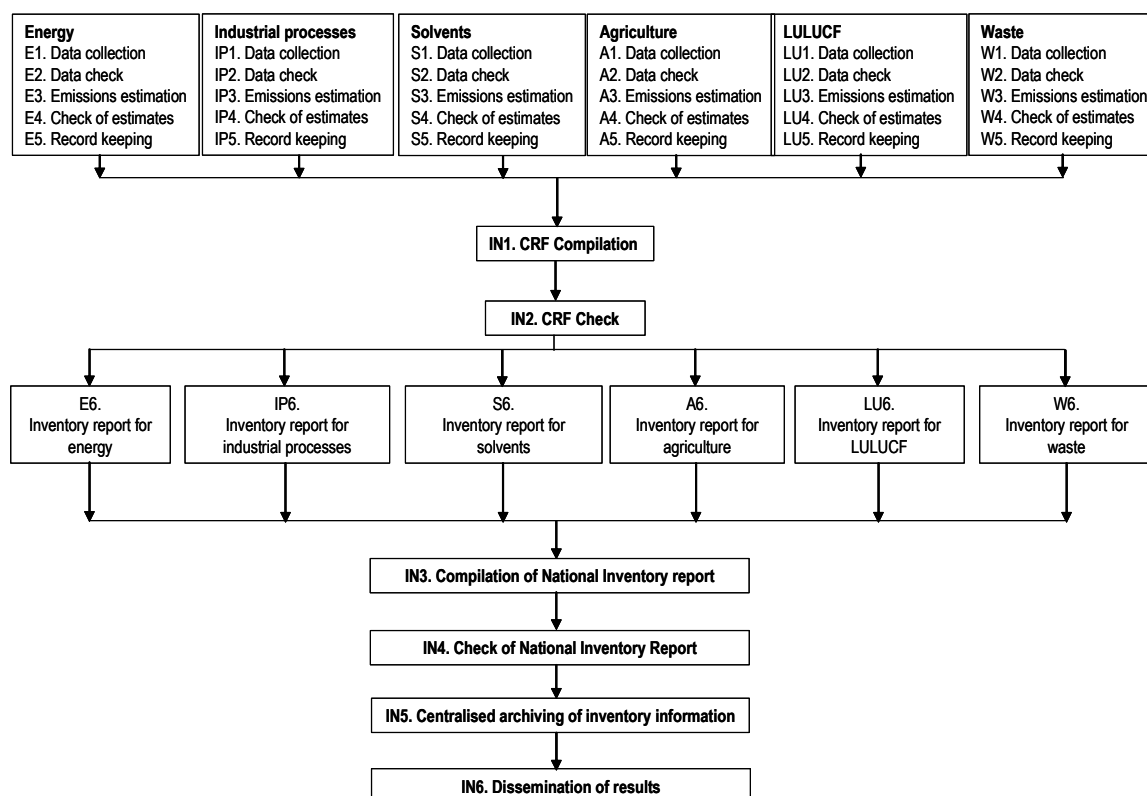


Figure 1.4 *Flow chart activities concerning the GHG emissions inventory*

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

The implementation of the plan started in April 2004 and the first internal review was carried out in June 2004, following procedures and manuals (available only in Greek) developed by in house staff and outside consultants. The current in use version of the QA/QC manual was revised in May 2008. All the procedures described there, are followed by both the MEECC and the NTUA staff members.

Moreover, as described in the next chapters and in the sections 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 September and November of each year and audits by independent local experts are planned and implemented.

The most important results of these audits and the main recommendations of the ERT 2011 Centralised Review are presented in **Table 1.8**. As described in the next chapters these findings were addressed in this submission.

Table 1.8 Findings and recommendations from reviews / audits of GHG inventory system

Sector	Areas of Further Improvement
General	<ol style="list-style-type: none"> 1. Information to be reported in the NIR to confirm whether the EU ETS data have been prepared and incorporated in the inventory submission in line with the IPCC good practice guidance. 2. Implement sector-specific QA/QC procedures for all key categories.
Energy	<ol style="list-style-type: none"> 3. Enhance transparency of the energy sector by providing in the NIR more information about the use of EU-ETS reporting, EFs, alternative fuels used in cement plants, carbon content of refinery gas, etc. 4. Through the comparison of Sectoral .vs. Reference approach, an error was located concerning the activity data used in calculations in Public electricity and heat production (CRF Source Category 1.A.1.a) – solid fuels for the year 2008. 5. Through the comparison of Sectoral .vs. Reference approach, an error was located concerning the activity data used in calculations in Public electricity and heat production (CRF Source Category 1.A.1.a) – gaseous fuels for the year 2009. 6. Reallocate H2 production from Energy to the IP sector. 7. Use CS EF for NG combustion in the road transport sector. 8. Correct the tables 1A(b), 1A(c) and 1A(d), so that fuels used as feedstocks to be reported consistently.
Industrial Processes	<ol style="list-style-type: none"> 9. Report publicly available Activity Data concerning Aluminium Production 10. The trend of the timeseries for Limestone and Dolomite Use shows an abrupt peak in 2005. The detailed ETS data have been re-entered and re-checked in the working files and emissions have been re-evaluated. Although minor errors have been corrected in years 2005-2007, there is no significant difference in the estimated trend. 11. Concerning Lime production, through comparison with ETS data an error has been detected concerning one plant's reporting emissions in 2005. 12. Report revised estimates for Soda Ash Use and transparently document the methodologies used. 13. Reallocate H2 production from Energy to IP Sector. 14. Use updated data, detailed methodologies and the corresponding recalculation methodologies to estimate CO2 emissions from Aluminium Production (in collaboration with the sole plant operating in Greece). 15. During the internal QA/QC procedures an error was located in the PFCs from Aluminium Production (error in copy/pasting data from working files to CRF Reporter). 16. In the framework of the national Inventory Improvement Plan, and in view of the Refrigeration and A/C equipment being a constant key category with increased emissions each year, new procedures are being implemented to improve the data collection, increase transparency and improve accuracy of the estimations from the respective category, in collaboration with Experts from the Sector 17. During the internal QA/QC procedures various improvements have been performed in the currently estimated Fgases emissions from Category 2.F.1. These include update of data, improving the accuracy of the methodology used by taking into account the different F-gases penetration and blend distribution rates in production and import of equipment and estimate emissions from disposal for the first time in some categories. 18. Refer to the assumptions, methodologies, AD and EF to estimate emissions from HFCs from Foam Blowing in NIR.
Agriculture	<ol style="list-style-type: none"> 19. Update activity data of animal population

Waste	20. Update activity data of nitrogen fertilizers
	21. Update activity data of crop production
	22. Inclusion of emissions from the Industrial solid waste
	23. Inclusion of emissions from the Construction and demolition solid waste
	24. Use of country specific factors for each industrial sector on the estimation of COD produced
	25. Inclusion of emissions from additional subsectors, these from the incineration of biogenic agricultural residues produced in slaughterhouses and from the incineration of small amounts of industrial chemical waste

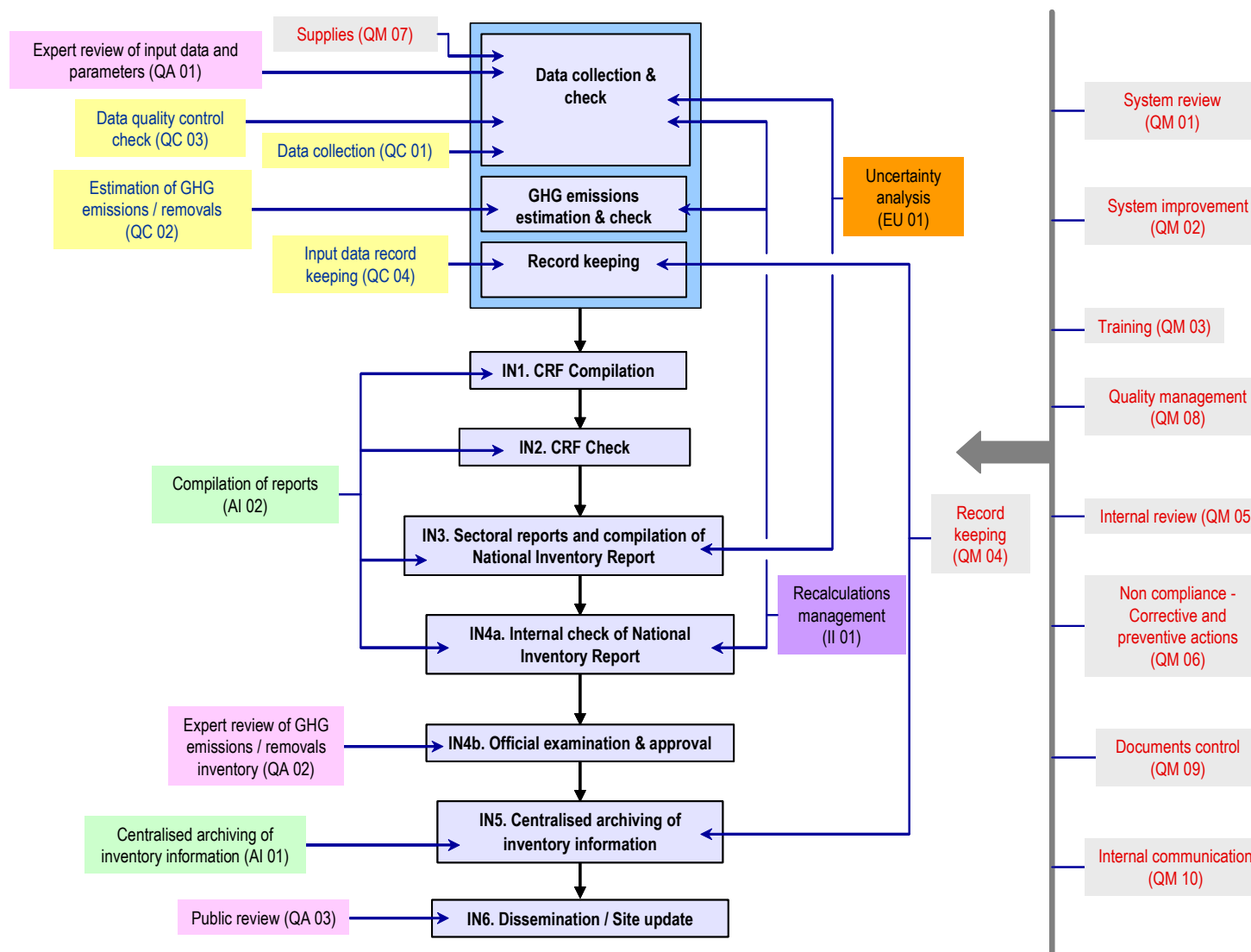


Figure 1.5 *QA/QC processes and procedures and inventory related activities*

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 current 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 2010, were estimated at:

2.5% for CO₂ emissions

42.2% for CH₄ emissions

94.1% for N₂O emissions and

168.3% for the F-gases emissions.

Table 1.9 *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 1.9(cont.) Uncertainty estimates per source category and gas (without LULUCF)

Source categories	Gas	Uncertainty (%)
Construction and Demolition Waste (Managed Waste Disposal on Land)	CH ₄	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	N ₂ O	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
PFC from Refrigeration and Air Conditioning Equipment		180.3
SF6 from electrical equipment		53.9
Total F-gases		168.3
Total uncertainty (%)		8.82

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 8.82% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 9.63%. 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 2010, were estimated at (the detailed calculations are presented in Annex IV):

- ↳ 2.7% for CO₂ emissions,
- ↳ 42.2% for CH₄ emissions,
- ↳ 94.1% for N₂O emissions and
- ↳ 168.3% for the F-gases emissions.

Total uncertainty is 9.05%, while the uncertainty that carried over into the GHG emissions trend is 9.90%.

Table 1.10 *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 1.11 *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 1990-2010 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 from *organic chemicals production* and *asphalt roofing-road paving with asphalt* are not estimated due to lack of emission factors in the IPCC GPG.
- ✦ *Potential emissions* of F-gases are not estimated as, for the time being, imports/exports of the relative chemical compounds are not recorded separately by the El. Stat.

It should be noted however that, during the implementation of the 2012 Improvement Plan, the inventory team has been able to come into contact and collaboration with the National Association of Refrigeration Importing & Trading Companies. In this framework the possibility of acquiring data on the imports/exports and use of the specific gases has been examined. So far the data collection process has not permitted the reporting of such information, but in any case the results will be used as appropriate 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 - 2010 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, but 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 107.23 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 2010, GHG emissions (without *LULUCF*) amounted to 118.29 Mt CO₂ eq showing an increase of 10.27 % compared to base year emissions and of 12.65% compared to 1990 levels. If emissions / removals from *LULUCF* were to be included then the increase would be 10.43 % (from 102.46 Mt CO₂ eq in 1990 to 115.64 Mt CO₂ eq in 2010).

Carbon dioxide emissions accounted for 82.40% of total GHG emissions in 2010 (without *LULUCF*) and increased by approximately 17.01% from 1990. Methane emissions accounted for 8.28% of total GHG emissions in 2010 and decreased by 5.1% from 1990, while nitrous oxide emissions accounted for 6.22 % of the total GHG emissions in 2010 and decreased by 28.44% from 1990. Finally, F-gases emissions that accounted for 3.1% of total GHG emissions in 2010, increased by 9.02% from 1995 (base year for F-gases).

Table 2.1a *Total GHG emissions in Greece (in kt CO₂ eq) for the period 1990-2000*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
A. GHG emissions per gas (excluding LULUCF)											
CO ₂	83301.00	83016.87	84718.81	84064.68	86339.80	86800.09	88917.19	93763.23	98671.77	98068.26	103210.17
CH ₄	10321.96	10276.63	10387.23	10369.93	10554.04	10580.86	10810.16	10716.54	10950.65	10865.81	10817.83
N ₂ O	10281.00	9978.05	9825.67	8952.02	8767.50	9033.48	9262.34	9042.57	8986.12	8898.09	8571.72
HFC	935.06	1106.82	908.39	1609.35	2150.52	3304.78	3844.18	4138.19	4638.51	5453.41	4345.18
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99
Total	105005.46	104545.70	106004.57	105096.30	107875.68	109776.76	112883.69	117771.93	123383.87	123379.76	127053.98
B. GHG emissions/removals from LULUCF											
CO ₂	-2571.00	-2657.11	-2958.90	-3313.84	-2937.17	-3274.50	-2857.52	-2742.97	-3057.28	-3216.25	-2935.72
CH ₄	26.90	16.76	50.13	39.99	39.20	19.61	15.50	28.31	67.64	6.05	95.19
N ₂ O	2.73	1.70	5.09	4.06	3.98	1.99	1.57	2.87	6.86	0.61	9.66
Total	-2541.37	-2638.65	-2903.68	-3269.80	-2893.99	-3252.89	-2840.46	-2711.79	-2982.78	-3209.58	-2830.87
C. GHG Emissions from International Transport											
CO ₂	10475.30	9478.60	10665.71	12212.33	13251.52	13862.55	12399.31	12343.16	13595.02	12685.32	13857.13
CH ₄	179.14	165.19	188.14	203.36	174.84	180.14	165.31	161.24	129.75	152.92	181.06
N ₂ O	574.83	545.18	646.67	704.95	693.40	767.69	661.37	651.82	597.71	616.43	686.81
Total	11229.27	10188.97	11500.52	13120.64	14119.76	14810.38	13225.99	13156.23	14322.47	13454.67	14725.01

Table 2.1b *Total GHG emissions in Greece (in kt CO₂ eq) for the period 2001-2010*

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
A. GHG emissions per gas (excluding LULUCF)										
CO ₂	105569.73	105216.19	109351.32	109635.71	113407.80	111928.39	114442.27	110707.29	104472.44	97468.85
CH ₄	10028.24	10047.00	10073.90	10113.24	10148.37	10189.71	10032.42	9988.42	9731.05	9794.61
N ₂ O	8395.15	8313.59	8236.60	8244.17	7942.56	7728.75	7911.16	7514.51	7058.04	7357.59
HFC	3964.27	4130.47	3930.35	4014.57	4086.28	2229.07	2574.46	2956.54	3356.11	3557.92
PFC	71.16	69.14	72.47	68.99	69.89	66.35	76.22	89.12	69.87	101.61
SF ₆	4.06	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14
Total	128032.61	127780.65	131668.89	132081.14	135661.35	132150.62	135046.45	131263.40	124692.77	118286.73
B. GHG emissions/removals from LULUCF										
CO ₂	-2786.57	-3079.29	-2766.77	-2965.92	-2896.74	-2957.87	-2383.65	-2751.34	-2836.79	-2649.58
CH ₄	15.37	2.49	3.40	8.53	4.90	9.64	167.23	20.26	20.94	7.06
N ₂ O	1.56	0.25	0.35	0.87	0.50	0.98	16.97	2.06	2.13	0.72
Total	-2769.64	-3076.55	-2763.02	-2956.53	-2891.34	-2947.25	-2199.45	-2729.02	-2813.72	-2641.81
C. GHG Emissions from International Transport										
CO ₂	13351.40	12214.71	13150.47	13327.28	11463.77	12661.00	12935.62	12808.67	10909.12	10735.60
CH ₄	184.97	225.09	200.39	234.39	114.04	123.87	158.13	119.77	104.31	16.39
N ₂ O	637.77	679.30	623.84	675.80	413.35	444.07	493.66	414.76	368.40	218.96
Total	14174.15	13119.10	13974.71	14237.47	11991.16	13228.95	13587.42	13343.19	11381.83	10970.96

2.2 Description and interpretation of emission trends by category

GHG emissions trends by sector for the period 1990 - 2010 are presented in *Table 2.2*.

- ↳ Emissions from *Energy* in 2010 (*Figure 2.1*) accounted for 78.80% of total GHG emissions (without LULUCF) and increased by approximately 20.21% compared to 1990 levels.

The living standards improvement due to the economic growth of the period 1990 – 2008, the important growth of the services sector, the introduction of natural gas in the Greek energy system and the economic recession starting in 2009 represent the basic factors affecting emissions trends from *Energy*.

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 0.9% 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 3.98% 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 1.99% 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 11% in 2010 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.

The majority of GHG emissions (56.0%) in 2010 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 24.7%, 7.3% and 10.6% respectively. The rest 1.5% of total GHG emissions from *Energy* derived from fugitive emissions from fuels. Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an average rate of increase of 2.3%, followed by energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) with a 1.1% and 1.0% average annual rate of increase, respectively. Emissions from manufacturing industries and construction emissions had a mean annual rate of decrease of 1.4%. Finally, fugitive emissions from fuels increased with an average annual rate of 1.5% for the period 1990 – 2010

The substantial increase of GHG emissions from road transport is directly linked to the increase of vehicles fleet but also to the increase of transportation activity. The renewal of the passenger car fleet and the implied improvement of energy efficiency, along with the improvement of public transport means limit the increase of GHG emissions.

- ↳ Emissions from *Industrial Processes* in 2010 accounted for 8.91% of the total emissions (without LULUCF) and increased by approximately 4.37% compared to 1990 levels. The deep decrease in this sector (mainly depicted in the CO₂ emissions) that took place in 2009 is attributed to economic recession, while in 2010 emissions remain at the same low levels. The intense fluctuation observed in the rest years of the time series are highly dependent on the HCFC-22 production until 2006 when the respective production has ceased. In the recent years

emissions from the Consumption of Halocarbons and SF₆ have an increasingly important role, enhanced by the decreased conventional industrial production. Emissions in 2010 show a slight increase, being 2.02% higher than the ones of 2009.

- ⇒ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.27% of the total emissions) and has increased by 2.54% compared to 1990 level of emissions.
- ⇒ Emissions from *Agriculture* that accounted for 7.85% of total emissions in 2010 (without *LULUCF*), decreased by approximately 19.17% 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 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* (4.17% of the total emissions, without *LULUCF*), decreased by approximately 11.50% from 1990. Greenhouse gases emissions from solid waste disposal on land present an increasing trend, 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.
- ⇒ The Land Use, Land Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2010. During this period, the *LULUCF* sector offset on average 2.2 % (1.6-3.1%) of the total national emissions (without *LULUCF*). The sink capacity of the *LULUCF* sector fluctuates between 2.2 Mt CO₂ eq. and 3.3 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.

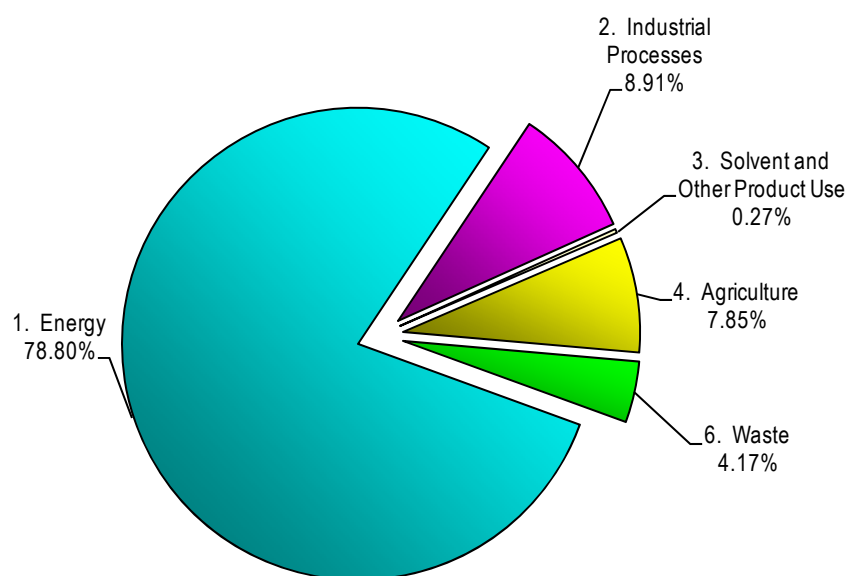


Figure 2.1 *Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2010*

Table 2.2a *Total GHG emissions (in kt CO₂ eq) by sector for the period 1990-2000*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	77538.63	77366.67	79104.68	78750.36	81084.34	81044.63	83263.16	87960.41	92785.54	92284.23	97167.30
Industrial processes	10100.90	10001.75	9876.86	10162.78	10650.25	12307.14	12966.54	13379.13	13985.95	14706.91	13846.85
Solvents	308.34	315.54	314.37	312.95	307.39	299.82	298.22	300.20	300.40	308.73	306.61
Agriculture	11483.24	11322.87	11086.56	10220.26	10035.38	10336.87	10480.53	10334.71	10347.17	10194.17	9956.34
Waste	5574.35	5538.87	5622.11	5649.95	5798.32	5788.29	5875.25	5797.47	5964.81	5885.72	5776.89
Total ¹⁾	105005.46	104545.70	106004.57	105096.30	107875.68	109776.76	112883.69	117771.93	123383.87	123379.76	127053.98
LULUCF	-2541.37	-2638.65	-2903.68	-3269.80	-2893.99	-3252.89	-2840.46	-2711.79	-2982.78	-3209.58	-2830.87
Index per sector											
Energy	100.00	99.78	102.02	101.56	104.57	104.52	107.38	113.44	119.66	119.02	125.31
Industrial processes	100.00	99.02	97.78	100.61	105.44	121.84	128.37	132.45	138.46	145.60	137.09
Solvents	100.00	102.33	101.95	101.49	99.69	97.24	96.72	97.36	97.42	100.13	99.44
Agriculture	100.00	98.60	96.55	89.00	87.39	90.02	91.27	90.00	90.11	88.77	86.70
Waste	100.00	99.36	100.86	101.36	104.02	103.84	105.40	104.00	107.00	105.59	103.63
Total ²⁾	100.00	99.56	100.95	100.09	102.73	104.54	107.50	112.16	117.50	117.50	121.00

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 2001-2010*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Energy	99603.51	99419.00	103379.12	103652.91	106842.82	105592.36	108195.62	104915.56	100491.25	93212.74
Industrial processes	13328.58	13379.86	13299.66	13374.00	13998.88	11754.72	12014.76	11887.28	10262.74	10542.02
Solvents	304.28	305.13	305.93	306.75	309.29	311.92	313.41	314.13	315.60	316.17
Agriculture	9859.75	9828.56	9764.65	9847.87	9555.08	9388.59	9603.27	9223.42	8939.37	9282.22
Waste	4936.49	4848.11	4919.53	4899.62	4955.28	5103.03	4919.39	4923.01	4683.80	4933.57
Total ¹⁾	128032.61	127780.65	131668.89	132081.14	135661.35	132150.62	135046.45	131263.40	124692.77	118286.73
LULUCF	-2769.64	-3076.55	-2763.02	-2956.53	-2891.34	-2947.25	-2199.45	-2729.02	-2813.72	-2641.81
Index per sector										
Energy	128.46	128.22	133.33	133.68	137.79	136.18	139.54	135.31	129.60	120.21
Industrial processes	131.95	132.46	131.67	132.40	138.59	116.37	118.95	117.69	101.60	104.37
Solvents	98.68	98.96	99.22	99.48	100.31	101.16	101.64	101.88	102.36	102.54
Agriculture	85.86	85.59	85.03	85.76	83.21	81.76	83.63	80.32	77.85	80.83
Waste	88.56	86.97	88.25	87.90	88.89	91.54	88.25	88.32	84.02	88.50
Total ²⁾	121.93	121.69	125.39	125.79	129.19	125.85	128.61	125.01	118.75	112.65

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 2010 by source category is presented in **Table 2.3**. Total CO₂ emissions increased from 83.30 Mt in 1990 to 97.47 Mt in 2010 (without LULUCF). The increase of 17.01 % from 1990 to 2010 is mainly attributed to the increased electricity production as well as to the increased energy consumption in the residential and transport sectors. The decrease in 2010 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* increase, from 75.24 Mt in 1990 to 90.86 Mt in 2010, presenting a total increase of 20.75% from 1990 to 2010. Carbon dioxide emissions from *Industrial processes* in 2010 decreased by 18.28% compared to 1990 levels and from *Solvents and other products use* decreased by 4.76% compared to 1990 levels. Finally, emissions from *Waste* in 2009 show a continuous increase from 1990. (**Figure 2.2**).

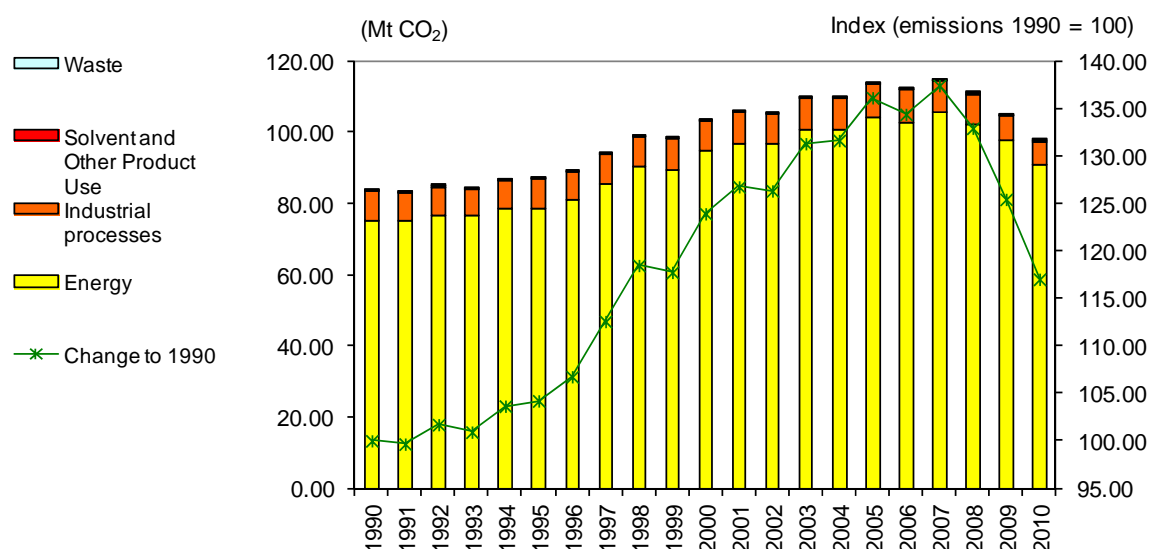


Figure 2.2 CO₂ emissions by sector (in Mt) for the years 1990 – 2010 (without LULUCF)

Table 2.3a *CO₂ emissions / removals by sector for the period 1990-2000 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total (with LULUCF)	80,730.00	80,359.76	81,759.91	80,750.83	83,402.63	83,525.59	86,059.67	91,020.26	95,614.49	94,852.01	100,274.45
Total (without LULUCF)	83,301.00	83,016.87	84,718.81	84,064.68	86,339.80	86,800.09	88,917.19	93,763.23	98,671.77	98,068.26	103,210.17
1. Energy	75,241.44	75,028.43	76,698.67	76,350.04	78,624.04	78,579.71	80,696.29	85,362.33	90,034.42	89,502.27	94,431.58
A. Fuel combustion	75,171.21	74,957.53	76,640.47	76,302.71	78,578.82	78,540.98	80,652.69	85,323.18	90,007.24	89,500.82	94,407.43
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
2. Man. Industry and Construction	9,566.03	9,467.36	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
3. Transport	14,486.54	15,218.73	15,620.29	15,826.75	16,141.96	16,503.89	16,981.63	17,746.03	19,506.31	19,931.29	19,059.72
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
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
2. Industrial processes	7,889.62	7,812.44	7,847.09	7,544.30	7,552.31	8,065.51	8,068.52	8,247.61	8,484.74	8,405.81	8,621.04
A. Mineral products	6,709.03	6,629.21	6,702.19	6,657.74	6,625.50	7,102.54	7,091.98	7,173.75	7,217.31	7,198.17	7,398.80
B. Chemical production	240.28	229.59	218.32	140.72	NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	83.17	350.99	344.81	275.90
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
3. Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33
5. LULUCF	-2,571.00	-2,657.11	-2,958.90	-3,313.84	-2,937.17	-3,274.50	-2,857.52	-2,742.97	-3,057.28	-3,216.25	-2,935.72
6. Waste	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⁾	10,475.30	9,478.60	10,665.71	12,212.33	13,251.52	13,862.55	12,399.31	12,343.16	13,595.02	12,685.32	13,857.13
Aviation	2,447.55	2,110.50	2,201.85	2,343.60	2,781.45	2,608.20	2,497.95	2,416.05	2,535.75	2,847.60	2,497.95
Marine	8,027.75	7,368.10	8,463.86	9,868.73	10,470.07	11,254.35	9,901.36	9,927.11	11,059.27	9,837.72	11,359.18

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

Table 2.3b *CO₂ emissions / removals by sector for the period 2001-2010 (in kt)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total (with LULUCF)	102,783.15	102,136.90	106,584.56	106,669.78	110,511.07	108,970.52	112,058.62	107,955.94	101,635.65	94,819.27
Total (without LULUCF)	105,569.73	105,216.19	109,351.32	109,635.71	113,407.80	111,928.39	114,442.27	110,707.29	104,472.44	97,468.85
1. Energy	96,774.10	96,508.91	100,478.64	100,740.76	103,958.20	102,758.60	105,364.70	102,131.65	97,843.80	90,856.45
A. Fuel combustion	96,757.05	96,491.06	100,467.02	100,729.29	103,948.74	102,749.48	105,357.74	102,126.32	97,836.28	90,845.85
1. Energy industries	55,149.40	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
2. Man. industry and Construction	9,894.81	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
3. Transport	19,868.72	20,088.48	21,239.77	21,620.49	21,708.17	22,573.97	23,365.16	22,377.68	25,330.72	22,572.74
4. Other sectors	11,844.13	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
B. Fugitive emissions	17.04	17.85	11.62	11.47	9.46	9.11	6.96	5.33	7.52	10.60
2. Industrial processes	8,640.74	8,551.68	8,716.34	8,738.03	9,289.97	9,007.74	8,914.09	8,411.27	6,463.67	6,447.57
A. Mineral products	7,454.10	7,223.89	7,256.69	7,264.95	7,789.96	7,502.29	7,341.67	6,962.97	5,324.52	4,925.08
B. Chemical production	135.77	165.68	286.61	304.52	296.92	313.93	317.94	338.06	453.25	662.97
C. Metal production	1,050.87	1,162.10	1,173.04	1,168.56	1,203.09	1,191.52	1,254.48	1,110.24	685.90	859.53
3. Solvents	154.67	155.12	155.50	155.87	157.70	159.64	160.34	160.68	161.38	161.64
5. LULUCF	-2,786.57	-3,079.29	-2,766.77	-2,965.92	-2,896.74	-2,957.87	-2,383.65	-2,751.34	-2,836.79	-2,649.58
6. Waste	0.22	0.48	0.85	1.05	1.93	2.41	3.13	3.68	3.60	3.19
International transport ¹⁾	13,351.40	12,214.71	13,150.47	13,327.28	11,463.77	12,661.00	12,935.62	12,808.67	10,909.12	10,735.60
Aviation	2,321.47	2,321.55	3,021.87	3,106.36	2,385.19	2,860.89	2,923.94	3,040.47	2,615.19	2,092.29
Marine	11,029.93	9,893.16	10,128.61	10,220.92	9,078.57	9,800.12	10,011.69	9,768.20	8,293.93	8,643.31

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

2.3.2 Methane

The trend of methane emissions from 1990 to 2010 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 2010 emissions are slightly higher than 2009.

Waste represents the largest anthropogenic source of methane emissions in Greece accounting for 46.31% of total methane emissions in 2010 (without *LULUCF*). Methane emissions from Waste decreased by 13.47% since 1990 and are mainly attributed to Solid Waste Disposal on Land and Wastewater Handling.

Methane emissions from *Agriculture* in 2010 increased by 0.18% compared to 1990 levels. Methane emissions from *Agriculture*, with enteric fermentation being the main source category in the sector, in 2009 accounted for 37.64% 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 16.05% of the total methane emissions. Finally the contribution of CH₄ emissions from *Iron and Steel Production* can be considered negligible.

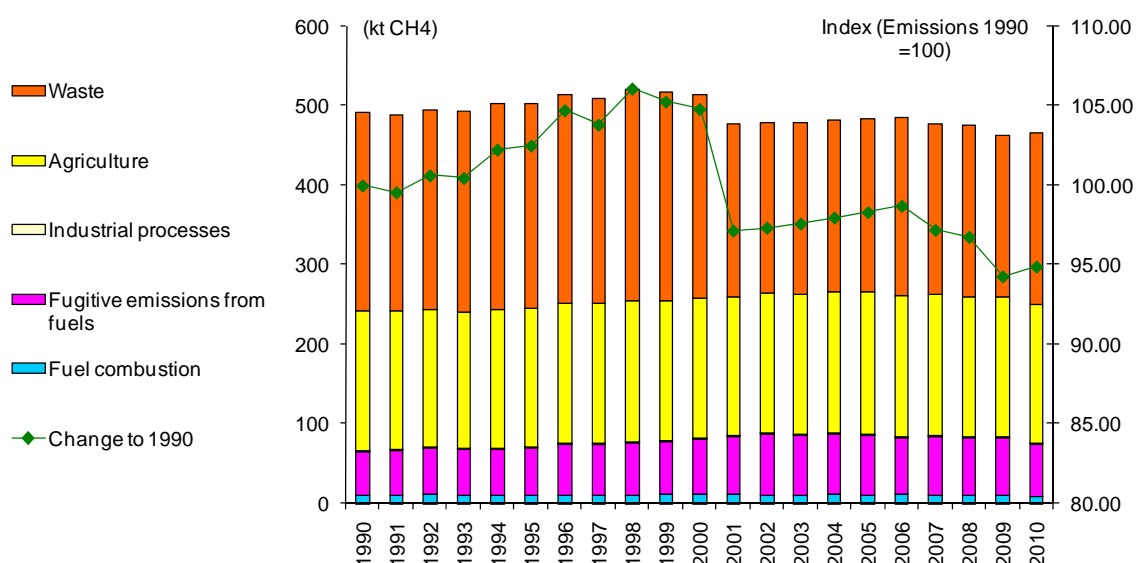


Figure 2.3 *CH₄ emissions by sector (in kt) for the period 1990 – 2010 (without LULUCF)*

Table 2.4a *CH₄ emissions by source category for the period 1990–2000 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total (with LULUCF)	492.80	490.16	497.02	495.71	504.44	504.78	515.51	511.66	524.68	517.71	519.67
Total (without LULUCF)	491.52	489.36	494.63	493.81	502.57	503.85	514.77	510.31	521.46	517.42	515.13
1. Energy	66.60	67.33	69.99	68.66	69.95	70.76	75.56	74.81	77.67	78.53	82.55
A. Fuel combustion	10.08	10.15	10.92	10.56	10.17	10.17	10.33	10.23	10.34	11.05	11.80
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
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
3. Transport	5.05	5.10	5.06	5.13	5.15	5.20	5.23	5.32	5.53	5.69	5.75
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
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
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
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
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
4. Agriculture	175.23	174.25	173.12	172.37	173.11	174.20	176.25	176.41	176.92	176.41	175.50
A. Enteric fermentation	154.58	153.49	152.63	150.85	150.81	151.58	153.12	153.16	154.29	154.42	154.31
B. Manure management	16.07	16.00	16.08	16.07	16.03	15.96	16.00	16.01	16.04	16.00	15.81
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
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
5. LULUCF	1.28	0.80	2.39	1.90	1.87	0.93	0.74	1.35	3.22	0.29	4.53
6. Waste	249.66	247.75	251.49	252.74	259.48	258.84	262.92	259.05	266.84	262.46	257.07
A. Solid waste disposal on land	105.99	109.28	112.52	116.13	119.98	124.13	128.45	133.05	137.80	142.68	148.39
B. Wastewater handling	143.67	138.47	138.97	136.61	139.50	134.72	134.46	126.01	129.04	119.78	108.68
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⁾	8.53	7.87	8.96	9.68	8.33	8.58	7.87	7.68	6.18	7.28	8.62
Aviation	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Marine	8.51	7.84	8.93	9.65	8.29	8.55	7.84	7.64	6.14	7.24	8.58

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

Table 2.4b *CH₄ emissions by source category for the period 2001-2010 (in kt)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total (with LULUCF)	478.27	478.55	479.87	481.99	483.49	485.68	485.70	476.60	464.38	466.75
Total (without LULUCF)	477.54	478.43	479.71	481.58	483.26	485.22	477.73	475.64	463.38	466.41
1. Energy	84.79	87.94	86.08	88.45	87.13	83.04	84.92	84.09	83.27	74.84
A. Fuel combustion	11.52	10.56	10.58	11.06	10.48	10.78	10.51	10.11	9.70	9.08
1. Energy industries	0.78	0.78	0.80	0.80	0.83	0.84	0.90	0.89	0.79	0.73
2. Manufacturing industry and Construction	0.47	0.48	0.41	0.42	0.49	0.46	0.45	0.49	0.42	0.42
3. Transport	5.90	5.86	5.84	5.88	5.70	5.60	5.36	5.06	4.84	4.37
4. Other sectors	4.37	3.45	3.52	3.97	3.46	3.87	3.79	3.66	3.65	3.56
B. Fugitive emissions from fuels	73.27	77.39	75.51	77.38	76.64	72.26	74.42	73.98	73.57	65.76
1. Solid fuels	66.68	70.82	68.64	70.39	69.74	64.84	66.80	66.05	65.22	56.80
2. Oil and natural gas	6.60	6.57	6.87	6.99	6.90	7.42	7.62	7.93	8.35	8.96
2. Industrial processes	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
4. Agriculture	175.53	177.28	177.50	177.83	178.33	177.67	177.28	175.96	175.95	175.55
A. Enteric fermentation	154.18	155.83	156.06	156.12	156.48	156.17	155.58	154.20	153.84	153.52
B. Manure management	15.70	15.60	15.65	15.75	15.80	15.73	15.42	15.21	15.03	14.98
C. Rice cultivation	4.22	4.48	4.52	4.55	4.62	4.46	5.00	5.00	5.60	5.60
F. Field burning of agricultural residues	1.42	1.38	1.27	1.42	1.43	1.32	1.28	1.54	1.48	1.45
5. LULUCF	0.73	0.12	0.16	0.41	0.23	0.46	7.96	0.96	1.00	0.34
6. Waste	217.20	213.18	216.11	215.28	217.78	224.49	215.51	215.57	204.14	216.01
A. Solid waste disposal on land	132.35	138.02	146.95	149.79	158.79	165.07	162.75	167.07	157.20	165.14
B. Wastewater handling	84.85	75.16	69.15	65.49	58.99	59.43	52.75	48.50	46.94	50.86
C. Waste Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
International Transport ¹⁾	8.81	10.72	9.54	11.16	5.43	5.90	7.53	5.70	4.97	0.78
Aviation	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Marine	8.77	10.68	9.50	11.12	5.40	5.87	7.50	5.67	4.94	0.75

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 2010 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 (76.05% approximately of the total nitrous oxide emissions in 2010, without *LULUCF*). Emissions from this sector decreased by 28.29 % since 1990, mainly because of new agricultural practices applied, affecting the use of synthetic nitrogen fertilizers.

Nitrous oxide is also produced from the reaction between nitrogen and oxygen during fossil fuel combustion. Nitrous oxide emissions from fossil fuels combustion (accounting for 10.67% of total nitrous oxide emissions in 2010) decreased by 12.66% 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 5.82% of total N_2O emissions in 2010. Nitrous oxide emissions from this source decreased by 61.37% 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, that was attributed to the economical recession, is counterbalanced by the increase by the 16.59% increase of emissions between 2009-2010.

N_2O emissions from *Waste* in 2010 (5.36% of total emissions without *LULUCF*) increased by 18.96% compared to 1990 levels.

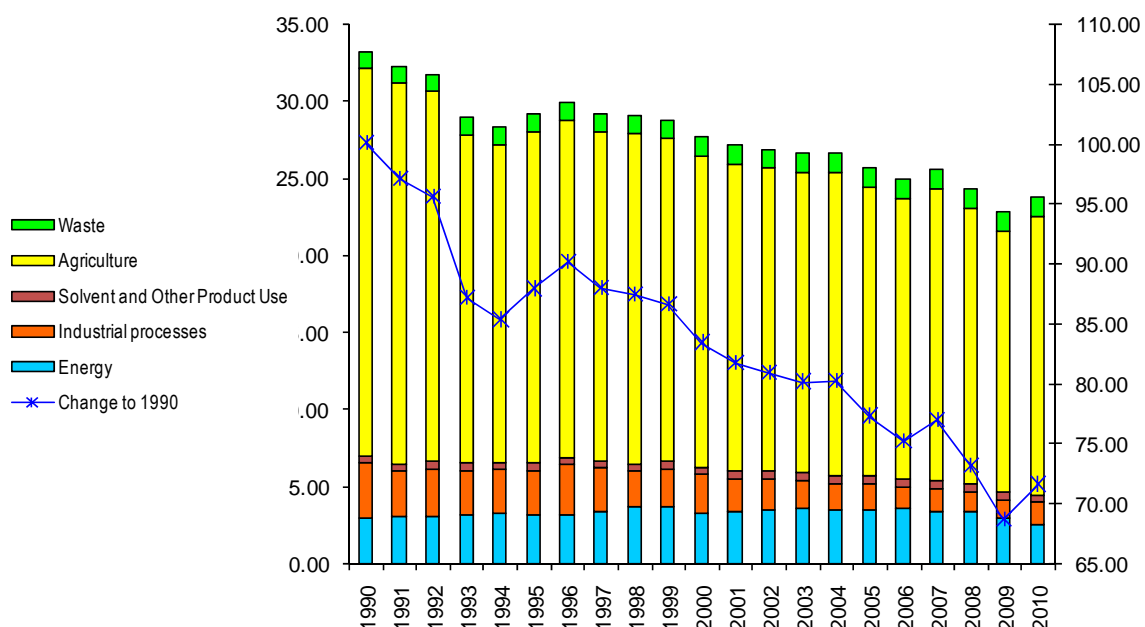


Figure 2.4 N_2O emissions by sector (in kt) for the period 1990 – 2010 (without *LULUCF*)

Table 2.5a *N₂O emissions by source category for the period 1990-2000 (in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total (with LULUCF)	33.17	32.19	31.71	28.89	28.29	29.15	29.88	29.18	29.01	28.71	27.68
Total (without LULUCF)	33.16	32.19	31.70	28.88	28.28	29.14	29.88	29.17	28.99	28.70	27.65
1. Energy	2.90	2.98	3.02	3.09	3.20	3.16	3.16	3.31	3.61	3.65	3.23
A. Fuel combustion	2.90	2.98	3.02	3.09	3.20	3.16	3.16	3.31	3.61	3.65	3.23
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
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
3. Transport	1.03	1.08	1.15	1.26	1.35	1.39	1.37	1.48	1.75	1.80	1.31
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
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	3.58	2.95	3.08	2.93	2.85	2.83	3.24	2.84	2.34	2.43	2.49
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
4. Agriculture	25.17	24.72	24.04	21.29	20.65	21.54	21.87	21.39	21.39	20.93	20.23
B. Manure management	1.10	1.08	1.07	1.00	0.97	0.95	0.98	0.97	0.97	0.96	0.95
D. Agricultural soils	24.04	23.59	22.93	20.26	19.63	20.56	20.85	20.38	20.39	19.94	19.24
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
5. LULUCF	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.03
6. Waste	1.07	1.08	1.10	1.10	1.13	1.14	1.14	1.15	1.16	1.21	1.22
International transport ¹⁾	1.85	1.76	2.09	2.27	2.24	2.48	2.13	2.10	1.93	1.99	2.22
Aviation	0.09	0.07	0.08	0.08	0.10	0.09	0.09	0.09	0.09	0.10	0.09
Marine	1.77	1.68	2.01	2.19	2.14	2.38	2.05	2.02	1.84	1.89	2.12

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

Table 2.5b *N₂O emissions by source category for the period 2001-2010 (in kt)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total (with LULUCF)	27.09	26.82	26.57	26.60	25.62	24.93	25.57	24.25	22.78	23.74
Total (without LULUCF)	27.08	26.82	26.57	26.59	25.62	24.93	25.52	24.24	22.77	23.73
1. Energy	3.38	3.43	3.52	3.40	3.40	3.52	3.38	3.28	2.90	2.53
A. Fuel combustion	3.38	3.43	3.52	3.40	3.40	3.52	3.38	3.28	2.90	2.53
1. Energy industries	0.61	0.60	0.61	0.63	0.63	0.59	0.62	0.61	0.59	0.55
2. Man. industry and Construction	0.17	0.16	0.15	0.14	0.15	0.15	0.15	0.15	0.13	0.12
3. Transport	1.44	1.43	1.41	1.45	1.44	1.53	1.49	1.44	1.30	1.07
4. Other sectors	1.16	1.24	1.35	1.18	1.19	1.24	1.12	1.08	0.88	0.79
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
2. Industrial processes	2.09	2.01	1.86	1.77	1.76	1.43	1.42	1.36	1.19	1.38
3. Solvent and Other Product Use	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50
4. Agriculture	19.91	19.70	19.47	19.72	18.74	18.25	18.97	17.83	16.92	18.05
B. Manure management	0.94	0.95	0.97	0.98	1.00	1.00	0.98	0.95	0.95	0.95
D. Agricultural soils	18.94	18.71	18.47	18.70	17.71	17.22	17.95	16.84	15.93	17.06
F. Field burning of agr. residues	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04
5. LULUCF	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00
6. Waste	1.21	1.20	1.23	1.22	1.23	1.25	1.26	1.27	1.27	1.27
International transport ¹⁾	2.06	2.19	2.01	2.18	1.33	1.43	1.59	1.34	1.19	0.71
Aviation	0.09	0.09	0.11	0.11	0.08	0.09	0.09	0.10	0.08	0.07
Marine	1.97	2.11	1.90	2.07	1.26	1.34	1.50	1.24	1.11	0.64

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

2.3.4 Halocarbons and sulphur hexafluoride

HFC and PFC 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 2008-2010 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. The estimates in the current submission include revised estimations of f-gases emissions from blends that were not considered in the past, following the implementation of 2012 Inventory Improvement Plan. Market data on the sales of gases confirm the use of various blends per application, especially for commercial refrigeration, resulting in an increasing trend that does not follow a linear pattern.
- ✎ 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 trend is generally increasing and emissions show a peak in 2008. Other aerosol applications regard the use of HFC-134a by one company in Greece, according to data received by the Hellenic Aerosol Association.
- ✎ 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.
- ✎ The use of SF₆ in the electricity transmission / 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 1990-2010 (in kt CO₂ eq)*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HFC	935.06	1,106.82	908.39	1,609.35	2,150.52	3,304.78	3,844.18	4,138.19	4,638.51	5,453.41
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
HFC-32						0.08	0.30	0.89	1.93	3.95
HFC-125						5.10	10.13	20.17	34.06	56.54
HFC-134a				2.71	6.61	38.95	73.44	125.99	191.01	284.15
HFC-152a										
HFC-143a						7.58	13.98	25.68	40.14	61.03
HFC-227ea										4.18
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32
SF₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87
Total	1,101.51	1,274.16	1,072.86	1,709.68	2,214.34	3,362.34	3,894.00	4,249.59	4,775.33	5,547.60

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HFC	4,345.18	3,964.27	4,130.47	3,930.35	4,014.57	4,086.28	2,229.07	2,574.46	2,956.54	3,356.11	3,557.92
HFC-23	3,768.07	3,219.93	3,233.29	2,720.91	2,613.64	2,224.50	77.24	115.87	126.45	145.67	167.83
HFC-32	6.69	10.97	15.40	25.34	34.25	43.45	56.10	70.10	86.72	105.81	127.96
HFC-125	85.14	114.32	135.10	213.44	261.57	345.24	418.42	512.51	618.22	749.30	883.63
HFC-134a	392.96	508.07	603.91	761.72	885.04	1,181.02	1,351.58	1,510.62	1,719.66	1,895.25	1,883.57
HFC-152a		1.67	30.40	40.90	35.19	37.69	46.73	41.22	40.91	35.88	32.25
HFC-143a	86.35	101.55	102.21	154.79	166.92	232.11	252.65	292.14	329.35	385.65	421.95
HFC-227ea	5.97	7.75	10.17	13.26	17.96	22.28	26.36	32.01	35.22	38.54	40.73
PFC	105.09	71.16	69.14	72.47	68.99	69.89	66.35	76.22	89.12	69.87	101.61
SF₆	3.99	4.06	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14
Total	4,454.26	4,039.50	4,203.86	4,007.07	4,088.03	4,162.63	2,303.78	2,660.60	3,053.19	3,431.23	3,665.67

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 2.36% from 1990 to 2010. Energy sector accounts for the high majority of emissions (99.26%). 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 46.77% of total NO_x emissions in 2010). Emissions from *Industrial processes* decreased by 45.23% 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 62.84% from 1990 to 2010 and as a result total CO emissions in 2010 decreased by 53.35%. Emissions from industrial processes in 2010 decreased by 1.87% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2010 emissions from *LULUCF* accounted for 1.27% of total CO emissions (incl *LULUCF*), and are by 34.97% lower than emissions of 1990.
- ✎ NMVOC emissions decreased by 31.48% from 1990 to 2010. Emissions from transport (25.83% of total NMVOC emissions in 2010), decreased by 65.76% compared to 1990 levels, while emissions from *Energy* decreased by 42.46% from 1990 to 2010. The significant increase of NMVOC emissions from *Industrial processes* (approximately 24.90% from 1990 to 2010) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 4.10% compared to 1990 levels.
- ✎ SO₂ emissions decreased by 44.28% from 1990 to 2010. Emissions from energy, which is the main source of SO₂ emissions in Greece (98.14 % of total SO₂ emissions for 2010), decreased with a mean annual rate of decrease of 2.21% for the period 1990 – 2010. 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

87.48% for the period 1990 – 2010. Emissions from *Industrial processes* decreased by 41% 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 1990-2000

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NO_x	329.61	339.45	346.42	344.05	351.98	331.56	335.56	348.81	371.62	368.87	362.89
1. Energy	326.66	336.42	343.45	341.12	349.10	328.99	332.97	346.16	368.66	366.49	359.53
Transport	183.97	186.29	187.79	188.79	191.40	181.54	178.84	186.55	205.72	206.23	185.99
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
2. Industrial processes	1.48	1.25	1.08	1.21	1.07	1.08	1.13	1.03	1.02	1.12	1.05
4. Agriculture	1.17	1.58	1.32	1.27	1.36	1.27	1.28	1.30	1.20	1.19	1.25
5. LULUCF	0.30	0.19	0.57	0.45	0.44	0.22	0.18	0.32	0.74	0.07	1.06
CO	1,143.30	1,125.11	1,094.45	1,085.76	1,063.24	962.06	954.93	957.61	973.92	956.83	959.94
1. Energy	1,085.95	1,060.36	1,023.45	1,020.99	997.37	906.69	901.95	898.83	900.20	905.99	872.16
Transport	878.86	849.89	800.96	806.31	788.42	701.38	694.99	691.91	693.75	690.84	642.01
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
2. Industrial processes	19.89	20.14	20.14	19.50	18.12	17.47	17.10	17.66	19.43	20.83	21.40
4. Agriculture	27.06	37.93	30.86	29.54	32.23	30.26	29.65	29.97	28.13	27.62	29.21
5. LULUCF	10.40	6.68	20.00	15.73	15.52	7.64	6.24	11.15	26.16	2.39	37.17
NM_{VOC}	269.12	271.30	268.68	267.86	266.14	259.56	259.99	261.54	266.96	269.74	265.48
1. Energy	186.99	185.48	182.42	181.38	180.28	170.97	171.37	171.97	173.05	172.50	163.24
Transport	139.09	137.50	132.78	133.48	131.47	120.67	120.00	119.95	120.54	120.08	106.90
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
2. Industrial processes	25.48	27.54	28.81	30.32	31.56	36.94	37.56	38.15	42.54	43.48	49.03
3. Solvents	56.65	58.27	57.45	56.16	54.31	51.64	51.05	51.43	51.36	53.75	53.20
SO₂	476.39	517.34	534.30	531.03	522.22	540.19	530.13	528.93	536.41	555.11	495.99
1. Energy	467.83	509.28	527.06	524.25	515.07	532.24	522.31	520.84	528.33	546.89	488.62
Transport	39.04	39.04	41.34	38.59	43.05	32.32	30.88	37.94	52.75	56.58	21.58
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
2. Industrial processes	8.56	8.07	7.25	6.79	7.15	7.96	7.82	8.08	8.07	8.21	7.37

Table 2.7b Emissions trends for indirect greenhouse gases and SO₂ (in kt) for the period 2001-2010

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NOx	384.38	385.29	394.98	401.01	418.66	415.03	418.26	394.59	382.16	321.82
1. Energy	382.04	382.93	392.70	398.60	416.34	412.80	414.25	392.04	379.91	319.46
Transport	197.48	191.91	191.09	196.62	189.98	195.53	191.05	181.90	193.94	150.50
Other energy sectors	184.56	191.01	201.60	201.98	226.36	217.27	223.20	210.14	185.97	168.96
2. Industrial processes	0.87	1.09	1.06	1.00	0.94	0.89	0.93	0.87	0.64	0.81
4. Agriculture	1.29	1.25	1.19	1.31	1.33	1.23	1.21	1.45	1.36	1.36
5. LULUCF	0.17	0.03	0.04	0.10	0.06	0.11	1.89	0.23	0.26	0.19
CO	919.11	857.50	813.05	811.84	722.82	741.22	748.53	630.36	600.38	533.30
1. Energy	861.41	804.77	762.09	755.23	667.01	685.90	630.93	566.62	542.56	476.54
Transport	639.25	599.96	579.01	566.75	501.22	519.17	455.38	405.77	385.56	326.58
Other energy sectors	222.16	204.80	183.08	188.47	165.79	166.72	175.55	160.84	157.00	149.96
2. Industrial processes	21.64	22.81	22.89	23.35	23.76	23.91	24.28	23.38	17.62	19.52
4. Agriculture	29.91	28.91	26.69	29.80	30.09	27.64	26.94	32.43	31.08	30.47
5. LULUCF	6.14	1.01	1.38	3.45	1.96	3.77	66.39	7.93	9.12	6.76
NMVOC	262.69	257.90	245.40	245.65	221.06	230.86	219.73	227.72	212.07	184.39
1. Energy	160.94	154.09	148.77	143.35	134.33	133.90	129.08	119.14	114.42	98.24
Transport	105.57	99.11	94.04	90.04	79.43	76.99	70.22	61.78	59.84	47.63
Other energy sectors	55.37	54.98	54.73	53.31	54.90	56.92	58.86	57.36	54.58	50.62
2. Industrial processes	49.40	51.32	44.02	49.56	33.68	43.27	36.75	54.57	43.41	31.82
3. Solvents	52.35	52.49	52.61	52.73	53.05	53.68	53.90	54.01	54.24	54.32
SO₂	503.94	515.19	553.43	547.80	540.68	533.24	537.97	445.15	425.56	265.44
1. Energy	496.68	507.78	545.99	540.25	531.80	526.78	531.43	439.00	420.91	260.50
Transport	28.89	25.26	26.83	31.86	27.98	30.63	27.67	23.54	46.99	34.35
Other energy sectors	467.79	482.52	519.16	508.39	503.81	496.15	503.77	415.47	373.92	226.15
2. Industrial processes	7.26	7.41	7.44	7.54	8.89	6.46	6.53	6.15	4.65	4.94

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 33248 ha, land areas deforested were 3922 ha and land areas under forest management were 1205761 ha. In 2010 net removals from ARD activities were 348.53 Kt CO₂ eq. and from Forest Management activities 1854.76 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 1990-2010 are summed up in order to illustrate the effect of deforestation.

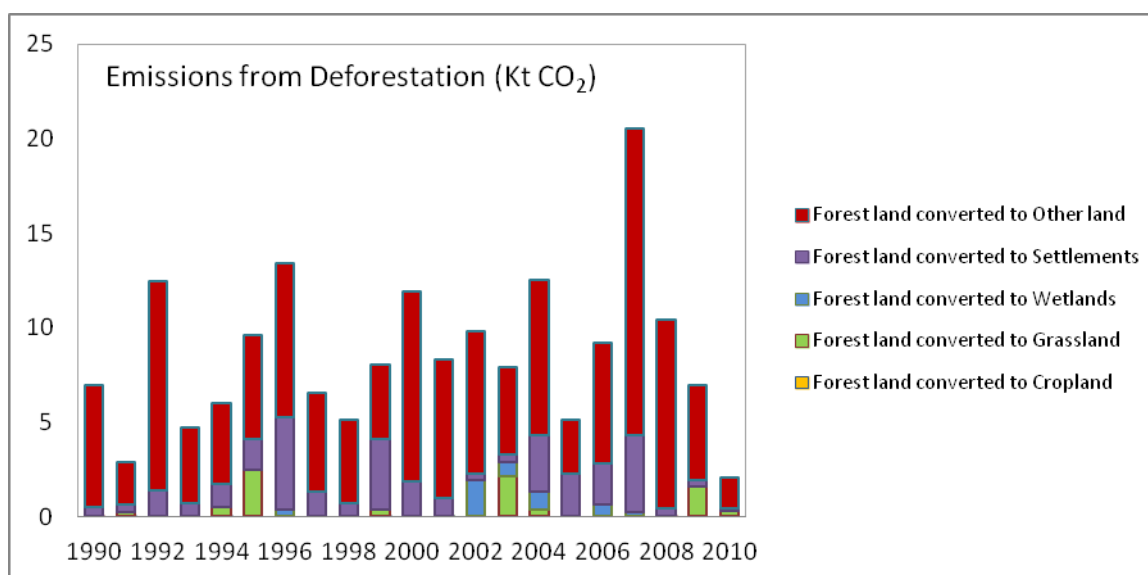


Figure 2.5 *CO₂ emissions (in kt) from deforestation for the period 1990 – 2010*

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 2010 amounted to approximately 1156 PJ. The consumption of solid fuels and oil products accounts for 80.6% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar, wind energy and geothermal) are 2.4% and 4.3% respectively. Finally, the share of natural gas in gross inland consumption is 11.0% while the rest 1.8% of gross inland consumption is covered by electricity (net imports – exports). In 2010, gross inland consumption increased by approximately 29% compared to 1990, presenting a 1.3% 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, till 2007 a decrease in gross inland consumption is observed, presenting a about 5% average annual rate of decrease.

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

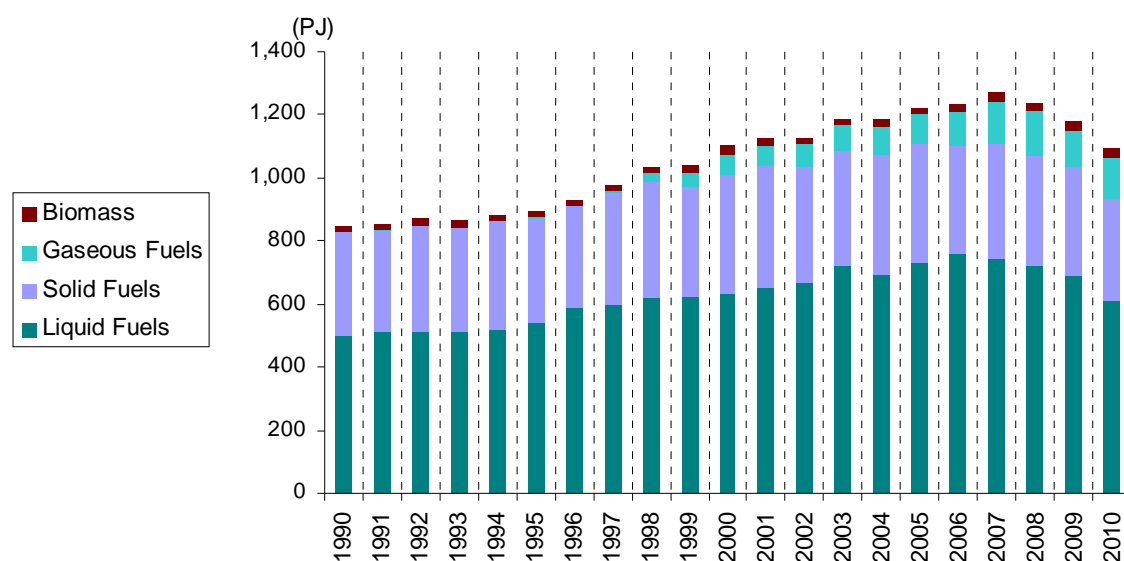


Figure 3.1 Gross inland consumption (in PJ) by energy type for the period 1990 - 2010

GHG emissions from *Energy* in 2010 increased by 20.4% compared to 1990 (**Figure 3.2**), while the average annual rate of increase for the period 1990 – 2010 was 1%. 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).

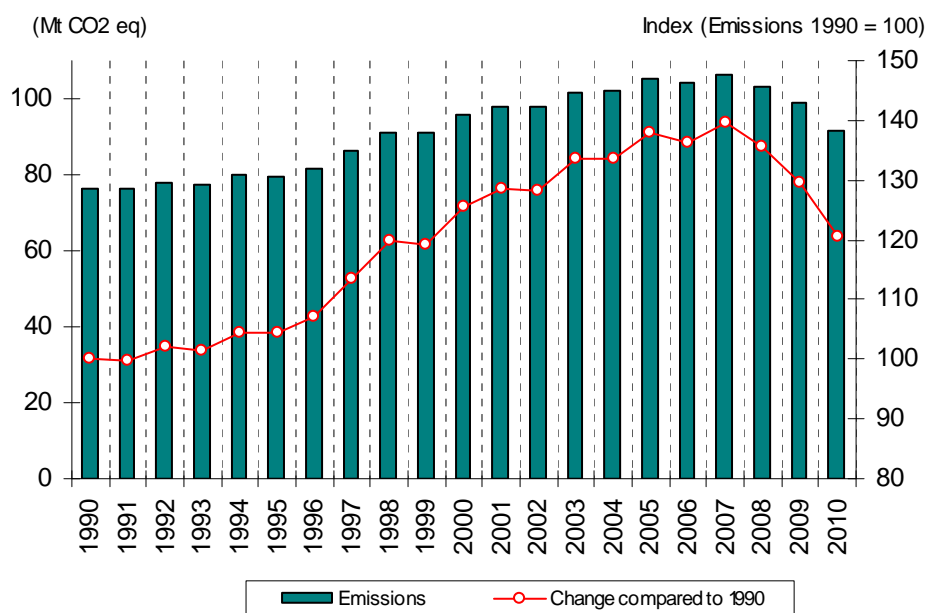


Figure 3.2 Total GHG emissions from Energy (in Mt CO2 eq) for the period 1990 – 2010

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 0.9% 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 1.9% 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 11% in 2010 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 (56.0%) in 2010 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 24.7%, 7.3% and 10.6% respectively. The rest 1.4% of total GHG emissions from *Energy* derived from fugitive emissions from fuels.

Within the fuel combustion activities, the sector with the greatest increase of emissions since 1990 is transport, showing an average rate of increase of 2.3%, followed by energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) with a 1.1% and 1.0% average annual rate of increase, respectively. Emissions from manufacturing industries and construction emissions had a mean annual rate of decrease of 1.4%. Finally, fugitive emissions from fuels increased with an average annual rate of 1.5% for the period 1990 – 2010.

Table 3.1 *GHG emissions from Energy by source category and gas for the period 1990 – 2010*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂ 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
2. Industry	9.57	9.47	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
3. Transport	14.49	15.22	15.62	15.83	16.14	16.50	16.98	17.75	19.51	19.93	19.06	19.87	20.09	21.24	21.62	21.71	22.57	23.37	22.38	25.33	22.57
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
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
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
CH ₄ 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
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
3. Transport	5.05	5.10	5.06	5.13	5.15	5.20	5.23	5.32	5.53	5.69	5.75	5.90	5.86	5.84	5.88	5.70	5.60	5.36	5.06	4.84	4.37
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
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
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	8.92
N ₂ O 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
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
3. Transport	1.03	1.08	1.15	1.26	1.35	1.39	1.37	1.48	1.75	1.80	1.31	1.44	1.43	1.41	1.45	1.44	1.53	1.49	1.44	1.30	1.07
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
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
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	0.09

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 2010 is briefly presented in *Table 3.2*.

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

CRF 1A	IPCC categories Fuel combustion	CO ₂		CH ₄		N ₂ O	
		Method	Emission factor	Method	Emission factor	Method	Emission factor
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	D	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	D	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 78.5% of total national GHG emissions in 2010 (without *LULUCF*).

Table 3.3 *Key categories from Energy*

IPCC source categories	Gas	Criteria
Energy Industries: Gaseous fuels	CO ₂	L, T
Energy Industries: Solid fuels	CO ₂	L, T
Energy Industries: Liquid fuels	CO ₂	L, T
Manufacturing Industries & Construction: Liquid fuels	CO ₂	L, T
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	L, T
Manufacturing Industries & Construction: Solid fuels	CO ₂	L, T
Other Sectors: Liquid fuels	CO ₂	L, T
Other Sectors: Gaseous fuels	CO ₂	L, T
Coal Mining (surface)	CO ₂	L
Road Transportation	CO ₂	L, T
Navigation	CO ₂	L, T
Civil Aviation	CO ₂	L, T

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 – 2010*

Year	Reference approach	Sectoral approach	Deviation %
1990	75940	75171	1.02
1991	75817	74958	1.15
1992	77447	76640	1.05
1993	77456	76303	1.51
1994	79794	78579	1.55
1995	80220	78541	2.14
1996	81057	80653	0.50
1997	85174	85323	-0.17
1998	89446	90007	-0.62
1999	88841	89501	-0.74
2000	93522	94407	-0.94
2001	96645	96757	-0.12
2002	96552	96491	0.06
2003	99246	100467	-1.22
2004	99766	100729	-0.96
2005	103940	103949	-0.01
2006	100951	102749	-1.75
2007	101627	105358	-3.54
2008	100191	102126	-1.90
2009	97716	97836	-0.12
2010	90068	90848	-0.86

As shown in the table above, the estimated deviation (which ranges from –3.54% to 2.14%) 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 – 2010 (%)*

Year	Liquid fuels	Solid fuels	Gaseous fuels
1990	1.14	0.53	0.00
1991	1.69	0.13	-0.63
1992	1.47	0.95	-0.84
1993	1.22	0.86	-0.88
1994	1.44	0.96	-0.09
1995	0.25	3.59	0.00
1996	0.01	0.85	0.00
1997	-1.42	0.63	1.05
1998	-2.49	0.62	0.15
1999	-2.23	0.38	0.07
2000	-1.87	-0.84	0.78
2001	-0.82	-0.08	1.42
2002	-0.55	0.25	0.03
2003	-1.93	-0.81	0.07
2004	-1.03	-1.37	0.03
2005	0.21	-0.63	0.62
2006	-3.30	-0.75	0.46
2007	-8.23	0.36	-0.56
2008	-3.41	-1.82	-0.93
2009	-1.03	-0.31	1.82
2010	-2.08	-1.69	1.34

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 allocation of fuel consumption between domestic and international transportation is based on the data of the national energy balance, as declared by oil trading companies. Finally, the allocation of LTOs between domestic and international aviation is based on data provided by the Civil Aviation Organisation (*Table 3.7*).

After ERT recommendation, revised emission estimates for CH₄ and N₂O emissions from liquid fuels in navigation, which are based on EFs from the Revised 1996 IPCC Guidelines are provided in this submission.

GHG emissions from international bunkers (*Table 3.8a,b,c*) increased by about 4% since 1990. The substantial decrease of 20% in 2010 international aviation emissions is associated with financial recession.

Table 3.7 *Allocation of LTOs to domestic and international aviation for the period 1990-2010*

Year	Domestic	International
1990	121070	123606
1991	105306	118074
1992	115898	143206
1993	127499	149398
1994	127565	160974
1995	135252	157113
1996	145115	153990
1997	164879	167612
1998	167701	175713
1999	200527	196097
2000	222962	204347
2001	199529	196663
2002	171441	188841
2003	195948	199825
2004	212216	207635
2005	200672	202491
2006	211854	217565
2007	222848	232351
2008	214364	226550
2009	240214	217570
2010	216203	212660

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	2474	2134	2227	2370	2812	2637	2526	2444	2565	2880
International marine	8755	8055	9274	10751	11307	12173	10700	10713	11758	10575

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	2527	2349	2349	3056	3142	2409	2890	2953	3071	2641
International marine	12198	11825	10770	10919	11096	9582	10339	10634	10272	8740

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*

		Memo items 1) – International bunkers
		Emissions (kt CO ₂ eq)
	2010	
International aviation	2113	
International marine	8858	

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, by using data from ETS reports and plant specific information. Non-energy use of lignite is accounted in the Energy 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.

- For the first time in this submission, the non-energy use of natural gas for hydrogen production has been reallocated to 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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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
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
Lignite (non ferrous)	2.5	2.6	3.4	4.9	3.8	3.9	4.9	4.1	4.0	2.6	4.1	1.7	1.3	1.7	1.9	2.1	3.3	2.7	2.4	0.2	0.2
Coal	2.3	2.4	2.3	1.8	3.0	2.8	3.2	2.4	2.1	1.7	1.9	3.8	4.4	4.4	4.0	3.6	2.5	3.5	3.5	2.9	4.6
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
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

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

³ paraffin waxes and other oil products

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*.

Table 3.11 *CO₂ emissions (in kt) from non-energy use and total amount of carbon stored (in kt) for the period 1990 - 2010*

Year	Carbon stored (kt)	CO ₂ emissions (kt)
1990	524.87	334.57
1991	522.57	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

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 69% - 75% of total fossil fuel consumption in Greece for the period 1990 – 2010 (*Figure 3.3*).

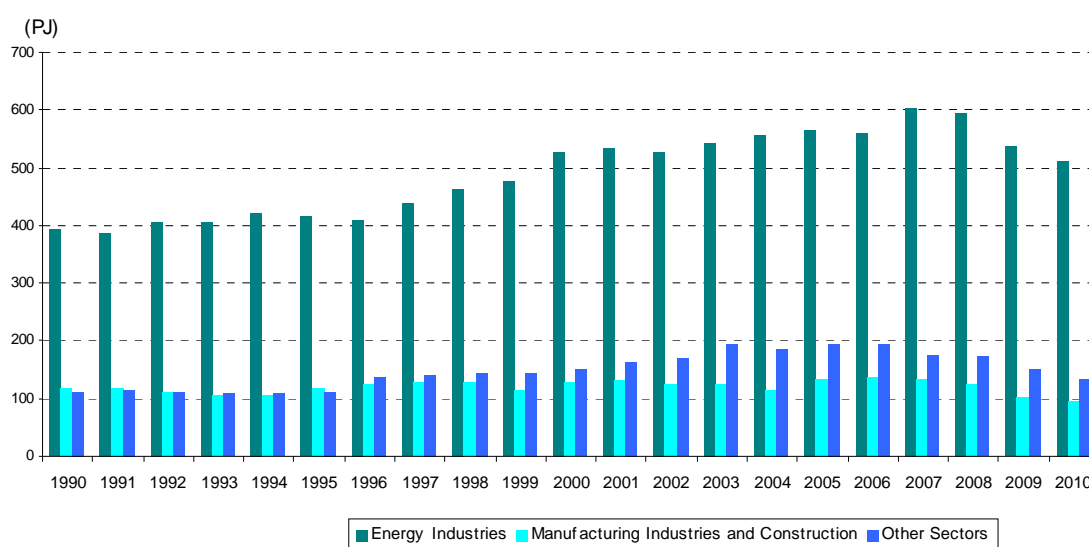


Figure 3.3 Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2010

The consumption of fossil fuels in 2010 increased by approximately 28% compared to 1990, with an average annual rate of increase of 1.3% for the period 1990 – 2010. In 2008, 2009 and 2010 the consumption of fossil fuels had a decreasing trend with annual rates of -2.9%, -5.2% and -7.7%, respectively.

↳ Fuel consumption in energy industries accounts for 65% (average value for the period 1990 – 2010) of fuel consumption in stationary combustion. The average annual rate of increase for the period 1990 – 2010 is estimated at 1.4%, resulting in an increase of 29% in 2010 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 – 2010 the fuel consumption in energy industries had a decreasing trend with an average annual rate of 5.4%.

✎ 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 2010 decreased by 20% compared to 1990 levels.

✎ Fossil fuels consumption in Other sectors increased by 21% from 1990 to 2010.

GHG emissions from stationary combustion follow the trend of fossil fuels consumption, presenting however a lower annual rate of increase. Therefore, GHG emissions in 2010 (68.8 Mt CO₂ eq) increased by 12.2% compared to 1990 (61.4 Mt CO₂ eq), with an average annual rate of increase estimated at 0.7% for the period 1990 – 2010 (**Figure 3.4**). The last 3 years, a decreasing trend of emissions is observed with average annual rate of 5.90%. 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.

It is noted that emissions from stationary combustion account for around 60% of total national emissions (without *LULUCF*) for the period 1990 – 2010, while **eight 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**).

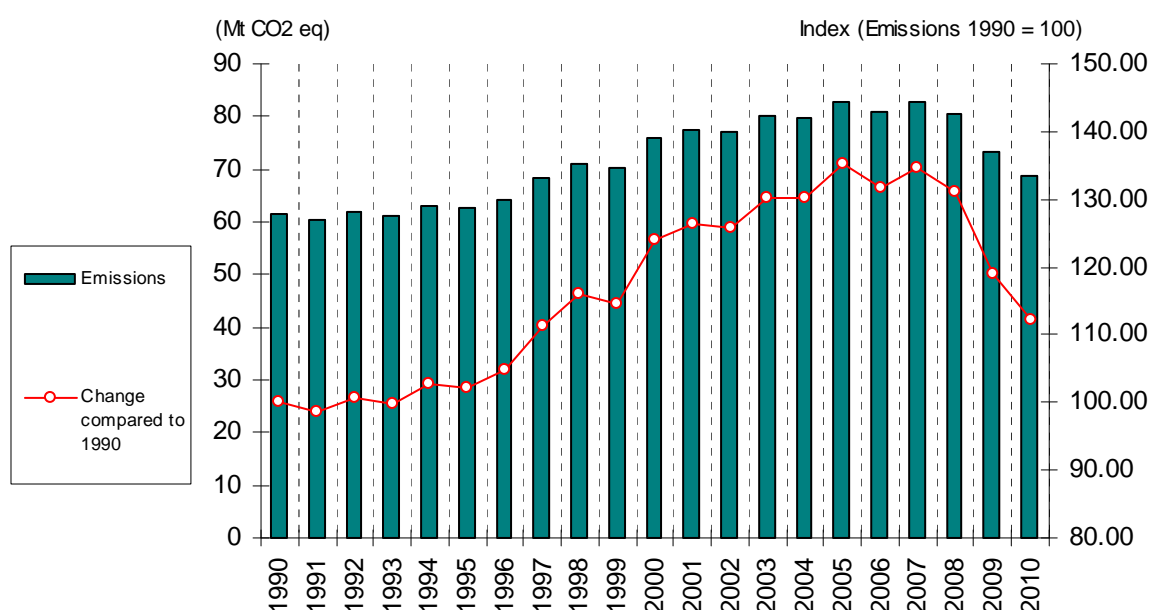


Figure 3.4 *GHG emissions (in Mt CO₂ eq) from stationary combustion for the period 1990 – 2010*

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 99.2% in 2010. Overall, CO₂ emissions in 2010

increased by 12.5% compared to 1990 levels with an average annual rate of increase estimated at 0.7%. N₂O emissions in 2010 account for 0.7% of emissions from stationary combustion, decreasing with an average annual rate of 1% during the period 1990 – 2010. CH₄ emissions account for the rest 0.1% of total emissions of the sector and decreased by 6.5% from 1990 to 2010. The average annual rate of decrease of CO₂ emissions in 2009 and 2010 was 7.5%, mainly due to the economic recession.

Table 3.12 *GHG emissions per gas and source category from stationary combustion for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GHG emissions per gas																					
CO ₂ (in Mt)	60.68	59.74	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
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
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
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
Industry	9.62	9.52	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
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
TOTAL (Mt CO₂ eq)	61.37	60.43	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	68.83

Energy industries constitute the major contributor (76% in 2010) 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 1.0% for the period 1990 – 2010. 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 and 2010).

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 the main 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.
- ✎ 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. Diesel's NCV was obtained from greek refineries' statistics.
- ✎ 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 (2010)*

Fuel type	Net calorific value (TJ/kt)	Carbon content. CC (tC/TJ)	Oxidation factor. OF (%)	EF (tCO ₂ /TJ)
Liquid fuels				
Refinery gas	48.81 ⁴	15.45	99.0	56.10
LPG	47.31	17.2	99.0	62.44 ⁵ , 62.54 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 , 32.01 ⁸	27.5 ⁷ , 25.9 ⁸	99.0	99.84 ⁷ , 94.02 ⁸
Other oil products	40.19	20.0	99.0	72.60
Solid fuels				
Steam coal	25.13 ⁹	26.7	98.0	95.94 ⁹
Lignite				
Electricity generation	5.497	34.75	98.0	124.87
Other sectors	8.025	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		15.97 - 16.24 ¹⁰	99.5	56.72 ¹¹
Natural gas – Imports		15.16 ¹² , 15.12 ¹³	99.5	55.31 ¹² , 55.17 ¹³
Gas works gas		15.3	99.5	55.82

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.

- ↪ 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:
 1. the South Kavala reservoir, which has a NCV of 11305 kcal/Nm³ and a carbon content of 15.97 tC/TJ.
 2. the Prinos reservoir, which has a NCV of 12195 kcal/Nm³ and a carbon content of 16.24 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**.

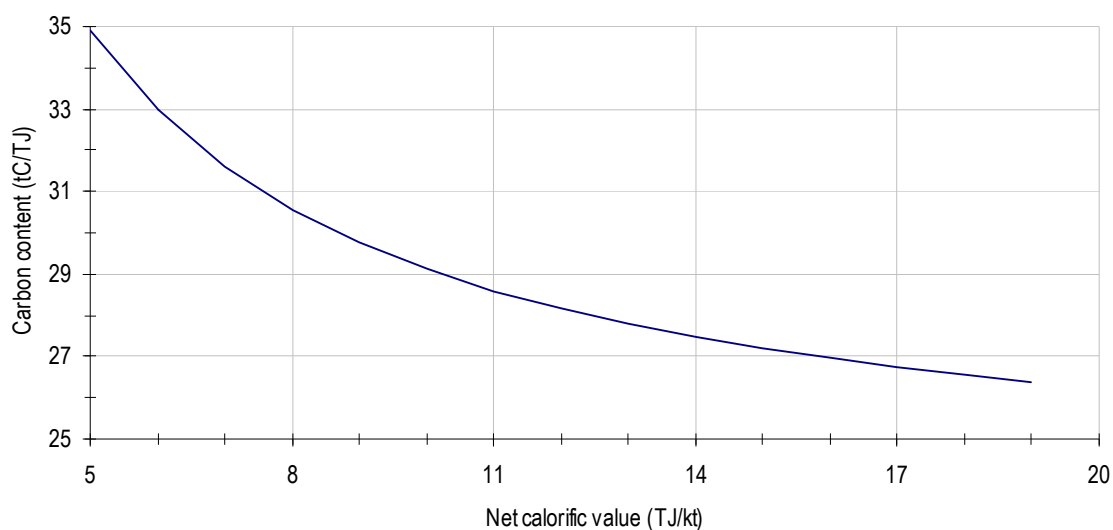
Table 3.14 *Net calorific value of lignite by sector (in TJ / kt) for the period 1990 - 2010*

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

- ↪ 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 2006-2010 plant specific values for CC were used, based on verified EU-ETS reports, ranging from 33.95 to 34.75 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 both NCV and EF used in Industry are greater than 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 2005-2009, 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 1A.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 4%. Gross electricity production in 2010 (58.6 TWh) was approximately 67% higher compared to 1990 levels (*Figure 3.6*).

Electricity generation from the use of fossil fuels is approximately 78% of electricity production in 2010. Specifically, 52% of electricity is produced by solid fuels (mainly lignite), while the share of liquid fuels (diesel, heavy fuel oil and refinery gas) and natural gas is 10% and 17% respectively. The rest of electricity production, i.e. around 20%, derives from renewable energy sources as hydropower, wind energy 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). Additionally, energy consumption for off-road transportation is not considered.

GHG emissions from electricity and heat production for the period 1990 – 2010 are presented in *Table 3.15*.

GHG emissions from electricity generation in 2010 increased by 19% compared to 1990 levels at an average annual rate of 1 % for the period 1990 – 2010. 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 2010 accounted for 99.65% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 82.2% of total emissions in 2010. However, due to the penetration of natural gas and RES technologies, total emissions per electricity produced by fossil fuels has a decreasing trend.

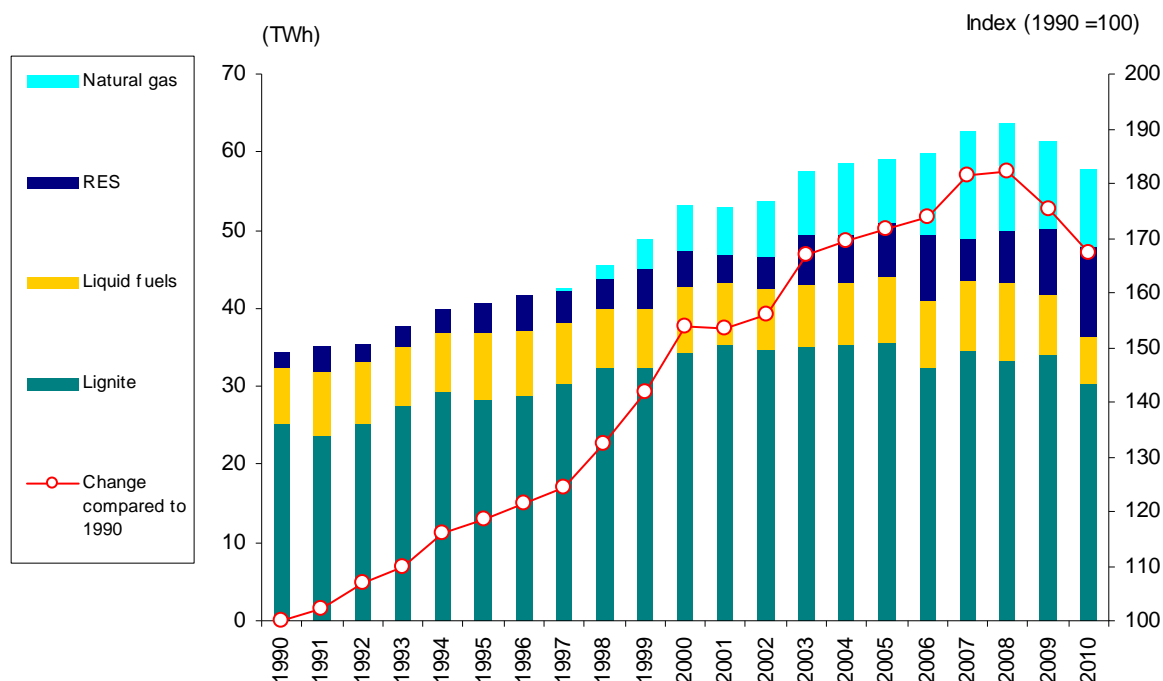


Figure 3.6 Electricity production (in TWh) by energy type for the period 1990 – 2010

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 2010, compared to 1990 levels, is estimated at 59%, with an average annual rate of increase estimated at 2.6% for the period 1990 – 2010. 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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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
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
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
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
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
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
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

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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂ (kt)	2308	2350	2283	2262	2433	2459	2694	2744	2821	2558	3072	3117	3222	3075	3225	3620	4287	4337	4047	3714	3669
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
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
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

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 - 2009) 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 2009 decreased by approximately 16% 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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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

3.2.4.3.2 Recalculations

In this submission, the following recalculations were performed compared to the estimates presented in the previous submission:

1.A.1a Public electricity and Heat Production / Solid fuels / 2008

1. The activity data of solid fuels (lignite) were updated for the year 2008, based on plant specific data, derived from verified ETS reports. Therefore, the emissions of CO₂, CH₄ and N₂O from solid fuels combustion were recalculated for the year 2008. The impact on total emissions was minor (less than 0.5%).

1.A.1a Public electricity and Heat Production / Gaseous fuels / 2009

2. The activity data of gaseous fuels (natural gas) were updated for the year 2009, based on data from national energy balance and DESFA (Hellenic Gas Transmission System Operator S.A.). Therefore, the emissions of CO₂, CH₄ and N₂O from solid fuels combustion were recalculated for the year 2009. The impact on total emissions was minor (less than 0.1%).

1.A.1b Petroleum Refining / Gaseous fuels

3. Based on data from verified EU-ETS reports of the four refineries located in Greece and DEPA (Public Gas Corporation) the emissions from the production of hydrogen, where natural gas is used as feedstock, were reallocated from the Energy to the Industrial Processes sector, for the whole time series. This recalculation has no effect on total emissions.

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 - 2010 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 – 2010 (**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 - 2010. 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 - 2010 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 - 2010. 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 - 2010 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 - 2010.

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 2010 decreased by 30% compared to 1990.

3.2.4.4.2 Recalculations

In this submission, minor recalculations were performed compared to the estimates presented in the previous submission:

1.A.2c Chemicals / Gaseous fuels / 2008

4. An error of the working file of the year 2008 was corrected (concerning AD), and the emissions of CO₂, CH₄ and N₂O from gaseous fuels combustion were recalculated for the year 2008. The impact on total emissions was minor (around +90 kt CO₂).

Table 3.18 *GHG emissions (in kt CO₂ eq) from manufacturing industries and construction for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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
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
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
Chemicals																					
CO ₂	1153.02	844.73	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
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
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
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
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
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
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
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
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
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
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
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
TOTAL	9618.6	9522.06	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

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 2010 increased substantially compared to 1990 levels (42% and 116% respectively), 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 – 2010.

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. Overall, in 2010 emissions from agriculture decreased by approximately 42% compared to 1990 emissions.

3.2.4.5.2 Recalculations

In this submission, minor recalculations were performed compared to the estimates presented in the previous submission:

1.A.4c Liquid fuels / 2009

5. An error of the working file of the year 2009 was corrected (concerning AD), and the emissions of CO₂, CH₄ and N₂O from liquid fuels combustion were recalculated for the year 2009. The impact on total emissions was minor (around +33 kt GHG).

Table 3.19 *GHG emissions (in kt CO₂ eq) from the residential sector for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO₂ emissions																					
Solid fuels	86.64	120.63	116.15	115.40	114.66	106.09	115.24	126.97	102.11	62.68	69.86	65.70	23.46	14.17	23.45	11.35	5.53	6.87	23.68	14.73	13.97
Liquid fuels	4584.82	4560.85	4470.27	4437.91	4466.13	4697.02	6397.26	6686.39	7032.67	6917.13	7494.44	8075.67	8402.61	9978.31	9497.86	9683.35	9213.55	8177.13	7880.55	6797.43	6073.93
Gaseous fuels									10.49	8.93	11.15	12.05	19.74	43.15	79.99	166.49	316.75	407.48	479.18	591.90	589.66
CH₄ emissions																					
Solid fuels	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Liquid fuels	3.76	3.75	3.66	3.65	3.69	3.89	5.35	5.60	5.92	5.84	6.35	6.85	7.15	8.50	8.08	8.24	7.84	6.96	6.70	5.78	5.15
Gaseous fuels									0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.12	0.16	0.18	0.23	0.22
Biomass	76.59	76.59	93.76	85.01	76.29	74.71	75.29	70.37	67.84	79.43	90.20	81.10	61.14	59.43	69.01	56.96	66.08	65.23	63.52	63.44	62.53
N₂O emissions																					
Solid fuels	0.44	0.61	0.59	0.59	0.58	0.54	0.58	0.64	0.50	0.31	0.35	0.32	0.12	0.07	0.12	0.06	0.03	0.03	0.11	0.07	0.07
Liquid fuels	10.95	10.92	10.66	10.61	10.74	11.34	15.67	16.40	17.37	17.13	18.65	20.12	21.03	25.02	23.78	24.27	23.09	20.48	19.72	17.02	15.14
Gaseous fuels									0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.09	0.18	0.23	0.27	0.33	0.33
Biomass	31.80	31.80	38.93	35.30	31.68	31.02	31.26	29.22	28.17	32.98	37.45	33.67	25.39	24.67	28.65	23.65	27.43	27.08	26.37	26.34	25.96

Table 3.20 *GHG emissions (in kt CO₂ eq) from the commercial / institutional sector for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂	527.06	671.02	625.79	595.82	614.20	659.38	798.84	772.29	787.34	760.73	777.09	1010.52	1029.17	1129.86	1219.98	1534.58	1595.88	1497.92	1494.01	1229.50	1140.29
CH ₄	0.45	0.55	0.52	0.49	0.51	0.53	0.64	0.60	0.61	0.60	0.62	0.81	0.83	0.91	0.92	1.17	1.21	1.11	1.08	0.84	0.76
N ₂ O	1.48	1.74	1.61	1.53	1.58	1.63	1.94	1.73	1.73	1.72	1.78	2.35	2.42	2.61	2.60	3.32	3.39	3.07	2.96	2.22	2.01

Table 3.21 *GHG emissions (in kt CO₂ eq) from agriculture for the period 1990 - 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂	2927.39	3068.66	2847.30	2769.57	2783.16	2589.00	2641.65	2632.32	2632.63	2641.80	2644.32	2680.19	2911.18	3119.16	2666.28	2734.12	2894.37	2568.32	2506.10	1979.60	1701.25
CH ₄	3.17	3.31	3.07	2.98	3.00	2.78	2.84	2.83	2.83	2.93	3.36	2.96	3.24	5.11	5.23	6.23	6.12	6.20	5.48	6.28	6.06
N ₂ O	337.65	349.96	323.96	316.06	318.40	295.55	299.92	299.50	299.50	299.58	299.77	303.54	334.92	366.70	310.66	316.51	331.68	295.20	286.79	226.56	201.54

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. By this way emission estimations were verified. The most appropriate EFs and NCVs per sector are selected and applied.

The application of the above-described procedures lead to recalculations that are summarised in the next chapter.

3.2.4.8 Recalculations

The recalculations of emissions that were performed in the present inventory, compared to the previous one, were discussed in details per category in the previous paragraphs. Summarizing, the recalculations performed in stationary combustion sector were as follows:

- ↳ Reallocation of emissions to more appropriate sector.
- ↳ Updated activity data.
- ↳ Correction of errors

The impact of recalculations on total emissions excuding LULUCF, between present and previous emissions estimates, was less than 1%.

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. The above-mentioned recalculations resulted from findings that were identified during these reviews.

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 2010 increased by approximately 58% compared to 1990 emissions (from 14.77 Mt CO₂ eq in 1990 to 23.33 Mt CO₂ eq in 2010). The average annual rate of emissions increase from transport for the period 1990 – 2010 was approximately 3%, 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 2010, the majority of GHG emissions derived from road transport, the contribution of which increased from 80% in 1990 to approximately 84% 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 9-13% during the whole time period with almost 10% in 2009. Additionally, the contribution of internal aviation ranges from almost 5% in 1990 to 6% in 2010, while the contribution of railways decreased from 1.5% in 1990 to less than 0.3% in 2010. The contribution of other transport (pipeline transportation) is negligible.

Finally, the aggregated contribution of transport in total National GHG emissions is 21%.

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	717	621	679	745	771	818	877	997	1014	1212
	CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	N ₂ O	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04
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	0.11	0.09	0.08	0.09	0.09	0.08	0.08	0.08	0.09	0.07
	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	1825	1851	1899	1738	1831	1744	1493	1812	2793	2761
	CH ₄	0.13	0.13	0.13	0.12	0.13	0.13	0.11	0.14	0.21	0.22
	N ₂ O	0.46	0.48	0.47	0.47	0.44	0.39	0.32	0.33	0.50	0.42
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	14487	15219	15620	15827	16142	16504	16982	17746	19506	19931
kt CH₄	Total	5.05	5.10	5.06	5.13	5.15	5.20	5.23	5.32	5.53	5.69
kt N₂O	Total	1.03	1.08	1.15	1.26	1.35	1.39	1.37	1.48	1.75	1.80
kt CO_{2eq}	Total	14911	15661	16084	16326	16667	17043	17515	18315	20164	20608

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	1331	1227	1052	1185	1227	1213	1280	1347	1296	1452
	CH ₄	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	N ₂ O	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05
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	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.06
	N ₂ O	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
Navigation	CO ₂	1580	2145	1937	1923	2153	2054	2262	2107	1885	2808
	CH ₄	0.11	0.16	0.14	0.14	0.16	0.15	0.17	0.16	0.14	0.23
	N ₂ O	0.36	0.48	0.45	0.42	0.43	0.45	0.49	0.44	0.42	0.40
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	19060	19869	20088	21240	21620	21708	22574	23365	22378	25331
kt CH₄	Total	5.75	5.90	5.86	5.84	5.88	5.70	5.60	5.36	5.06	4.84
kt N₂O	Total	1.31	1.44	1.43	1.41	1.45	1.44	1.53	1.49	1.44	1.30
kt CO_{2eq}	Total	19585	20439	20654	21800	22194	22273	23165	23939	22931	25837

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

	Year	2010
	Emissions (kt)	
Aviation	CO ₂	1308
	CH ₄	0.02
	N ₂ O	0.05
Road transport	CO ₂	18907
	CH ₄	4.14
	N ₂ O	0.61
Railways	CO ₂	63
	CH ₄	0.04
	N ₂ O	0.02
Navigation	CO ₂	2286
	CH ₄	0.18
	N ₂ O	0.39
Other	CO ₂	0
	CH ₄	0
	N ₂ O	0
kt CO₂	Total	22573
kt CH₄	Total	4.37
kt N₂O	Total	1.07
kt CO_{2eq}	Total	22996

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

Year	Energy consumption (in TJ)									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aviation	10152	8792	9623	10554	10926	11583	12428	14120	14362	17173
Road transport	167182	179052	183365	187638	190257	196369	205851	210651	221208	225134
Railways	2730	2123	2037	2080	2253	1863	1950	1820	2037	1773
Navigation	24848	24913	25568	23445	24652	23482	20091	24333	37397	36918
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	204912	214880	220592	223717	228088	233296	240319	250923	275003	280998
Energy consumption (in TJ)										
International aviation	34646	29875	31168	33175	39373	36921	35360	34201	35895	40309
International marine	106578	97909	112585	131104	138960	149526	131447	131752	146341	130423

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

Year	Energy consumption (in TJ)									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aviation	18846	17373	14901	16781	17394	17185	18143	19084	18358	20572
Road transport	227903	232929	241641	256195	257910	260893	270979	285270	274546	297633
Railways	1773	1773	1773	1773	1773	1758	1801	1630	1587	1329
Navigation	21363	28895	26155	26024	28980	27674	30610	28405	25371	37251
Other	NO	37	97	65	40	68	88	133	257	0
Total	269885	281007	284567	300838	306098	307579	321622	334522	320118	356784
Energy consumption (in TJ)										
International aviation	35360	32863	32863	42776	43972	33762	40497	41389	43039	37018
International marine	150495	145963	131216	134067	135395	119726	129215	132085	128662	109312

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

Energy consumption (in TJ)	
Year	2010
Aviation	18516
Road transport	274056
Railways	859
Navigation	30490
Other	0
Total	323921
Energy consumption (in TJ)	
International aviation	29614
International marine	114006

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. This is what was in last year's submission where a reconstruction of the whole time-series input data was completed and used for the calculations. 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**.

It is obvious that an updated vehicles fleet population and composition along with different traffic characteristics and the use of COPERT IV has lead, in last year's calculations, to an important differentiation of emissions values. Moreover, in this year submission, recalculations were performed for the whole time series of CH₄ and N₂O, as new updated emissions factors were applied. Finally, recalculations of natural gas emissions were carried out taking into account updated country specific emissions factors.

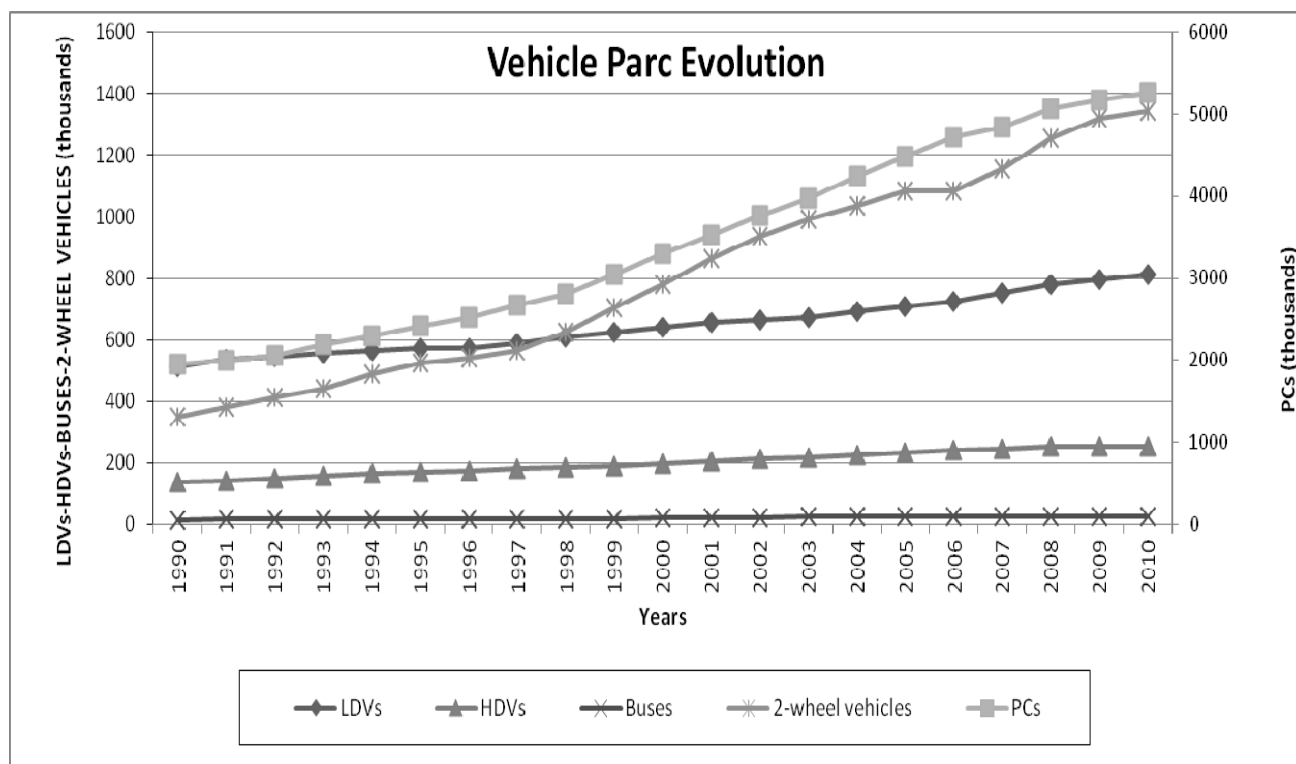


Figure 3.7 Vehicles population evolution for all vehicles categories during the whole time period 1990 – 2010

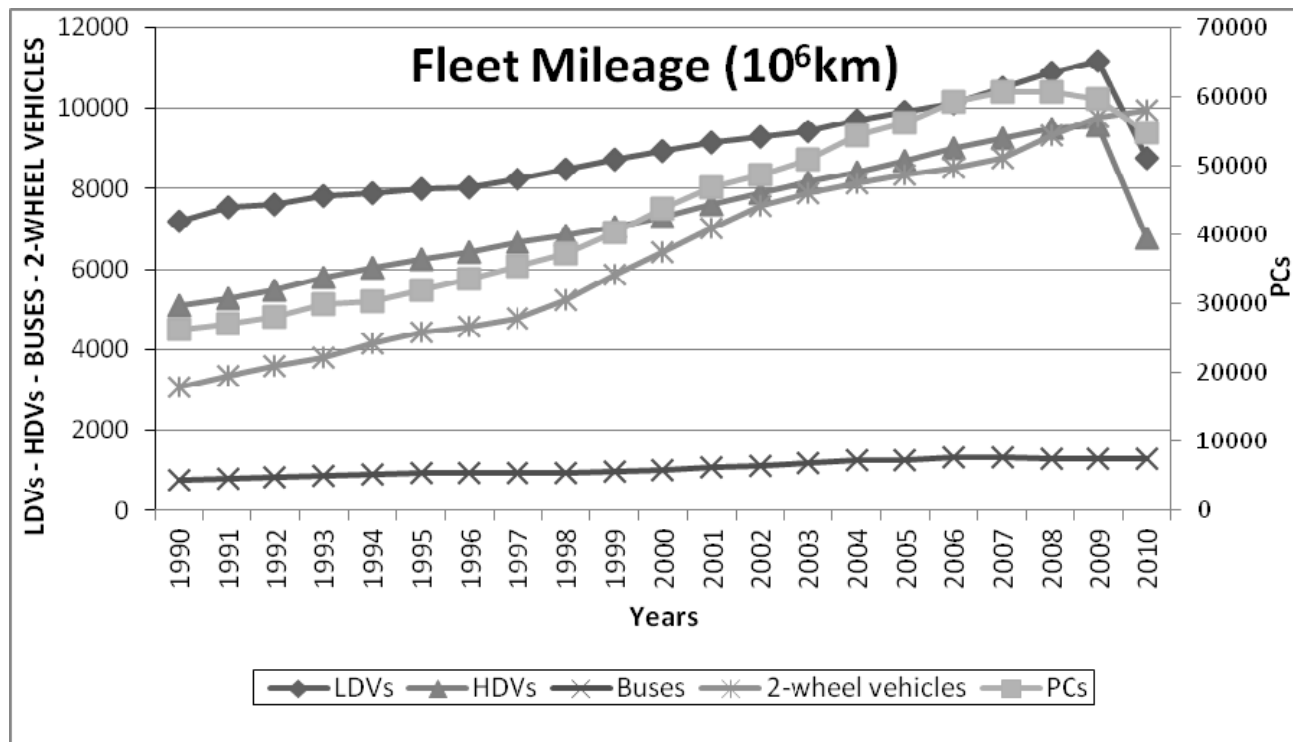


Figure 3.8 Annual mileage driven by all vehicles categories during the whole time period 1990 – 2010

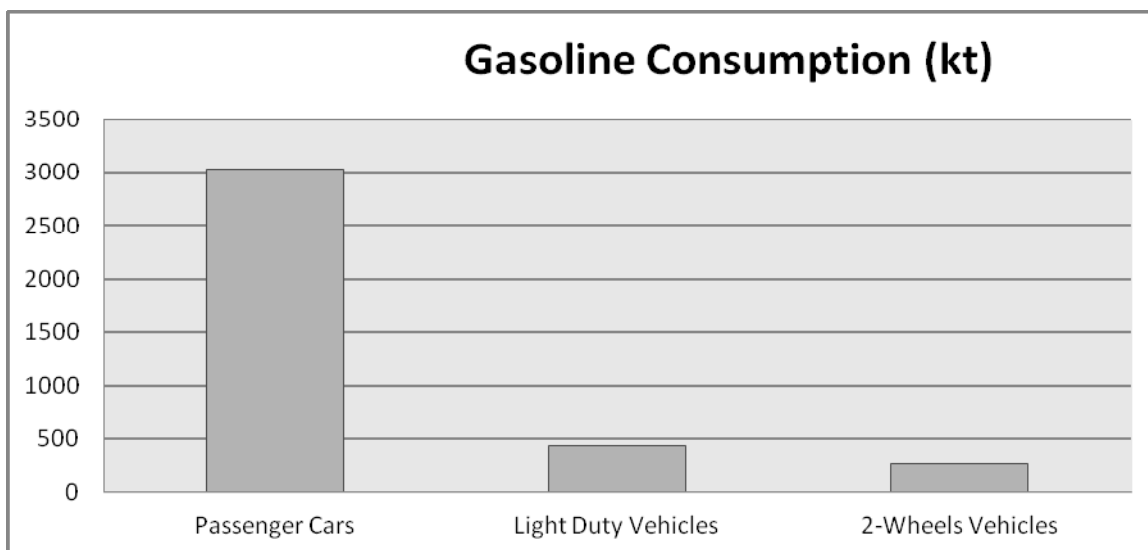


Figure 3.9 Gasoline consumption (kt) by all vehicles categories for 2010

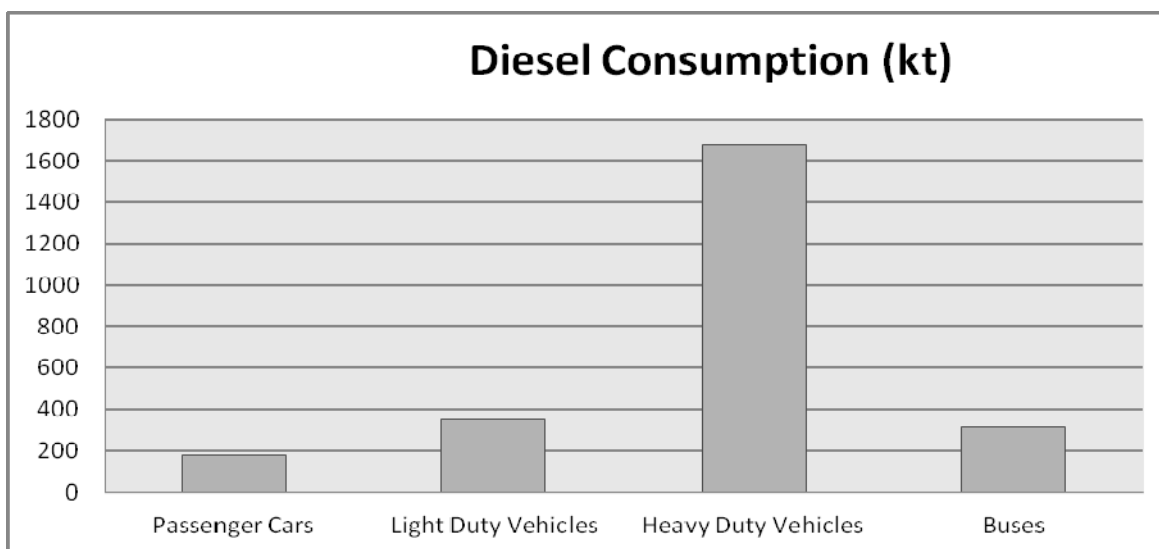


Figure 3.10 Diesel consumption (kt) by all vehicles categories for 2010

In the last years, the vehicle fleet has increased by 265% 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.

Road transport is a key category of CO₂ emissions. CO₂ emissions in 2010 increased by approximately 58% compared to 1990 emissions, CH₄ emissions decreased (about 15%), while N₂O emissions increased slightly by 3% (*Table 3.24(a,b,c)*). During this period, energy consumption augmented by 58%.

The significant increase of GHG emissions is attributed to the increase of passenger cars. This trend is expected to decelerate in the near future as a consequence of the economic crisis, 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 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.

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, is 0.0236 (3.938,62 TJ/166.745,16 TJ), which is nine times higher than the average of other countries that report CO₂ emissions from combustion of lubricants. 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.

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.

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	167,182	179,052	183,365	187,638	190,257	196,369	205,851	210,651	221,208	225,134

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	227,903	232,929	241,641	256,195	257,910	260,893	269,021	281,682	274,820	300.900

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

Year	2010
Emissions (in kt CO₂ eq)	
CO ₂ (kt)	18907
CH ₄ (kt)	4.14
N ₂ O (kt)	0.61
TOTAL	19184
Energy consumption (in TJ)	
Gasoline	161.778
Diesel	108.919
LPG	1987
Natural Gas	658
Other liquids	714
TOTAL	274,056

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). After ERT recommendation, revised emission estimates for CH₄ and N₂O emissions from liquid fuels in navigation, which are based on EFs from the Revised 1996 IPCC Guidelines are provided in this submission.

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.

Internal navigation (CO₂ emissions) is a key category. GHG emissions from navigation in 2010 were higher (22%) than the emissions in 1990, on the basis of fuel consumption data from this sector (*Table 3.25*).

Table 3.25 *GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from internal navigation for the period 1990 – 2010*

	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	1,825	0.13	0.46	1,969	14,559	9,525	764	24,848
1991	1,851	0.13	0.48	2,004	15,469	9,284	161	24,913
1992	1,899	0.13	0.47	2,049	15,079	10,248	241	25,568
1993	1,738	0.12	0.47	1,887	15,166	8,078	201	23,445
1994	1,831	0.13	0.44	1,971	14,082	10,289	281	24,652
1995	1,744	0.13	0.39	1,868	12,349	10,771	362	23,482
1996	1,493	0.11	0.32	1,594	9,923	9,847	322	20,091
1997	1,812	0.14	0.33	1,919	10,226	13,665	442	24,333
1998	2,793	0.21	0.50	2,953	15,252	21,622	522	37,397
1999	2,761	0.22	0.42	2,897	12,522	23,752	643	36,918
2000	1,580	0.11	0.36	1,694	11,396	9,485	482	21,363
2001	2,145	0.16	0.48	2,296	14,949	13,464	482	28,895
2002	1,937	0.14	0.45	2,080	14,299	11,374	482	26,155
2003	1,923	0.14	0.42	2,055	13,042	12,298	683	26,024
2004	2,153	0.16	0.43	2,290	13,346	15,071	563	28,980
2005	2,054	0.15	0.45	2,197	14,090	13,102	482	27,674
2006	2,262	0.17	0.49	2,418	15,378	14,428	804	30,610
2007	2,107	0.16	0.44	2,247	13,746	14,067	592	28,405
2008	1,885	0.14	0.42	2,019	13,274	11,735	362	25,371
2009	2,808	0.23	0.40	2,938	11,770	25,320	161	37,251
2010	2,286	0.18	0.39	2,410	11,641	18,568	281	30,490

Internal aviation

GHG emissions from domestic aviation 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, while data on LTOs are provided by the Civil Aviation Organisation. However, 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 have been made to the energy consumption data of the whole time period, as suggested in a previous in-country review (*Table 3.26(a,b)*).

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. After the in-country review, Greece provided additional information on domestic LTOs and number of passengers travelling on domestic flights. The number of passengers, travelling on domestic flights, increased by 40 per cent over the period 1990-2004. The ERT identified that there is a potential overestimation of CO₂, CH₄ and N₂O emissions from civil aviation in the base year and decided to calculate and apply an adjustment.

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. Since the discrepancies between the number of LTOs and the corresponding fuel consumption still persist, the above adjustment continues to be applied.

GHG emissions from internal aviation increased by 82% since 1990 with an average annual increase rate of approximately 4% (*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 and N₂O for the whole time series from liquid fuels were reimported in all relevant CRF tables after having corrected a compilation error.

GHG emissions from railways (*Table 3.27(a,b,c)*) decreased by 69% from 1990 to 2010.

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	717	621	679	745	771	818	877	997	1014	1212
CH ₄	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
N ₂ O	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04
TOTAL (in kt CO ₂ eq)	725	628	687	753	780	827	887	1008	1025	1226
<i>Energy Consumption</i> (TJ)										
<i>Kerosene</i>	10.152	8.792	9.623	10.554	10.926	11.583	12.428	14.120	14.362	17.173
<i>Aviation gasoline</i>	118.55	102.66	112.37	123.24	127.58	135.26	145.12	164.88	167.70	200.53

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	1331	1227	1052	1185	1227	1213	1280	1347	1296	1452
CH ₄	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N ₂ O	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05
TOTAL (in kt CO ₂ eq)	1345	1240	1064	1198	1241	1226	1294	1362	1310	1468
<i>Energy Consumption</i> (TJ)										
<i>Kerosene</i>	18.846	17.373	14.901	16.781	17.394	17.185	18.143	19.084	18.358	20.572
<i>Aviation gasoline</i>	220.07	202.87	174.00	195.95	203.11	200.67	211.85	222.85	214.36	240.21

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

Year	2010
Emissions (in kt CO₂)	
CO ₂	1308
CH ₄	0.02
N ₂ O	0.05
TOTAL (in kt CO ₂ eq)	1322
Energy Consumption (TJ)	
Kerosene	18.275
Aviation gasoline	240.46

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)	200.16	155.68	149.33	152.51	165.22	136.62	142.97	133.44	149.33	130.04
CH ₄ (kt)	0.11	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.09	0.07
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)	226.97	176.53	169.32	172.93	187.34	154.91	162.12	151.31	169.32	147.45

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)	130.04	130.04	130.04	130.04	130.04	128.95	132.10	119.50	116.35	97.45
CH ₄ (kt)	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.06
N ₂ O (kt)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
Total (in kt CO ₂ eq)	147.45	147.45	147.45	147.45	147.45	146.21	149.78	135.50	131.93	110.49

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

Year	2010
CO ₂ (kt)	63.00
CH ₄ (kt)	0.04
N ₂ O (kt)	0.02
Total (in kt CO ₂ eq)	71.44

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

Road transportation:

CH₄, N₂O from gasoline and diesel

A recalculation of the whole timeseries was carried out with new updated emission factors.

CO₂ from CNG

Natural gas country specific emission factors for CO₂ emissions were applied and calculations were performed for the whole time series.

Navigation

In response to the ERT recommendation, revised emission estimates for CH₄ and N₂O emissions from liquid fuels in national navigation were performed, which are based on EFs from the Revised 1996 IPCC Guidelines. The ERT agrees with these estimates. The overall impact of this revision is an increase of 106.50 Gg CO₂ eq in 2009, equivalent to 0.1 per cent of total sectoral emissions.

Finally, after ERT's raised question, CH₄ and N₂O emissions from lubricant use were revised because previous values were not transferred correctly to the CRF Reporter. CH₄ and N₂O EFs from tables 1.7 and 1.8 of the IPCC Reference Manual (under the oil column) for lubricant use are applied.

Railways

Methane and nitrous oxides emissions for the whole time series from liquid fuels were reimported in all relevant CRF tables after having corrected a compilation error.

International Bunkers

In response to the ERT recommendation, revised emission estimates for CH₄ and N₂O emissions from liquid fuels marine bunkers were performed, which are based on EFs from the Revised 1996 IPCC Guidelines. The ERT agrees with these estimates.

Finally, after ERT's raised question, CH₄ and N₂O emissions from lubricant use were revised because previous values were not transferred correctly to the CRF Reporter. CH₄ and N₂O EFs from tables 1.7 and 1.8 of the IPCC Reference Manual (under the oil column) for lubricant use are applied.

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.
- As for lubricants use, the method used by the ERT in the initial review for calculating the consumption of lubricants for road transportation (based on the average lubricant consumption/fuel consumption ratio for the cluster of countries for the whole time series rather than on the data from the national energy statistics) is still applied. Effort will be made to verify the data on lubricants used for road transportation and report thereon in the next annual submission.

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.
- The approaches for the allocation between internal and external transportation are investigated in collaboration with the Civil Aviation Organisation (CAO). After a survey by CAO, it was found that the only possible way to collect detailed data was through fuel companies. These data are subject to confidentiality issues. However, they will become available through the inclusion of the aviation sector in the EU ETS. It is expected that from 2012 new data will be available in this matter.

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 2010 account for 1.28% 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 8.9% increase for the period 1990 – 2010 is observed.

Table 3.28 *CH₄ emissions from lignite mining (in Mt) and primary production of lignite (in kt) for the period 1990 – 2010*

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

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 ($=1.5\text{m}^3 \text{CH}_4/\text{t lignite} * 0.67 \text{ kgCH}_4 / \text{m}^3\text{CH}_4$), 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 plans to contact the inventory teams of the above mentioned countries 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), since 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 772 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 2010 accounted for 0.21% of total GHG emissions from *Energy*. Overall, emissions in 2010 increased by 22% 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 – 2010*

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	19.45	124.41	53.05	0.03	196.94

Table 3.30a *Key activity data for the estimation of GHG emissions from oil systems for the period 1990 - 2010*

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

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 – 2010 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 - 2010*

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

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

Recalculations were performed for the categories 1.B.2.b.3 and 1.B.2.b.4 for the year 2009. The reason of the recalculations was the availability of updated activity data as concerns the activated NG distribution and transmission network. The impact of recalculation on total emissions was minor.

Table 3.31 GHG emissions (in t) from venting and flaring for the period 1990 – 2010

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Venting																					
Oil – Production																					
CO ₂	11.99	12.02	9.85	8.04	7.64	6.55	7.40	6.70	4.55	0.23	4.05	2.80	2.79	2.02	1.95	1.61	1.55	1.18	0.89	1.27	1.79
CH ₄	1348.88	1352.09	1108.20	904.79	859.52	736.80	832.63	753.86	512.16	25.94	455.84	314.73	314.09	227.42	219.84	181.48	174.10	132.54	99.97	142.52	200.85
Oil – Transport																					
CO ₂	39.19	33.32	37.64	31.74	34.81	41.31	47.24	48.40	50.05	42.97	52.21	50.96	51.52	53.32	54.70	50.40	53.46	54.79	51.98	47.92	54.25
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	547.80	581.11	595.58	565.00	520.88	589.69
N.G. – Production																					
CO ₂	2556.00	3053.00	2556.00	1917.00	2130.00	1775.00	1850.34	1353.74	1427.11	78.11	1214.33	1144.16	1925.16	150.16	363.16	292.16	293.11	222.58	223.40	294.80	436.88
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
CH ₄							1608.19	2019.20	2930.86	3152.60	3376.35	3666.70	3650.11	4103.37	4249.79	4291.64	4666.11	4883.35	5245.24	5607.95	5919.90
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
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	10.00	14.25	20.09
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	0.10	0.09	0.08	0.06	0.05	0.07	0.10
N.G. – Production																					
CO ₂	221.40	208.80	196.20	145.80	68.40	64.80	68.40	66.60	59.40	3.60	64.80	63.00	66.60	48.60	45.00	28.80	41.40	37.80	25.20	19.80	12.60
CH ₄	1.35	1.28	1.20	0.89	0.42	0.40	0.42	0.41	0.36	0.02	0.40	0.39	0.41	0.30	0.28	0.18	0.25	0.23	0.15	0.12	0.08
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N.G. – Processing																					
CO ₂	165.60	197.80	165.60	124.20	138.00	115.00	119.60	87.40	92.00	4.60	78.20	73.60	124.20	9.20	23.00	18.40	18.40	13.80	13.80	18.40	27.60
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
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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 2010, GHG emissions from *Industrial processes* account for 9.12% of total emissions (excluding LULUCF) and have decreased by 14.72% compared to base year emissions and increased by 4.37% compared to the emissions of 1990 (**Figure 4.1**), while the average annual rate of increase is estimated at 0.44% for the period 1990 – 2010.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2010 reaching a minimum value of 9.88 Mt CO₂ eq in 2009 and a maximum value of 14.71 Mt CO₂ eq in 1999. The minimum value for 2009 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 cease its operation and about 2,157 kt are removed from the inventory. It should be noted that in 2009 and 2010 emissions are only slightly higher than the ones in 1990, depicting the low production levels of the country.

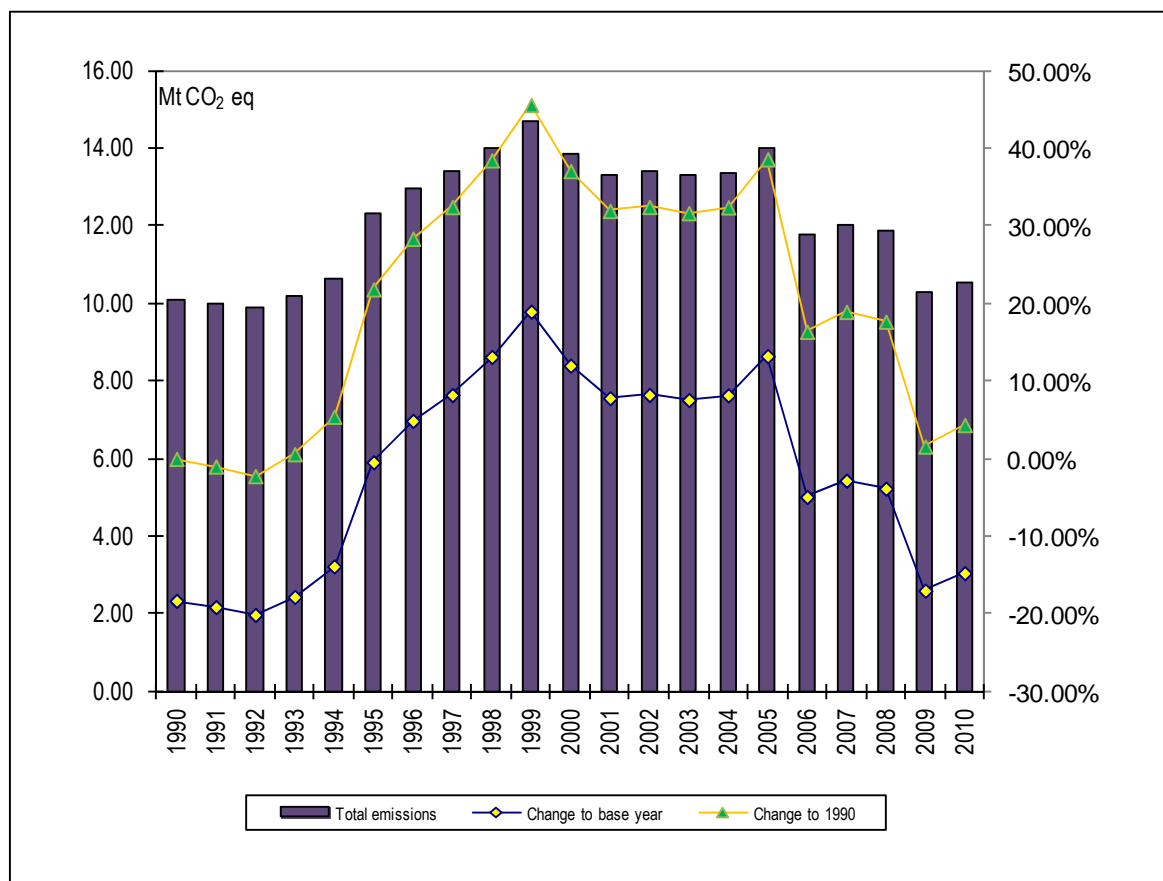


Figure 4.1 *Total GHG emissions (in Mt CO₂ eq) from Industrial Processes for the period 1990 - 2010*

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 57.16% to 79.45%. Overall, CO₂ emissions in 2010 decreased by 18.28% from 1990, with an average annual rate of increase estimated at -0.01%. CO₂ emissions derive mainly from mineral products and metal production.

The contribution of F-gases to total emissions from industrial processes is also very significant, increasing from 10.86% in 1990 to 37.72% in 1999 (peak). The contribution continues to be important until 2006 where an abrupt decrease is observed (from 29.74% in 2005 to 19.60% 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 53.45% in 2005). In the recent years (2006-2010) the trend is again increasing, following the substitution of CFCs according to the protocol of Montreal.

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2009, with an average annual rate of change of -5.26%. In 2010 this trend is changing with an

increase of 16.59%. However this is not to be attributed to an overall change, rather than a counterbalancing fact, since emissions in 2009 had already experienced a very intense decrease (-13.00%) due to 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 and emissions are only due to metal production. The average rate of decrease is 1.42% for the period 1990-2010.

Table 4.1 *GHG emissions (in kt CO₂ eq) per gas from industrial processes for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	7,889.62	7,812.44	7,847.09	7,544.30	7,552.31	8,065.51	8,068.52	8,247.61	8,484.74	8,405.81	8,621.04
CH ₄	0.73	0.76	0.71	0.76	0.75	0.80	0.80	0.84	0.82	0.53	0.47
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
HFC	935.06	1,106.82	908.39	1,609.35	2,150.52	3,304.78	3,844.18	4,138.19	4,638.51	5,453.41	4,345.18
PFC	163.37	164.17	161.21	96.98	60.37	53.97	46.14	107.67	133.04	90.32	105.09
SF ₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99
TOTAL	10,100.90	10,001.75	9,876.86	10,162.78	10,650.25	12,307.14	12,966.54	13,379.13	13,985.95	14,706.91	13,846.85

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂	8,640.74	8,551.68	8,716.34	8,738.03	9,289.97	9,007.74	8,914.09	8,411.27	6,463.67	6,447.57
CH ₄	0.27	0.39	0.36	0.41	0.48	0.51	0.54	0.52	0.42	0.38
N ₂ O	648.08	623.93	575.90	547.53	545.80	442.70	439.53	422.30	367.42	428.39
HFC	3,964.27	4,130.47	3,930.35	4,014.57	4,086.28	2,229.07	2,574.46	2,956.54	3,356.11	3,557.92
PFC	71.16	69.14	72.47	68.99	69.89	66.35	76.22	89.12	69.87	101.61
SF ₆	4.06	4.25	4.25	4.47	6.45	8.37	9.92	7.53	5.26	6.14
TOTAL	13,328.58	13,379.86	13,299.66	13,374.00	13,998.88	11,754.72	12,014.76	11,887.28	10,262.74	10,542.02

Throughout the inventory years, the main sources of emissions from *Industrial processes* are mineral products and production 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. As a result the contribution of GHG emissions from mineral sources and HFC production to the total sector emissions decreases from 75.68% in 1990 to 46.72% in 2010.

The contribution of halocarbons consumption to total emissions from the sector has increased considerably in the recent years (34.45% in 2010 against 0.45% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons. The average annual rate of increase is 55.97% for the period 1995 – 2010.

Metal Industry in general has a stable contribution to the Emissions of Industrial Processes (10.93% in 1990 versus 8.48% in 2010).

Finally, the contribution of emissions from the chemical production decreases from 13.36% in 1990 to 10.35% in 2010. 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.

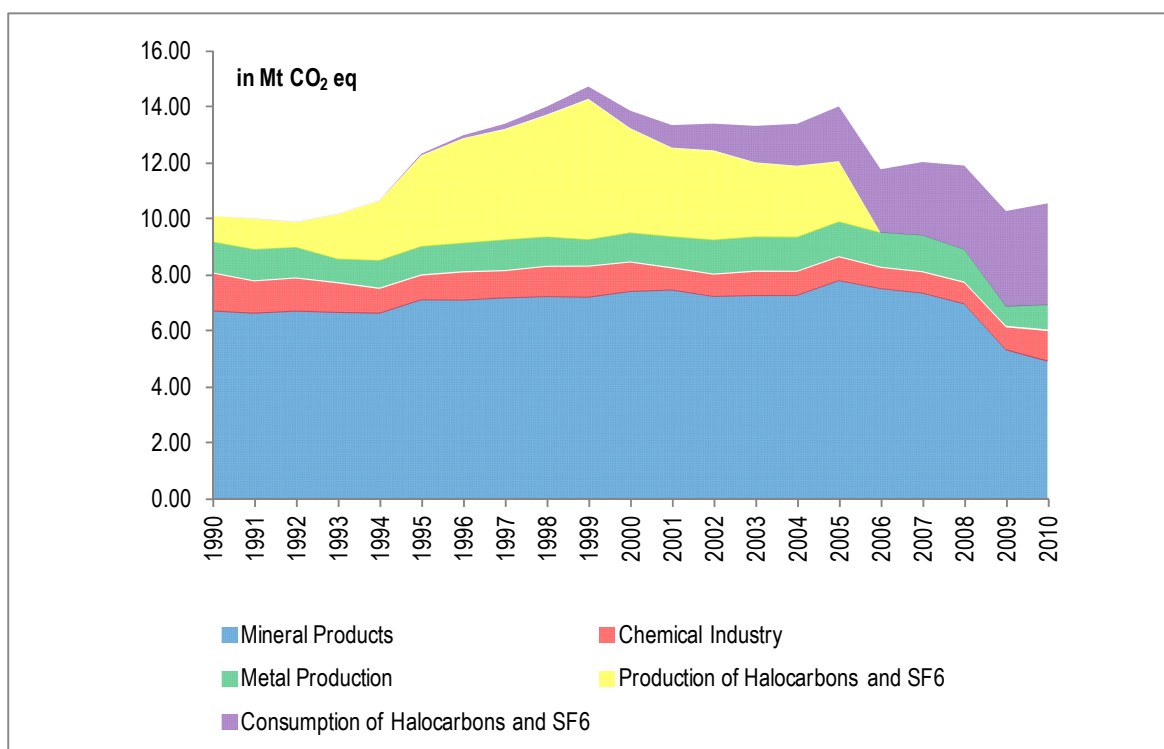


Figure 4.2 *GHG emissions (in Mt CO₂ eq) from Industrial processes, per main source category for the period 1990 – 2010*

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. Also, 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 2005-2008). 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.
- ✎ 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, the National Association of Refrigeration Importing and Trading Companies and other private companies that are related to the sales of equipment containing f-gases. It should be noted that the National Association of Refrigeration Importing and Trading Companies and the Appliances Recycling SA have been contacted for the first time in the current inventory preparation, following the Improvement Plan of 2012. In this context a total number of 30 companies has reported information on the imports, production, exports and sales of f-gases blends and equipment. The collected information has been used to re-evaluate and update the 2.F.1 Subcategory's structure, updating the blends used for each application and the f-gases penetration considered. This is also in line with the outcome of several meetings that have taken place between the inventory team, members of the ElStat, experts on the consumption of f-gases in the

Refrigeration and A/C Equipment and experts on the implementation of the F-gases regulations in Greece. As regards to the foam blowing and aerosols subcategories data have been collected by the respective producing industries (that are also importers of foam products). In addition, an attempt has been made to contact the Panhellenic Association of Insulating Companies, although there has been no safe conclusion up to the moment.

- ✎ 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	PS	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 2010 (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 2010*

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		☒
Ferroalloys production	CO ₂	☒	
Other Chemicals	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 detail 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:

- CO₂ emissions from *Soda Ash Use* have been estimated for the first time.
- CO₂ emissions from *H₂ production* have been transferred from the Energy sector to Category 2.B.5 (Chemical Industry / Other Production)
- In some cases of Category 2.F.1, namely domestic and transport refrigeration and mobile A/C, actual emissions from disposal have been estimated for the first time, based on the default methodologies.
- Emissions from blends that were not included in the inventory before have been reported for the same time, based on the information collected by gas and equipment companies. This resulted in reporting of HFC-23, HFC-143a and PFC-116 emissions in category 2.F.1.

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	☒							
B. Chemical industry								
1. Ammonia production	☒	NA						
2. Nitric acid production							☒	
3. Adipic acid production							NO	
4. Carbide Production	NO	NO						
5. Other								
Sulphuric acid production	NO	NO	NO					
Organic chemicals production	NA / NE	☒ / NA	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						NA/NO		
D. Other production								
1. Pulp and paper								
2. Food and drink							NA	
E. Production of halocarbons and SF ₆								
1. Production of HCFC-22				☒				
2. Fugitive				NO			NO	NO
F. Consumption of halocarbons and SF ₆								
1. Refrigerating and air conditioning equipment				☒	☒	NA		
2. Foam blowing				☒	NO	NO		
3. Fire extinguishers				☒	NA,NO	NO		
4. Aerosols/metered dose inhalers				☒	NO	NO		
5. Solvents				NA, NO			NA, NO	NA, NO
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 2010 (**Table 4.5**) accounted for 43.46% of total GHG emissions from industrial processes and for 4.96% of total national emissions including LULUCF (3.87% of total national emissions excluding LULUCF). The average annual rate of increase of CO₂ emissions from cement production during the period 1990 – 2010 was -0.01% (emissions decreased by 18.78% from 1990 to 2010).

Table 4.5 *CO₂ emissions from cement production (in kt) and clinker production (in kt) for the period 1990 - 2010*

Year	Clinker production (kt)	CO ₂ emissions (kt)
1990	10,645.13	5,640.90
1991	10,561.79	5,595.93
1992	10,831.27	5,738.26
1993	10,851.82	5,751.85
1994	10,930.92	5,792.37
1995	11,743.73	6,223.13
1996	11,773.83	6,240.61
1997	11,831.56	6,273.35
1998	11,789.07	6,249.41
1999	11,761.21	6,232.89
2000	12,071.73	6,399.72
2001	12,130.78	6,428.26
2002	11,666.18	6,180.91
2003	11,754.73	6,234.62
2004	11,754.73	6,230.48
2005	12,442.36	6,648.74
2006	12,244.24	6,460.86
2007	12,035.08	6,272.31
2008	11,361.40	6,053.53
2009	8,649.32	4,581.72
2010	7,926.64	4,208.60

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 2005-2010 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 in 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 2010 the average content of the raw materials in CaCO₃ and MgCO₃ has been estimated at 76.31% and 2.55%, whereas the emission factor used is 44% and 52.2%, respectively, deriving from the stoichiometry of the reaction. Also, the raw material used throughout 2010 was 12,204.62 kt.

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 – 2010) the plants report also emissions from non-carbonate carbon (organic carbon). The percentage of organic carbon to the raw material has been low (average content of 0.2%) and the respective emissions constitute the 0.68% of total emissions from cement production.

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 acc to the IPCC GPG, the overlap method has been used in order to ensure the consistency of the time-series. This has been explained in detail 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.).

For reasons of consistency between both the previous years and the other countries, the activity data of the more recent years (2005-2010) 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 method 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 described above). The recalculation methodology applied is in line with the IPCC GPG and has been approved by the ERT in the 2009, 2010 and in the 2011 centralised review.

It is quite clear from the Chart in Figure 4.3 that the cement production is experiencing intense reduction in 2009 and 2010, which is attributed to the economical recession that has been very important in the Construction Sector of Greece. It should be mentioned however that the decrease of 2010 is not as intense as the one of 2009 (-8.14% versus 24.31% respectively).

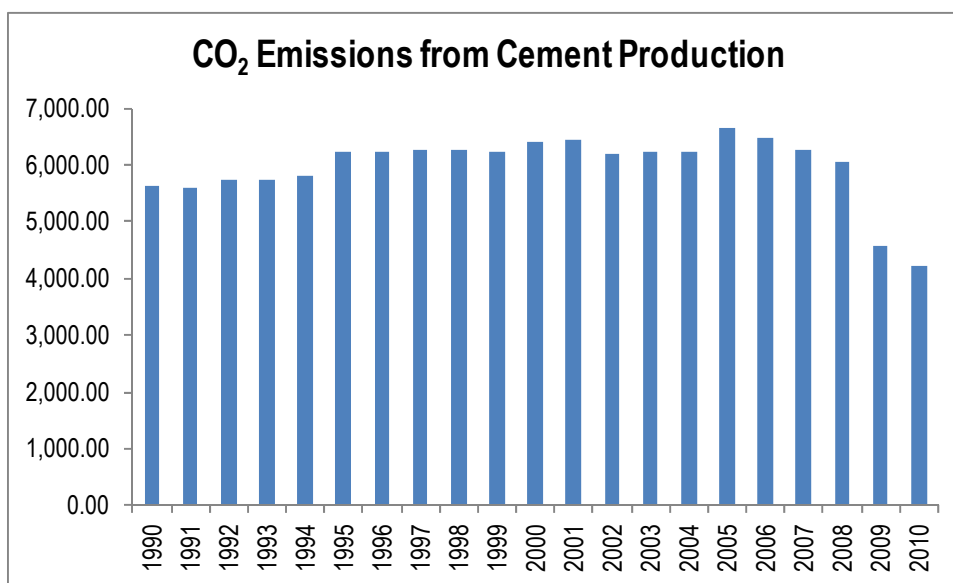


Figure 4.3 *CO₂ emissions (in kt) from Cement Production for the period 1990 – 2010*

Table 4.6 Country specific CO₂ emission factor (in t / t) for clinker (cement) production for the period 1990 – 2010

Year	Emission factor (t CO ₂ / t clinker)
1990	0.5299
1991	0.5298
1992	0.5298
1993	0.5300
1994	0.5299
1995	0.5299
1996	0.5300
1997	0.5302
1998	0.5301
1999	0.5300
2000	0.5301
2001	0.5299
2002	0.5298
2003	0.5304
2004	0.5300
2005	0.5344
2006	0.5277
2007	0.5212
2008	0.5328
2009	0.5297
2010	0.5309

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, although it quite smoothened. This is also verified by the decreased number of new constructions in the recent years (34,021 in 2008 versus 274,47 in 2009 and 23,380 in 2010).

The IEF of 2010 is close to the mean IEF of the previous years (0.5309 versus a mean of 0.5298), probably because the carbonates percentage of the raw materials is close to the values of previous years (**Table 4.6**). The average CaO and MgO content of clinker for the years 2005-2010, as provided by the plants, is presented in **Table 4.7**.

Table 4.7 *CaO and MgO content of clinker (2005-2010)*

Year	CaO content of clinker (%)	MgO content of clinker (%)
2005	64.68	2.93
2006	64.65	3.03
2007	64.47	3.26
2008	64.73	3.25
2009	65.00	2.79
2010	65.21	2.74

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. An slight exception to that is the national value of 2010, that is about 0.64% lower than the one reported directly by the plants. However it should be mentioned that the national Prodcom data are provisional and have been provided confidentially to the Inventory Team, since they are not yet officially published, therefore no safe conclusion can be made.

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 Construction are used as additional indications of the overall trend. All data seem to agree that the recent trend is ongoing, although the decrease from 2008 to 2009 is more abrupt than the one of the two last inventory years (2009-2010).

4.2.5 Recalculations

No recalculation has been performed in the 2012 submission. This is in line with the results of the 2011 Centralized Review.

4.2.6 Planned improvements

Gaps in activity data time series will be filled in as soon as new data become available. It should be noted that emissions from non carbonate carbon sources have been taken into account only in the recent years (as of 2008), and a recalculation in order to improve the time-series consistency is likely to be performed in the years to come.

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.

Lime production (CO_2 emissions) is a trend assessment key category. CO_2 emissions from lime production in 2010 (**Table 4.8**) account for 2.18% of total GHG emissions from Industrial processes and for 0.20% of total national emissions (including LULUCF) and 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 – 2010, is estimated at -2.57%.

Table 4.8 *CO₂ emissions (in kt) from lime production and production of lime (in kt) for the period 1990 - 2010*

Year	CO ₂ emissions (kt)	IEF	Lime production(kt)
1990	431.97	0.880	491.03
1991	412.89	0.880	476.17
1992	405.82	0.880	461.31
1993	392.63	0.886	443.21
1994	379.67	0.886	428.38
1995	392.00	0.884	443.49
1996	400.63	0.883	453.85
1997	409.96	0.875	468.46
1998	449.35	0.877	512.29
1999	481.76	0.889	541.63
2000	444.12	0.892	498.09
2001	426.38	0.892	477.76
2002	441.63	0.891	495.47
2003	388.41	0.891	435.71
2004	403.16	0.890	505.76
2005	403.16	0.797	505.76
2006	408.85	0.830	492.48
2007	468.98	0.844	555.97
2008	341.76	0.758	451.11
2009	288.78	0.758	380.77
2010	229.96	0.791	290.89

4.3.2 Methodology

For years 2005 – 2010, 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 518.66 kt of $CaCO_3$ eq for the production of lime in 2010. 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 and hydraulic lime. Both values are provided by the ElStat for the years 1993-2010, 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 2010 values are provisional, since the Prodcom file has not been publicly available yet. Hydraulic lime data for 2008-2010 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, however this should be attributed to the carbonates content of the raw material. Especially between the years 2007 and 2008 a very high inconsistency has been observed between reported production and emissions, in a way that part of the production reported in 2008 has been transferred from 2008 to 2007.

Lime production in the national statistics is reported as non hydrated lime, hydrated lime and hydraulic lime. 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%. The average proportion of hydrated lime is 34% while, according to the data provided by the El.Stat, this value amounts to 51% for 2010 (provisional data).

4.3.3 Uncertainties and time-series consistency

The uncertainty of the estimate is medium, although data derive of 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 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 binded during the production process.

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 method, 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 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 for 2008 and 2009, 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 2008-2010 than the one used in the previous years. Comparing to the default factors the above mentioned factor is in an accepted range however is more close to the factor used for dolomite lime than for the high calcium one. This issue has already been observed during the QC checks and any update will be provided in the next NIR.

It should be also noted that during the Qa/QC verification tests run by the Inventory Team, a mismatch has been noticed between the ETS and the reported data. An error has been detected, concerning the emissions reported by one plant in 2005. Using the corrected value, an inconsistency has been noticed concerning the resulted IEF. In specific, the value was 0.95% and was considered an outlier, therefore the average EF of years 2006-2010 (0.80%) has been used to correctly depict production. The years selected are the ones that best describe the national circumstances, since the respective emissions are estimated using detailed plant-specific data. The calculated production and emissions level is presented in *Table 4.8*.

4.3.5 Recalculations

A recalculation has been performed for emissions reported in 2005, due to an error in the working files (see previous paragraph). The difference between the previous and the current estimates and the impact on total emissions are 8.29% and 0.02% respectively.

4.3.6 Planned improvements

In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 level and trend key category, according to the results of the key analysis carried out in the present inventory. Emissions in 2010 (**Table 4.9**) accounted for 4.34% of total GHG emissions from *Industrial processes* and for 0.39% of total national emissions (without *LULUCF*).

4.4.2 Methodology

The present inventory includes emission estimates from limestone use in metal production (iron & steel and primary aluminium), SO_2 scrubbing, magnesia and ceramics production.

CO_2 emissions are estimated according to the following general equation:

$$\text{CO}_2 \text{Emissions} = \sum_i (M_i \cdot EF_i \cdot F_i)$$

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:

Table 4.9 *Limestone use (in kt) and CO₂ emissions (in kt) for the period 1990 – 2010*

Year	Limestone & magnesite consumption (kt)	CO ₂ emissions (kt)
1990	1,249.40	582.80
1991	1,215.96	563.20
1992	1,108.94	510.54
1993	1,006.80	466.33
1994	872.18	406.25
1995	938.32	439.93
1996	864.36	402.99
1997	948.03	442.40
1998	1,013.40	471.31
1999	949.46	439.59
2000	1,111.23	512.37
2001	1,195.47	549.56
2002	1,200.82	553.92
2003	1,287.63	588.84
2004	1,325.62	605.06
2005	1,282.33	698.86
2006	1,236.00	596.60
2007	1,237.94	577.73
2008	1,178.90	545.21
2009	948.24	431.03
2010	1,017.04	457.50

- ↳ **Steel production:** Data are generally plant specific, deriving from the EU ETS verified reporting of the plants (for the years 2005-2010) and the reporting performed for the NAP formulation in the previous years. For 2010, the total CaCO₃ equivalent amounts to 16.70 kt.
- ↳ **Primary aluminium production:** Data on primary aluminium production are plant specific and confidential (there is only one plant in Greece). The emission factor used is 0.44, whereas the single carbonate estimated is CaCO₃. Plant specific data on limestone consumption cover the years 1990 and 1998 – 2010. The specific limestone consumption has been used for filling in missing data. In 2010 the limestone consumption amounts to 114.82 kt of CaCO₃ eq.
- ↳ **Ceramics production:** Carbonates consumption data (in the context of the ETS reports) have been used to estimate emissions in the years 2005-2010. Activity data refer to CaCO₃ and MgCO₃ consumption (emission factors 0.44 and 0.522 respectively). The total CaCO₃ equivalent amounts to 149.66 kt, showing a decrease with reference to 2009. It is also interesting that fourteen ceramics plants (three more than in 2009) have declared zero emissions in 2010, 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. 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.

↳ **SO₂ scrubbing:** The operation of flue gas desulphurization systems in Greece started in 2000. The estimation of emissions is based on data collected during the formulation of the NAP for the period 2005 – 2007. For years 2005-2010 data from verified installation ETS reports were used. The emission factor used (0.44 t CO₂ / t limestone) derives from the stoichiometry of the reaction. Emissions have increased considerably in 2009-2010 as a result of the inclusion of new operation plants in the system in 2009.

↳ **Magnesia production:** Emissions are estimated using information for the single plant operating in Greece for the years 1999-2010 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 2005-2010: 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 to the one estimated in 2010, 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 1.05-1.17, while the average is 1.10 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.

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 due, in part, 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 2010 an additional QA/QC referred to the abrupt increase of emissions in 2005. Although slight corrections have been made for years 2005, 2006 and 2007 to accurately depict reports 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 the respective decrease in emissions in the Ceramics Sector is -22.11%, effecting the overall decrease of the category's emissions by 14.63%.

With reference to the emission factor used in the most recent years (2005-2010), the deviation from the stoichiometric one is attributed to the fact that the IEF for magnesia production (0.495 t CO₂/t magnesite) is also taken into account, leading to a value higher than 0.44.

Finally, a few plants account for the pet coke used in the ceramics production process. In order to transform the carbon of the pet coke to carbonates equivalent, the carbon content of pet coke must be known. However, this is not reported by the plants, in a way that the activity data correspond to all the other emissions.

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, as described above).

Especially for the magnesia production data have been available by different sources that include the 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

Following the QA/QC activities regarding the time-series consistency, additional checks have been performed in 2010, as described in paragraph 4.4.3. Minor errors have been detected concerning the reported data for 2005, 2006 and 2007, due to errors in the copy pasting of the relevant informations. The % change and the impacts on overall emissions can be viewed in the *Table* below.

Year	2005	2006	2007
Difference (%)	0.04	1.09	0.09
Impact on total emissions (excl LULUCF) (%)	0.00	0.00	0.00

4.4.6 Planned improvements

The current submission can be considered satisfactory. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

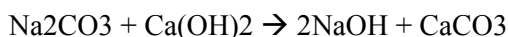
4.5 Soda ash use (CRF Source Category 2.A.4.2)

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:

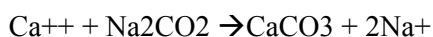


(In Greece is more possible that NaOH is directly purchased by the plants)

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 this cases there are no CO₂ emissions.

d. in detergents

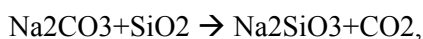
In this case soda ash is used for three reasons:

-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 the water hardness' regulation, aiming at the formulation of Ca and Mg carbonates based on the reaction provided above.

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



resulting in CO₂ emissions.

e. chemicals production

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

f. glass production (included in CRF Source Category 2.A.7.1 and described in Paragraph 4.6)

CO₂ emissions from soda ash are not a key source. CO₂ emissions from soda ash in 2010 have decreased by 58.21% compared to 1990 levels (**Table 4.10**), representing 0.13% of GHG emissions from *Industrial processes* and 0.01% 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:

Table 4.10 Soda ash (in kt) and CO₂ emissions (in kt) for the period 1990 - 2010

Year	Soda ash consumption (kt)	Soda ash use in Glass production (kt)	Soda ash use for other uses (kt)	CO2 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

- ↳ The required activity data on imports and exports of soda ash at a national level are provided by the Hellenic Statistical Authority (ElStat). Provided there is no soda ash production in Greece the annual national consumption refers to the 'Imports-Exports' value. Data referring to years previous to 1998 are not easily accessible since they are available only on hard copies and therefore are estimated using the Trend Extrapolation methodology, as described in the IPCC GPG
- ↳ The soda ash used by the glass industry is removed, as it is already accounted in emissions from Glass Production. In order to estimate the emissions the following should be mentioned:
 - For years 2005-2009 the consumption is estimated based on the data provided by the one plant operating in Greece.
 - For years 2000-2004, Na₂CO₃ 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 2005-2010 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 4.4. 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.

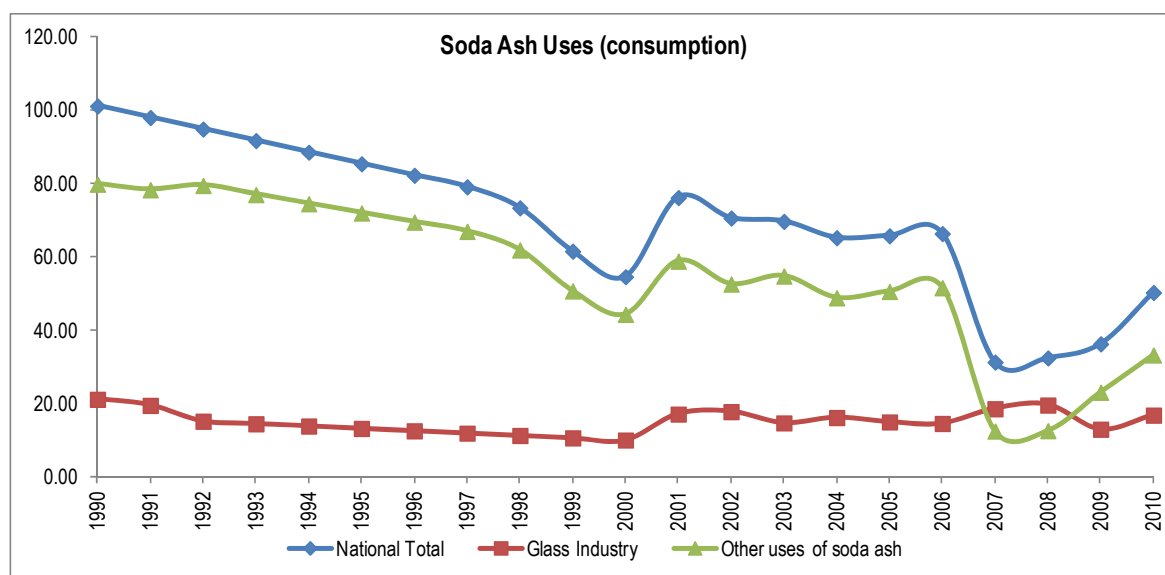


Figure 4.4 Soda ash consumption (in kt) for the period 1990 – 2010

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

Emissions have been included for the first time, apart from the re-submission of September 2011. The 2011 ERT agrees with the estimates. The impact of the recalculation on total emissions is presented in the Table below.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Impact on total emissions (excl LULUCF) (%)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
Impact on total emissions (excl LULUCF) (%)	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.01		

4.5.6 Planned improvements

The current submission can be considered satisfactory for the time being. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 is not a key source. CO₂ emissions from glass production in 2010 have decreased by 24.96% compared to 1990 levels (*Table 4.11*), represent 0.14% of GHG emissions from *Industrial processes* and 0.01% of total GHG emissions (including LULUCF).

Table 4.11 **Glass production (in kt) and CO₂ emissions (in kt) for the period 1990 - 2010**

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	114.44	17.15
2009	93.66	13.33
2010	113.64	15.16

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 2010 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 2007-2010. Also for the years 2005-2010 the reports in the EU ETS context have been extensively used.

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

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 4.5**, emissions of 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. This is partially counterbalanced in 2010 with an increase of 13.73%, as it happens with other Categories of the IP Sector.

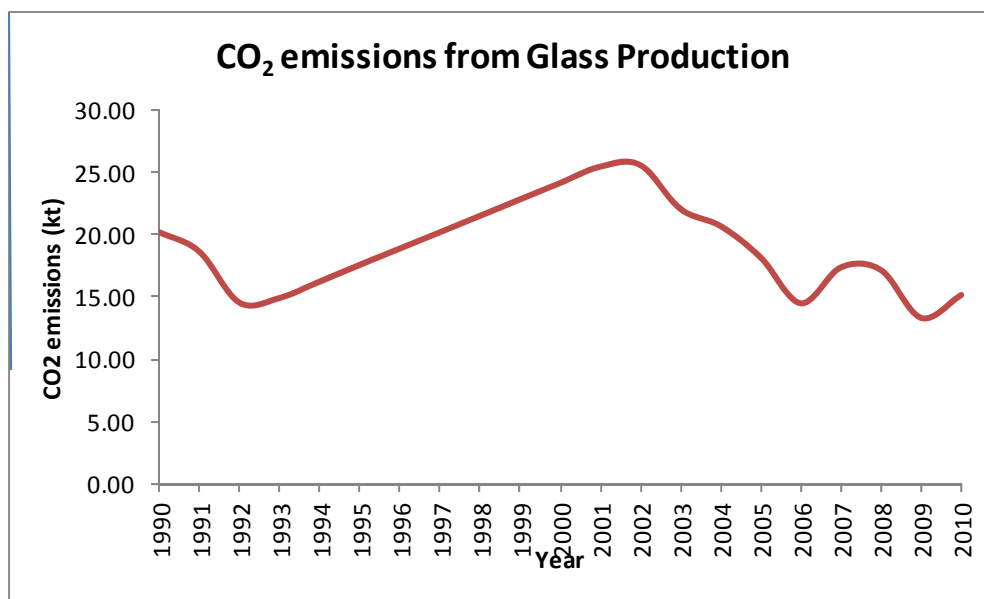


Figure 4.5 *CO₂ emissions (in kt) from Glass Production for the period 1990 – 2010*

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. In any case the divergence is explained by the plant, and is attributed to the range of the cullet ratio and the desired quality of the production.

4.6.5 Recalculations

No recalculations have been performed in the 2011 submission. This is in line with the conclusions made by the ERTs in the 2009, 2010 and 2011 centralised review.

4.6.6 Planned improvements

The current submission can be considered satisfactory for the time being. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 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 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 absence of gas consumption data, only CO₂ emissions from the first plant have been estimated. CO₂ emissions in IP refer to emissions from natural gas (years 1990-1993 and 1998-2007), whereas emissions from the other fuels used (years 1990-1999) are included in the energy sector.

CO₂ emissions from ammonia production is not a key category. CO₂ emissions have increased by 25.20% since 1990 and by 60.36% since 2009 and represent 0.26% of total GHG emissions from *Industrial processes* and 2.85% of emissions from *IP Sector*.

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 tC/TJ (it is the mean value of CC of NG from the different reservoirs that NG was extracted). This value has been used for years 1990-1993.
- The CC of imported NG is calculated 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 4.12**:

Table 4.12 Carbon Content of imported NG for years 1997-2010

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CC (tC/TJ)	15.03	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10	15.10	15.10	15.12	15.14	15.16

The carbon oxidation factor is assumed to be 100%.

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 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 1998-2010 by the one plant still operating in Greece. All the activity data and the estimated emissions are presented in *Table 4.132*.

Table 4.13 *Ammonia production, natural gas consumption and CO₂ emissions for the period 1990 - 2010*

Year	Ammonia Production (kt)	NG consumption (TJ)	CO ₂ emissions (kt)
1990	313.03	4,046	240.28
1991	255.61	3,866	229.59
1992	167.94	3,667	218.32
1993	69.78	2,370	140.72
1994	NO	NA	NO
1995	96.98	NA	IE
1996	133.91	NA	IE
1997	122.16	NA	IE
1998	244.76	3,221	177.48
1999	233.32	5,152	283.96
2000	147.48	5,006	275.90
2001	68.70	2,452	135.77
2002	94.14	2,816	155.94
2003	150.18	4,918	272.40
2004	159.92	5,224	289.46
2005	143.90	4,756	263.30
2006	160.90	5,285	292.59
2007	165.77	5,402	299.16
2008	125.91	4,156	230.37
2009	102.86	3,379	187.61
2010	159.00	5,412	300.84

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. Emissions show a minimum in 2001 (135.77 kt CO₂) and a maximum in 2009 (300.84 kt CO₂). The IEF values also show significant variation throughout the time-series, since the emissions that resulted from the use of solid fuels are not included, and thus part of emissions from the reported ammonia production are included in the energy sector. It should be noted however that the emissions factors of kt CO₂/TJ of NG is quite stable throughout the inventory years, as already described above.

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. 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 4.6**.

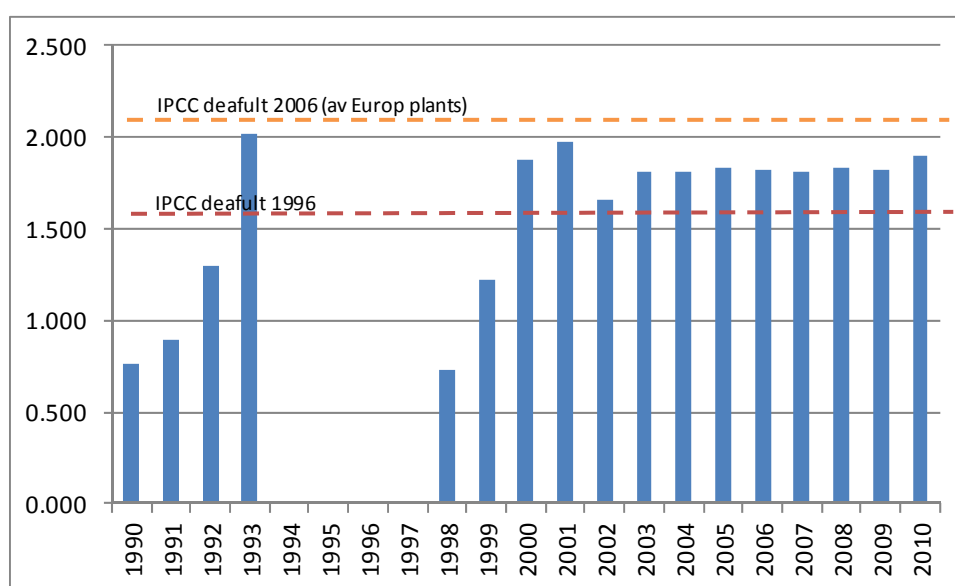


Figure 4.6 Fluctuation of the IEF in the inventory years

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_EIStat(Prodcom department, confidential data) and the Ministry of Economy, Competitiveness and Shipping 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

The emissions that are described in the previous paragraphs have been estimated and submitted in September 2010. The estimations have been generally approved by the Expert Review Team in the Centralised Review; however there was a recommendation to re –check the values of 2008. This has been performed and the reported data of the energy sector have been corrected, while no recalculation has been performed in the IP sector.

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 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.

In case that any other gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 2010 (**Table 4.14**), account for 4.06% of total GHG emissions from *Industrial Processes* and for 0.37% of total national emissions (without *LULUCF*). Emissions in 2010 have decreased by 61.37% from 1990 and increased by 16.59% from 2009.

Table 4.14 Nitric acid production (in kt) and N₂O emissions (in kt) for the period 1990 – 2010

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

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).
- Nitric acid production data derive from El.Stat and the individual industrial units for 1990-2010. Actually in the recent years there is only one unit producing nitric acid in Greece therefore, data are sent directly to the inventory team 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 N₂O 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 4.7**. As it can be seen from the Figure, the trend is generally decreasing, apart from 2010 that emissions appear to be increased in relation to 2009. This however should be seen with caution, as in the current unstable economical circumstances no safe projection can be made for the years to come. 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.

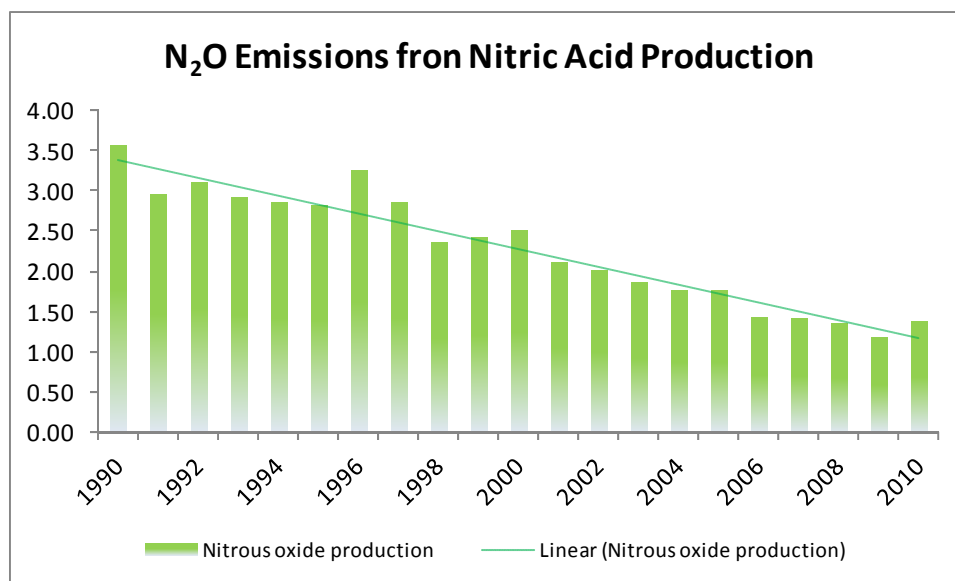


Figure 4.7 *N₂O emissions (in kt) from Nitric Acid Production for the period 1990 – 2010*

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 Economy, Competitiveness and Shipping, 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 HNO₃ production. Although PRODCOM data are provided each year, they may not be finalized by the annual submission of the inventory to the UNFCCC, following the QC procedures of the Service (however, even in that case the Service unofficially provides the Inventory Team with the provisional data). 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 Economy, Competitiveness and Shipping 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 in 2010. This is in line with the 2011 ERT report.

4.8.6 Planned improvements

Although this category is a trend key one, it has not been included in the Improvement Plan. This is justified by the fact that the current category is trend key one due to the continuous decrease of nitric acid production and, thus, the bearing of cost of additional measurements, which are required by higher tier methodologies, seems quite irrational to the plant. The inventory team would also like 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 and the selection of the appropriate N₂O generation factor.

For these reasons, the current submission can be considered satisfactory. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 this previous submissions these emissions were included in the Energy Sector, but in this submission they have been reallocated here, in line with the ERT recommendation.

The contribution of CO₂ emissions from Hydrogen Production account for 3.44% of the *Industrial Processes* emissions and for 0.31 of *Total Emissions* (excl LULUCF) for 2010, showing an increase of 36.32% from 2009.

With regards to CH₄ emissions, their contribution to total GHG emissions from *Industrial Processes* is negligible (less than 0.01% for the period 1990 – 2000).

Table 4.15 presents the emissions from Other Chemical Production.

Table 4.15 Emissions from Other Chemical Production (in kt) for the period 1990 – 2010

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

4.9.2 Methodology

CO₂ emissions are estimated on the basis of the natural gas consumed for the process. Data are provided by DEPA for the whole time-series and by the verified EU ETS reports of the refineries for years 2005-2010. In **Table 4.16** 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.

Table 4.16 *Parameters for the Estimation of CO₂ Emissions from Hydrogen Production*

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NG Consumption (TJ)	1,509.38	3,149.11	1,104.06	0.00	0.00	176.05	256.52	271.72	607.30	385.44	339.15	1,942.69	4,785.09	6,459.80
CC (t C/TJ)	15.03	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10	15.10	15.10	15.12	15.14	15.29
EF (t CO ₂ /TJ) (Oxid Fact=100%)	55.10	55.10	55.11	55.12	55.37	55.38	55.39	55.41	55.37	55.37	55.38	55.43	55.52	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 is very intense for 2010, due to the important increase of both carbon content and natural gas consumption in the activity data.

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 2005-2010, 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. With regards to CH₄ emissions, no specific QA/QC control procedures have been performed, since the category is not a key one.

4.9.5 Recalculations

Emissions from Hydrogen Production have been reallocated from the Energy Sector, following the 2011 ERT Recommendation. There is no impact on total emissions, since data have been reallocated and not recalculated.

4.9.6 Planned improvements

The current submission can be considered satisfactory. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 2010 (**Table 4.17**) accounted for 1.10% of total GHG emissions from *Industrial production* and for 0.10% of total national emissions (without *LULUCF*). Emissions have increased by 24.71% from 1990 to 2010, following the increasing trend of the production, especially in years 1990-2000. It should be noted, however, that emissions in 2010 and 2009 have significantly decreased from 2008 by 44.28% and 33.95% respectively, as a result of the decreased economic activity of the sector (decrease of almost 8% of the production level in 2009 and 16% in 2010).

Methane emissions are considered negligible and account for 0.004% of emissions from *Industrial Processes* in 2010.

Table 4.17 *Steel production, CO₂ emissions and CH₄ emissions (in kt) for the period 1990 – 2010*

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	1,015.67	94.24	0.01
1998	1,108.29	102.83	0.01
1999	951.53	88.29	0.01
2000	1,104.78	102.50	0.01
2001	1,281.51	118.90	0.02
2002	1,839.80	170.70	0.02
2003	1,700.90	157.81	0.02
2004	1,966.24	182.43	0.02
2005	2,296.40	221.66	0.02
2006	2,415.80	222.02	0.02
2007	2,554.52	229.71	0.03
2008	2,468.10	207.49	0.02
2009	1,999.35	137.04	0.02
2010	1,824.14	115.61	0.02

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 CO_2 emissions from iron and steel production, it should be noted that:

- ↪ Activity data for 2005-2010 are plant specific and are based on the verified reports under the EU ETS context.
- ↪ For the period 1990-2004, information has been collected through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC from all individual plants in Greece in the framework of the formulation of the NAP, according to the EU Directive 2003/87/EC.
- ↪ Data regarding steel production are provided by the ElStat for the years 2004-2010 (in the previous years the relevant Prodcom code did not exist). These data are reported as activity data. Especially in 2010 data are characterized as provisional since they are not yet publicly available and have been provided to the Inventory Team in line of the Greek Inventory System.
- ↪ According to information received by the ElStat, all the iron and steel plants of the country are included in the EU ETS.
- ↪ In 2010 the average carbon content of the scrap and steel produced has been estimated at 0.36% and 0.18% 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).

4.10.3 Uncertainty and time-series consistency

The uncertainty associated with the CO_2 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 CH_4 emissions, the uncertainty values are at the same level, in absence of any other data.

The methodology used for the CO_2 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 CO_2 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 and there has been no reference to the issue by the 2010 and 2011 Expert Review Teams.

In general, CO₂ emissions from steel production follow an increasing trend, reaching a maximum value of 229.71 kt in 2007. Then and in the next two years emissions are decreased by 9.67%, 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 destined for use in infrastructure). Figure 4.8 presents the timeseries of production and emissions.

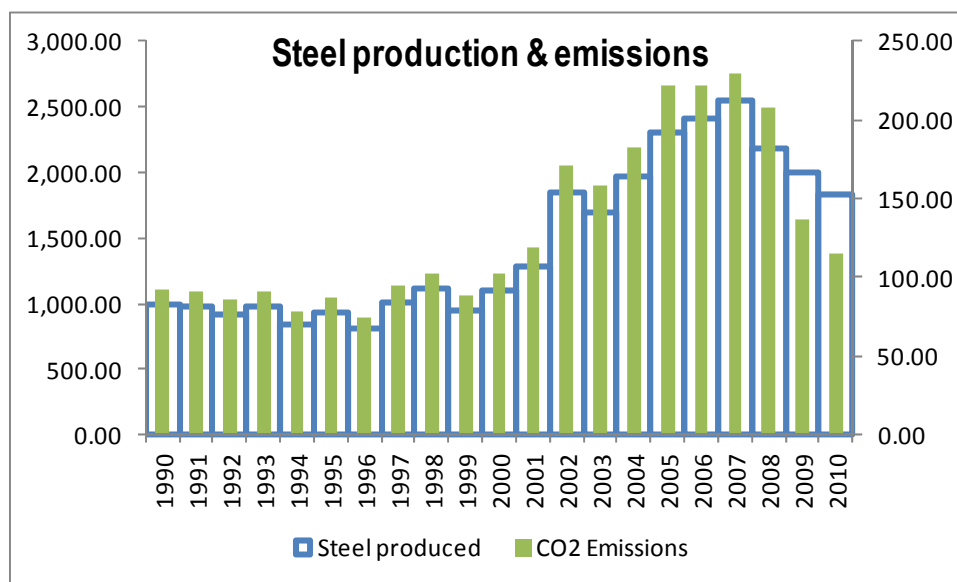


Figure 4.8 *Steel production and CO₂ emissions (in kt) for the period 1990 – 2010*

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 and 2010 (0.069 and 0.064 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.

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 spreadsheet 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. In 2010 the production data reported by the plants and the one provided by the national statistics differ by 0.56% (the ElStat value has been used in order to ensure time-series consistency with the values used in the previous years). Also, less detailed data are collected by international sources, such as the World Steel Association. These data are also used to as additional sources and for years 1999-2010 the average difference between the two values has been considered quite low (0.28%).

4.10.5 Recalculations

No recalculations have been performed in the current submission.

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 2010 account for the 5.09% of total emissions from *Industrial Processes*, and for the 0.45% 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 2010 key category by level assessment (analysis including LULUCF).

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 2005-2010 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 2000-2010. The above mentioned data are combined with supplementary information relevant to the plant production in order to complete the

missing data for the all 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 2000-2010 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 2000-2010 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 2000-2010 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 4.9 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, 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, as it is also the case for other subcategories of the Sector.

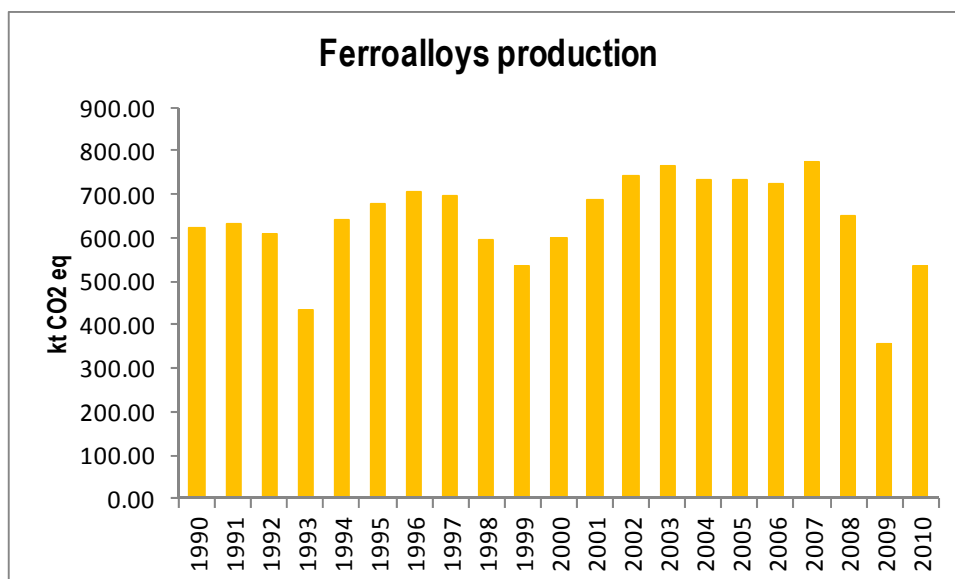


Figure 4.9 *CO₂ emissions (in kt) from Ferroalloys Production for the period 1990 – 2010*

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 39.66 t/t, and is not characterised by intense fluctuations in the time-series. The differences 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

No recalculations have been performed in the current submission.

4.11.6 Planned improvements

The current submission can be considered satisfactory. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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 2010 (**Table 4.15**) accounted for 1.97% and 0.32%, respectively, of total GHG emissions from *Industrial processes*. The average annual rate of decrease of CO₂ emissions during the period 1990 – 2010 was -0.18 %. Respectively, the average annual rate of decrease of PFC emissions is estimated at -1.56%, while emissions have decreased by 37.37%, 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 4.18 *CO₂ emissions (in kt) and PFC emissions (in kt CO₂ eq) from primary aluminium production for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
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
PFC emissions	163.37	164.17	161.21	96.98	60.37	53.97	46.14	106.14	129.70	84.35	93.54
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CO ₂ emissions	244.05	246.85	250.85	250.97	249.08	247.66	249.16	250.32	192.39	207.22	
PFC emissions	58.11	55.90	49.88	45.66	45.40	38.88	37.52	47.34	22.50	33.80	

4.12.2 Methodology

The estimation of emissions from aluminium production are 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 binded 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 analysers that operate on a permanent base. The average λ value is 0.0522 for the years 2005-2010. The outcome is then multiplied by 44/12 to express the CO₂ emitted.

2. Pitch Volatiles Combustion Emissions

$$CO_2(t) = (GA - H_w - BA - WT) * 44/12$$

Where :

GA: initial weight of green anodes, t

H_w: hydrogen content of GA, t, estimated as 0.005*GA

BA: baked anode production, t

WT: Waste tar collected, t, which is considered insignificant.

3. Bake Furnace Packing Material Emissions

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

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 2005-2010. 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). 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 C₂F₆ emissions are then calculated by using the following formula:

$$\text{C}_2\text{F}_6 = 0.1 \cdot \text{CF}_4$$

The estimations are provided directly by the plant to the inventory team.

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. 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 4.10**. 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 fluctuation in 2009-2010, 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.

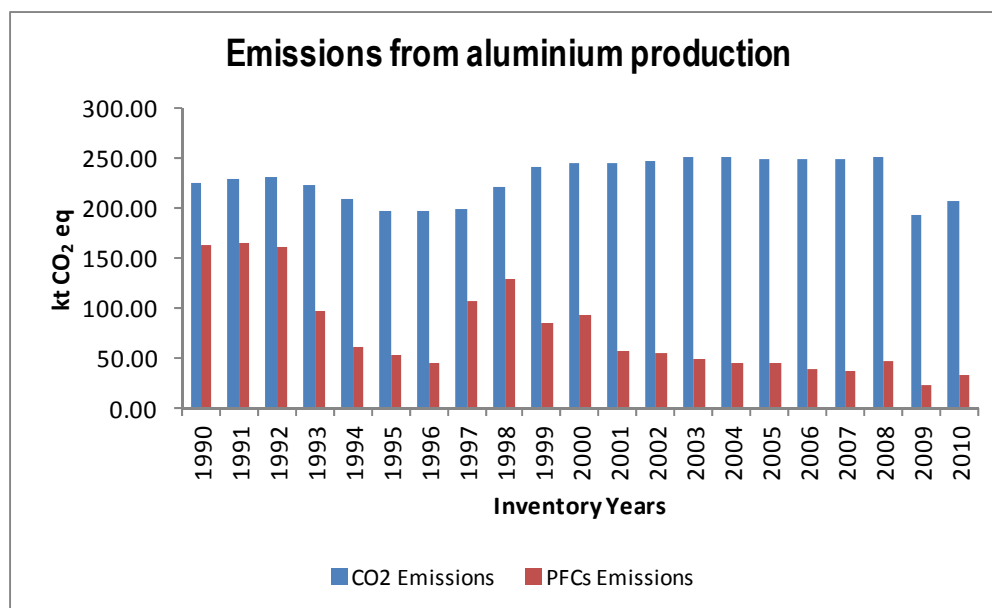


Figure 4.10 *CO₂ and PFCs emissions (in kt CO₂ eq) from aluminium production for the period 1990 – 2010*

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 and which include the internal archiving of information, compatible with the Quality Management Procedure of their Internal Quality System, which has been 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 2005-2008 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 sought in the US Geological Survey and they are the same as the ones reported by the Greek Mining Enterprises Association. As already reported during previous reviews there has been a pressure on Greece to publish the confidential data reported by plant. In the 2010 and 2011 reviews Greece has also been recommended to report the publicly available data instead of the plant specific ones. In order to resolve this issue, and respecting the accuracy principle of the inventory, the plant specific production data is being used and the publicly available information is reported to help understand the timeseries trend.

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 2005-2010 is 1.51 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

CO₂ emissions have been recalculated following the provision of updated detailed values provided by the plant. Since the updated data refer to years 2005-2010, emissions of years 1990-2005 have been recalculated using the Overlap method, in line with the IPCC GPG.

PFCs emissions have been also recalculated following the detection of an error in the passing of information from the working files to the CRF Reporter.

The difference between the previous and the current estimates and the impact on total emissions is presented in *Table 4.19*.

4.12.6 Planned improvements

In general, the current submission can be considered quite satisfactory. In case that any other gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

Table 4.19 *Recalculations of CO₂ and PFCs emissions from Aluminium production[1990-2009]*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO2 emissions											
Difference (%)	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91	-2.91
Impact on total Emissions (excl LULUCF, %)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01
PFC emissions											
Difference (%)	-37.97	-37.88	-37.60	-38.06	-37.15	-37.08	-37.32	-37.43	-37.80	-37.75	-38.34
Impact on total Emissions (excl LULUCF, %)	-0.10	-0.10	-0.09	-0.06	-0.03	-0.03	-0.02	-0.05	-0.06	-0.04	-0.05
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
CO2 emissions											
Difference (%)	-2.91	-2.91	-2.79	-2.91	-2.88	-3.25	-3.27	-1.52	-1.18		
Impact on total Emissions (excl LULUCF, %)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00		
PFC emissions											
Difference (%)	-37.79	-38.34	-37.66	-37.64	-37.85	-37.72	-37.67	-37.78	-37.72		
Impact on total Emissions (excl LULUCF, %)	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01		

4.13 Production of halocarbons and SF₆ (CRF Source Category 2.F.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 – 2009*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC-23 (kt CO ₂ eq)	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
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
HFC-23 (kt CO ₂ eq)	3,181.46	3,194.57	2,661.05	2,550.60	2157.48	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. In case that any gaps in activity data time series shall be observed, it will be filled in as soon as new data become available.

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. It should be mentioned that the current category has been considered as a priority in the 2012 Improvement Plan and various improvements have been implemented, as it will be discussed in the following paragraphs.

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. To this end, the inventory of Italy has been used, on the grounds that the climatic and socio-economic conditions between Greece and Italy are quite similar. According to the reported data of Italy, the respective emissions are considered Not Occurring. As a result the above mentioned notation keys have changed from NE to NO in the 2011 submission.

Emissions from ODS substitutes constitute a key category in the Greek inventory system by level and trend assessment. Emissions in 2010 (**Table 4.21**) accounted for 34.39% of total GHG emissions from *Industrial processes* and for 2.11% of total national emissions (without *LULUCF*). The average annual rate of emissions' increase for the period 1995 – 2010 is estimated at 34.86%, with the increase being more moderate in the recent years, following the removal of equipment exceeding lifetime. The significant increase of emissions is attributed to the increased emissions from commercial and industrial applications of refrigeration (54.51% of total emissions from Refrigeration and A/C Equipment), mostly due to the high value of the equipment's charge. 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 96.23% to the emissions from ODS substitutes, while emissions from aerosols and metered dose inhalers are at the second place (1.73% contribution to the emissions from ODS substitutes in the 2010 inventory). **Figure 4.11** 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 - 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC-23				5.25	11.50	20.53	32.96	5.25	11.50	20.53	32.96
HFC-32						0.08	0.30	0.89	1.93	3.95	6.69
HFC-125						5.10	10.13	20.17	34.06	56.54	85.14
HFC-134a				2.71	6.61	38.92	73.40	125.96	190.98	284.06	392.86
HFC-143a						7.58	13.98	25.68	40.14	61.03	86.35
HFC-152a											
HFC-227ea										4.18	5.97
PFC-116								1.53	3.34	5.97	11.55
TOTAL				2.71	6.61	51.71	97.84	179.50	281.97	436.34	621.62
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
HFC-23	38.47	38.72	59.86	63.04	67.02	77.24	115.87	126.45	145.67	167.83	
HFC-32	10.97	15.40	25.34	34.25	43.45	56.10	70.10	86.72	105.81	127.96	
HFC-125	114.32	135.10	213.44	261.57	345.24	418.42	512.51	618.22	749.30	883.63	
HFC-134a	504.55	591.66	760.45	883.75	1,152.78	1,254.31	1,438.92	1,612.68	1,829.16	1,819.86	
HFC-143a	101.55	102.21	154.79	166.92	232.11	252.65	292.14	329.35	385.65	421.95	
HFC-152a	1.67	30.40	40.90	35.19	37.69	46.73	41.22	40.91	35.88	32.25	
HFC-227ea	7.75	10.17	13.26	17.96	22.28	26.36	32.01	35.22	38.54	40.73	
PFC-116	13.05	13.23	22.58	23.34	24.49	27.46	38.70	41.78	47.37	67.80	
TOTAL	795.86	949.14	1,291.89	1,487.30	1,953.30	2,256.53	2,613.16	2,998.32	3,403.47	3,625.73	

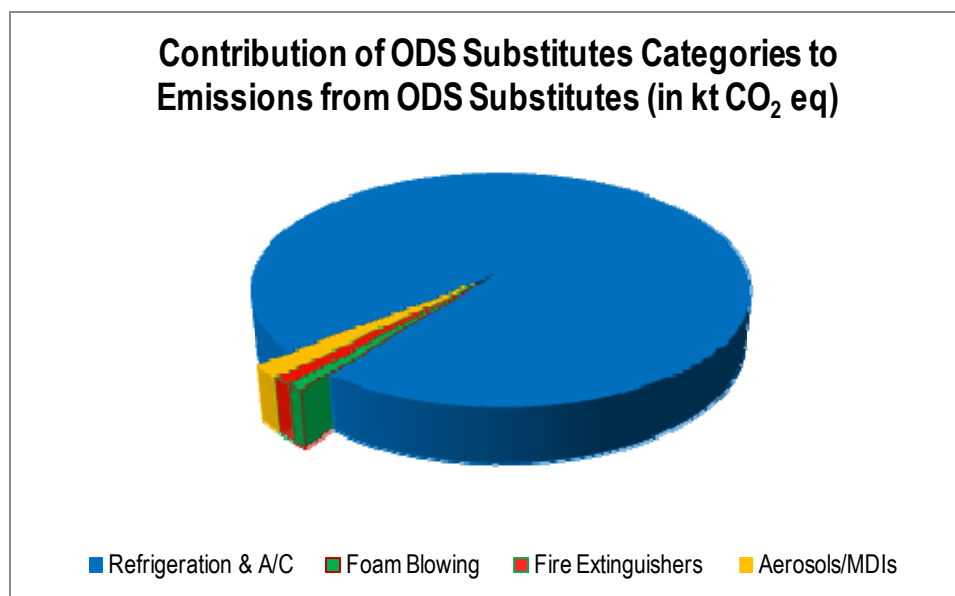


Figure 4.11 *F Gases emissions from ODS substitutes in 2010 (in kt CO₂ eq)*

The demand of A/C equipment is highly dependent on the climate conditions. Generally, the raise of temperature and the occasional extreme heat waves increase the demand. The price is no longer a decisive factor, due to multiple credit systems made available by electrical stores and supermarkets. However in the last two years this is not the case, since the economical recession plays a strong role in the market. The demand of refrigerating equipment usually is driven by the need to replace existing equipment. The replacement depends on the product life, which is usually a factor of the quality and the conditions of use. Also, an important part of the demand derives of the generation of new households. 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. It should be also noted that in the recent inventory years sales are decreased as a result of the economical recession of the country.

As part of the 2012 Improvement Plan, 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, base on previous 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 market 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.

In the framework of the 2012 Improvement Plan, an attempt has been performed to improve the reported information after coming into contact and close collaboration with the National Association of Refrigeration Importing & Trading Companies. In specific, the Inventory Team has been first informed by the President of the Association on the refrigerant blends that are in the market (or have been during the inventory timeseries). From the information provided it was made clear that there are various blends being used in the Greek market during the last 15 years, and therefore the inventory had to be changed accordingly. For this reason an excel form has been prepared and 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, indicating the quantities sold, whether they have been obtained by the national market or imported, 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.

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. Since no data on the disposal practice is available, at the moment the assumption of total emission of remaining refrigerant in the retiring equipment is being made. With reference to that, it should be mentioned that the Inventory Team is in process of collecting data from the official Electrical Appliances Recycling Company to account for the recovery of f-gases in line with the Greek Recycling System. It should be mentioned, however, that in the meeting held between employers of the Appliances Recycling SA and members of the Inventory Team, the company informed the Inventory Team that about 27% of the retiring equipment lacks compressors, in a way that no further f-gases recovery is applicable. Also, in absence of any activity data, for the time being all the equipment exceeding lifetime is considered as removed from the 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, **Table 4.22-4.23**) the following should be mentioned:

- Data on the air conditioning equipment stock for the period 1993 – 2010 are provided by market surveys (ICAP 2000, 2002, 2003, 2005, 2008, 2009, 2011).
- Data residential refrigeration equipment stock for the period 1993 – 2009 are provided by market surveys (ICAP 2000, 2002, 2006, 2008, 2010). For 2010 emissions are estimated using the trend of the more recent years 2005-2008, 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 stock are determined based on the elaboration of ElStat and EUROSTAT data. Refrigerated show cases and counters are included in the category of large commercial applications while the rest refrigeration equipment (except residential refrigeration) is considered as small commercial installations.
- Data on the number of new vehicles are provided by the Ministry of Infrastructure, Transport and Networks and by the Association of Motor Vehicle Importers Representatives.
- Data on the number of transport refrigeration for 2000-2009 are provided by the Ministry of Infrastructure, Transport and Networks and by the Association of Motor Vehicle Importers Representatives.

In line with the 2012 Improvement Plan, a form has been sent out 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 (a 22% 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 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 4.24**. 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. It should be noted that IEFs used for MAC and transport refrigeration have been changed in September 2010, following the ERT's recommendation, in order to be in the default range proposed by the IPCC Guidelines. It has been noticed that this is also the case for other categories, and to ensure consistency and comparability the Inventory Team has accordingly changed the values in order to belong to the default ranges. With reference to the blends used in each application, additional information has been provided by the President of the National Association of Refrigeration Importing and Trading Companies and cross-checked by the conclusions made from the reporting of the equipment companies.

The percentage contribution of each blend has been determined based on information provided by the importing companies, as described above. The resulted distribution for the years 1995-2010 is presented in **Figure 4.12**.

Table 4.22 Refrigeration and air conditioning equipment (number of units) 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	567
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	32,801
Small commercial applications			193,287	183,250	191,514	182,560	133,487	129,895	180,319	193,287
Domestic production			58,640	71,680	63,730	44,302	66,856	76,871	77,219	58,640
Imports			163,848	154,481	152,528	166,843	200,530	214,455	225,382	163,848
Exports			29,201	42,911	24,744	28,585	133,899	161,431	122,282	29,201
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	305,750
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	341,000
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	2,850

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
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	1,450
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 4.23 *Refrigeration and air conditioning equipment for the years 2003 – 2010*

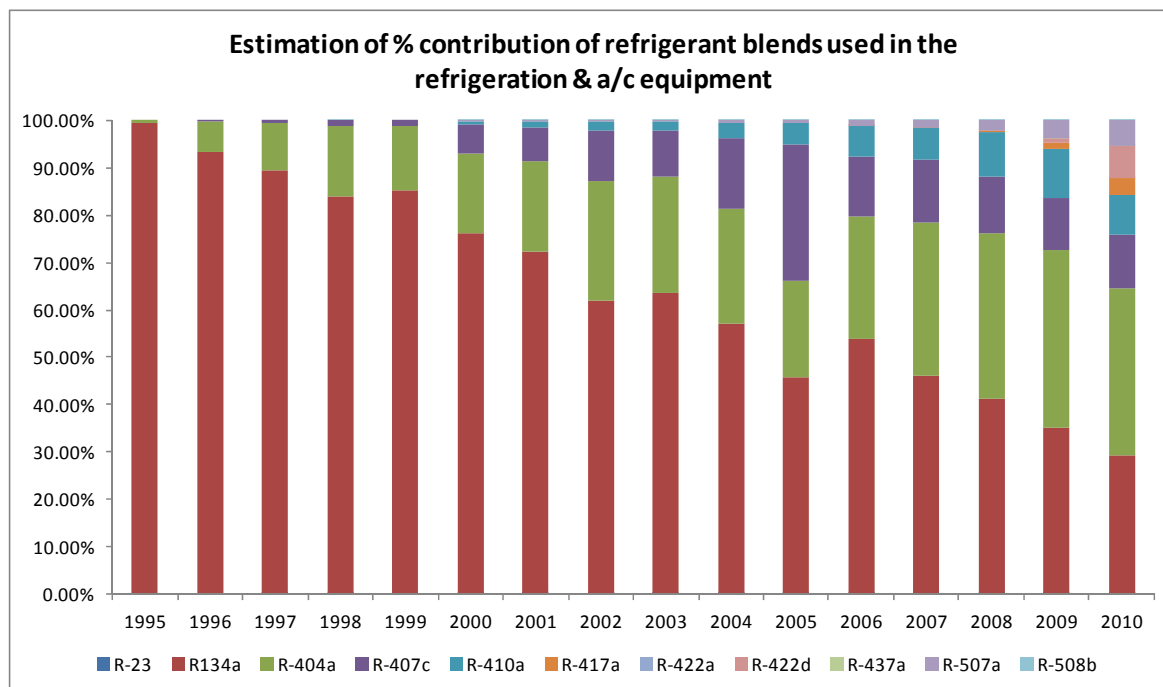
	2003	2004	2005	2006	2007	2008	2009	2010
Refrigeration								
Residential	390,000	406,000	402,000	410,000	433,000	452,000	401,000	396,667
Domestic production	368,000	408,000	431,000	507,200	390,700	307,400	257,000	184,667
Imports	342,000	320,000	340,000	313,400	350,000	390,000	335,000	343,333
Exports	320,000	322,000	369,000	410,600	307,700	245,400	191,000	131,333
Other commercial applications	25,825	4,738	4,738	12,312	2,049	5,445	5,342	5,265
Domestic production	20,310	23,004	23,004	17,117	16,383	16,378	15,053	14,050
Imports	21,357	30,000	30,000	23,306	17,712	13,091	12,849	14,147
Exports	15,842	48,266	48,266	28,111	32,046	24,024	22,560	22,931
Small commercial applications	213,443	242,483	208,630	139,569	141,329	162,148	268,636	208,269
Domestic production	161,789	150,845	104,688	115,885	110,502	115,307	120,748	125,680
Imports	231,459	245,152	282,929	276,746	216,429	206,039	267,668	207,909
Exports	179,805	153,514	178,987	253,062	185,602	159,198	119,780	125,320
Transport Refrigeration	649	826	466	731	817	747	372	183
In circulation	649	826	460	731	817	747	372	183
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
Domestic production	500	700	300	220	210	190	130	50
Imports	626,350	644,500	522,500	614,200	730,800	732,760	560,120	459,550
Exports	122,900	152,100	92,000	124,900	156,700	158,700	123,500	144,000
Chillers	2,400	1,950	1,770	1,580	1,860	1,900	1,600	1,350

	2003	2004	2005	2006	2007	2008	2009	2010
Domestic production	1,100	700	520	480	560	540	400	280
Imports	1,650	1,450	1,400	1,300	1,600	1,740	1,500	1,370
Exports	350	200	150	200	300	380	300	300
Other applications of air conditioning	73,200	48,250	42,100	44,100	45,950	46,500	32,000	23,400
Domestic production	34,500	26,000	19,350	16,700	17,100	16,600	10,500	5,500
Imports	48,350	29,600	25,400	32,000	37,600	42,100	29,300	25,750
Exports	9,650	7,350	2,650	4,600	8,750	12,200	7,800	7,850
Mobile air-conditioning	273,870	317,508	344,339	346,551	316,721	296,201	244,893	154,269
In Circulation	273,870	317,508	344,339	346,551	316,721	296,201	244,893	154,269

Table 4.24 *Basic assumptions for the calculation of F- gases emissions*

	Charge	Leakage rate (%)		Lifetime	Disposal	Refrigerant
	(kg/unit)	Charge	Operation	(years)	Initial Charge Remaining (%)	used
Refrigeration - Residential	0.18	0.6	0.25	15	70	R134a
Refrigeration – Other commercial & Industrial applications	100	0.5	10	10	85	R134a, R404a, R407c,R507a, R23, R508b, R410a, R422a, R422d, R437a
Refrigeration – Small commercial applications	1.5	1.75	10	10	75	R134a, R410a,R407c
Transport Refrigeration	2.38(a)	0.6	25	8	75	R134a, R404a, R410a
Air conditioning – Split units and semi central systems	2	0.6	5	15	80	R407c, R410a, R417a
Air conditioning – Chillers	50	0.6	15	10	90	R134a, R407c, R410a
Air conditioning - Other applications of central air conditioning	12	0.6	20	10	70	R407c, R410a, R417a
Mobile Air conditioning	1	0.5	12	8-10	40	HFC-134a

- (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.

**Figure 4.12** *Distribution of refrigerant blends in the Greek market, 1995-2010*

The structure of the emissions from each sub-source for 2010 is presented in **Figure 4.13**.

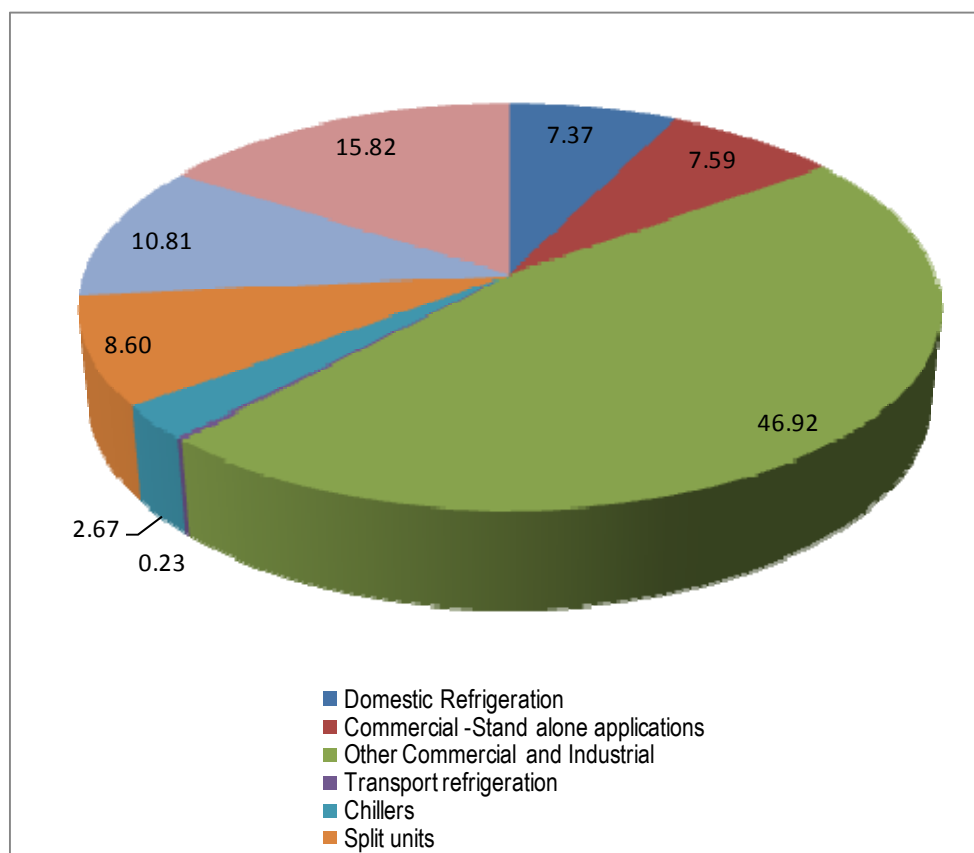


Figure 4.13 Contribution of each sub-source for 2.F.1 – Year 2010

Total F-gases emissions from the above mentioned applications are presented in **Table 4.25** for the period 1993-2010.

With regards to Residential Refrigeration, according to the data provided by ICAP SA, the majority of the equipment concerns small capacities (lower than 150 lt), with a contribution oscillating between 22 and 35% during the years 2003-2008. Other important categories include combinations of refrigerators and freezers characterised by individual external doors, residential refrigerators with compression of a capacity above 340 lt and also refrigerators of medium capacity (between 250-340 lt). The respective contribution percentages in 2008 are 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 crossechecked with a 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).

Table 4.25 *F-gases emissions (in kt CO₂ eq) from refrigeration and air conditioning equipment for the period 1993 – 2010*

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Domestic refrigeration	2.71	6.61	14.63	26.91	41.26	55.79	72.15	89.03	105.60	124.00	142.55
Commercial-Stand Alone Appl.	0.00	0.00	0.58	1.47	3.44	7.00	11.33	16.92	25.70	34.60	51.57
Other Commercial-Industrial Appl.	0.00	0.00	32.45	60.03	116.67	186.32	287.00	397.59	460.75	462.18	661.55
Transport Ref	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.81	1.45	2.11
Chillers	0.00	0.00	0.07	0.15	0.30	0.72	1.55	2.85	6.51	12.41	19.81
Split-Units	0.00	0.00	0.24	0.47	1.04	2.79	7.84	14.46	28.78	38.24	57.83
Other Applications of Central AC	0.00	0.00	0.59	1.24	2.70	6.66	14.86	23.98	39.15	64.54	99.40
MAC	0.00	0.00	3.13	7.55	14.05	22.66	37.33	70.37	115.61	158.91	201.63
TOTAL	2.71	6.61	51.68	97.81	179.47	281.94	432.07	615.54	782.91	896.32	1,236.46
Year	2004	2005	2006	2007	2008	2009	2010				
Domestic refrigeration	160.14	178.37	192.98	208.34	229.06	241.41	256.99				
Other Commercial-Stand Alone Appl.	72.74	95.77	115.31	141.73	177.39	224.38	264.75				
Commercial- Large Applic.	701.80	976.51	1038.32	1238.52	1364.48	1585.24	1636.95				
Transport Ref	2.96	3.46	4.26	5.20	6.80	7.66	8.06				
Chillers	28.71	37.60	45.84	56.91	69.80	82.24	93.06				
Split-Units	80.85	104.62	136.11	178.23	225.03	264.69	299.89				
Other Applications of Central AC	127.20	156.69	186.79	224.94	276.53	324.80	377.33				
MAC	258.46	312.06	366.57	414.37	466.13	532.54	551.99				
TOTAL	1,432.86	1,865.09	2,086.19	2,468.24	2,815.21	3,262.95	3,489.03				

With reference to a/c equipment, the following can be noted:

- The Production trend for the years 1995-2010 is a decreasing one with an average annual rate of decrease at 14.1%. Production had already experienced a decrease of 3% in 2008 which continued in 2009 and 2010 in line with previous years projections. The production mainly refers to fan coils, central A/C units and chillers. Split unit production is considered negligible in the recent years, while production of semi-central units is also very low.
- The majority of Imports regards split units (about 89% for 2010). Total Imports of a/c equipment are characterised 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 are reduced by about 52% as a result of the reduced in country demand (see also comment above). This continues in 2010. It is also noted that an important percentage of the imported a/c units is re-exported in other countries (mainly Balkans and Turkey).
- The exports time-series generally present intense fluctuations. In general the trend is increasing, especially in 2009 and 2010, while the main category is split units (about 92% of exports in 2010).
- 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 at 23.4%), while this changes in the period 2001-2005. This is attributed to the lower temperatures in 2004-2005. Then and for the years 2006-2008 emissions are increased due to the favorable climate conditions. In the last two years imports in this category show a decreasing trend. The decrease between 2008-2009 is about 17% for split units, and would have been lower had it not been for the 'Changing A/C Equipment' programme that has been implemented by the Ministry of Development, Competitiveness and Shipping in 2009 (see also paragraph 4.14.3 below). The Greek market shows a more intense decrease in 2010, depicting the decrease of the average household income, while the relatively mild climatological conditions of June-July 2010 also contributed. Semicentral systems are also reduced by 23% from 2009 to 2010, while in 2009 they were already lower by 22% with respect to 2008 levels.
- Chillers: They have presented an important increase, characterised by high rates of change in the years 2000-2003 (about 20-40%). This is attributed 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 2009-2010. Chillers of efficiency up to 14 RT are estimated to be responsible for 49% of the market in 2010, while chillers with scroll compressor covered 83% versus chillers with screw compressor that covered the 16% of the market in the same year. Chillers with reciprocating compressor cover a very low percentage of the market.
- Central A/C Units are characterised by an increasing trend in the years 1994-2003 which is then followed by a decrease in the next years. The majority of the country's production and

consumption refers to small size units (<8000 m³/h). In 2010 the Greek market is 33% lower than the previous year.

- Finally, fan coils follow the same pattern, showing a generally increasing trend until 2004, followed by an abrupt decrease in 2005 and being at about the same levels in years 2006-2009 and significantly lower in 2010 (26% decrease versus 2009).

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:

$$\begin{aligned} \text{Emissions from closed-cell foam} = & [(\text{Total HFCs and PFCs used in manufacturing of new closed-cell foam in year } t) \cdot (\text{first-year Loss emission factor})] \\ & + [(\text{Original HFC or PFC charged blown into closed-cell foam manufacturing between year } t \text{ and year } t-n) \cdot (\text{annual loss emission factor})] \\ & + [(\text{Decommissioning losses in year } n) \cdot (\text{HFC or PFC destroyed})] \end{aligned}$$

In order to perform the estimation of the emissions, data have been collected using information by the questionnaires filled by the industries of the sector for this reason. According to the information received, the following remarks can be made:

1. No industry makes any use of PFCs, while one of the industries reported no use of HFCs neither.
2. The use of HFCs has begun in 2001.
3. HFC-134a has been used for years 2000-2001 by one plant, while all the others plants of the sector use HFC-152a.
4. All the HFCs used concerns the manufacturing of XPS panels.
5. According to the information received by the respective companies the Greek market is mainly covered by the products produced in Greece. From the four companies that report in the Greek system only one has mentioned, apart from XPS production, imports of XPS foams. In this case the HFC-152a emitted from the imported products has 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.

6. Some of the companies are also performing exports of products produced in Greece, and this has been also taken into account in the Inventory of the recent years.
7. 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.

Emissions of foam blowing are presented in *Table 4.26*.

Table 4.26 *HFCs emissions (in kt CO₂ eq) from foam blowing for the period 1995 – 2010*

Year	First Year Emissions (HFC-134a)	Annual Emissions (HFC-134a)	First Year Emissions (HFC-152a)	Annual Emissions (HFC-152a)	TOTAL
1995					
1996					
1997					
1998					
1999					
2000					
2001	3.38	0.00	1.67	0.00	5.05
2002	11.86	0.25	30.28	0.13	42.51
2003	0.00	1.14	38.50	2.40	42.04
2004	0.00	1.14	29.90	5.28	36.33
2005	0.00	1.14	30.16	7.53	38.83
2006	0.00	1.14	36.94	9.79	47.87
2007	0.00	1.14	28.66	12.56	42.37
2008	0.00	1.14	26.21	14.71	42.06
2009	0.00	1.14	19.21	16.67	37.03
2010	0.00	1.14	14.14	18.12	33.39

It should be noted that in the 2011 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 contact the Panhellenic Association of Insulating Companies. Unfortunately it is not yet clear whether the Association disposes of such data. In any case, any data that may become available shall be used as appropriate.

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 4.27**.

Table 4.27 *HFC-227ea emissions (in t) from fire protection equipment for the period 1999 – 2009*

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HFC-227ea	1.44	2.06	2.67	3.51	4.57	6.19	7.68	9.09	11.04	12.15	13.29	14.04

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

in 2010, based on information received by the President of the Hellenic Aerosol Association. The characteristics of the categories can sum up to the following:

- 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.
- As regards to the other categories on MDIs, only one plant has reported HFCs emissions. This is in line with the information received by the President of the Hellenic Aerosol Association.
- 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 2005-2010. 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 65 and 100%, being 72% for 2010. In the past emissions have been estimated using this ratio, but in the current submission 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) and therefore emissions have been recalculated as appropriate.

Emissions from the aerosols category can be viewed in *Table 4.28*.

Table 4.28 *HFC-134a emissions from Aerosols (in kt CO₂ eq) for the period 1995 - 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC-134a Emissions						0.02	0.03	0.02	0.02	0.07	0.08
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
HFC-134a Emissions	0.10	0.10	0.10	0.11	20.84	73.94	54.27	81.41	49.97	48.13	

4.14.3 Uncertainty and time-series consistency

The uncertainty related to emissions from ODS substitutes is generally characterized by high values. However, to account for the various improvements performed in the current inventory, in line with the Improvement Plan, some of the values have been lowered. 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 2010 values for the air conditioning equipment.

In **Figures 4.14** and **4.15**, the trend of each subcategory is presented.

As regards the first chart, the general trend is increasing. Production and import levels in 2009 and 2010 show important reductions, 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. An exception to that is the two values referring to equipment quantities of small applications. The inventory team has tried to investigate the increase reported in the national data and according to the information received by experts of the sector, this is probably due to the fact that equipment is ordered in advance, so the effects of the crisis had not yet been depicted in the orders. In any case the f-gases penetration percentage is quite lower in the recent years, following the intense use of R600. It should be also mentioned that the rate of decrease of sales of split units in 2009 has not been as intense as first considered, due to the programme 'Changing A/C Equipment' that has been implemented by the Ministry of Development, Competitiveness and Shipping. According to the programme for the withdrawal of one old A/C equipment the final consumer would benefit from a discount of 35% of the final price of a new one. According to the programme's final account, 141,323 units have been sold during the period 10.6.2009-22.8.2009 (ICAP, 2011).

One trait that is also important, is that part of the equipment has reached its lifetime and therefore is considered to be disposed. In view of the current absence of data regarding recovery of gases, this means that an increasing number of emissions concerns the disposal procedures. At the same time however, this will lead to their removal from the next year and therefore the total effect is quite counterbalanced. As the years go by, it is to be expected therefore that emissions from disposal will continue to increase, although this may not be as obvious to the trend.

The second chart refers to emissions from the other subcategories of the ODS substitutes sector. As it can be seen from the figure, the increase of the MDIs is the more important in the recent years, mainly due to the inclusion of new MDIs brands in the recent years. In 2009 and 2010 emissions experience a strong decline which is 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 is a decreasing one.

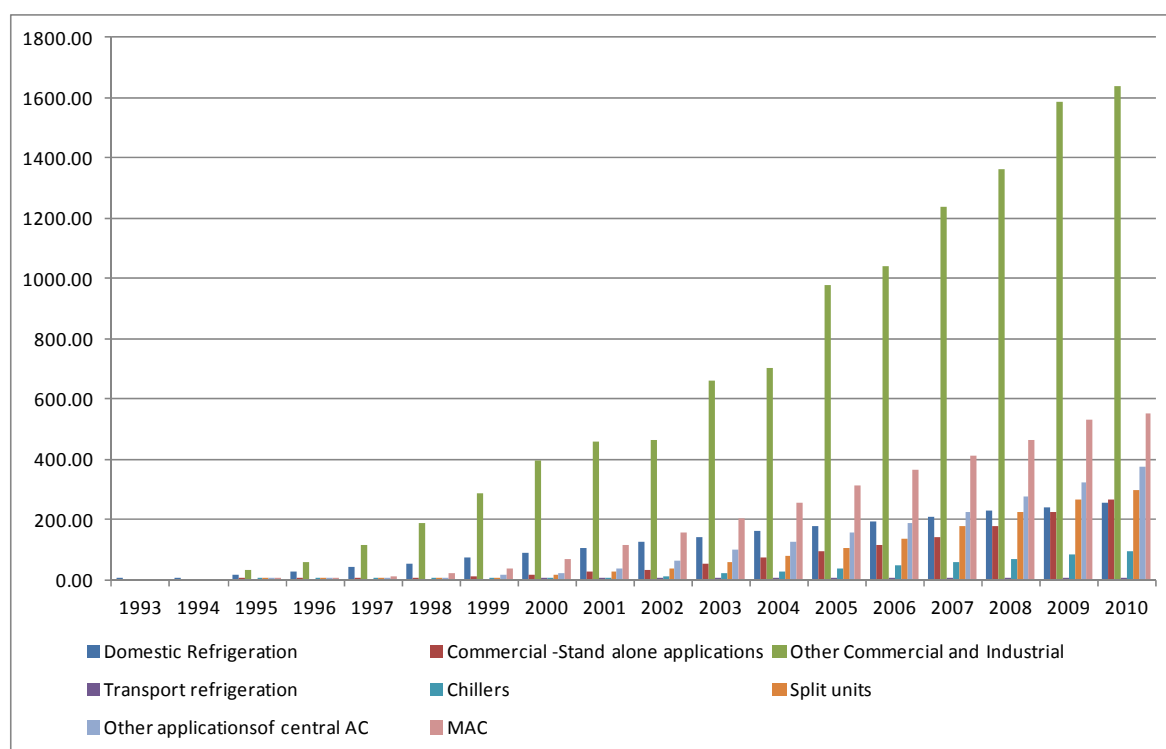


Figure 4.14 *HFCs emissions from Refrigeration and A/C equipment for the period 1993-2010 (in kt CO₂ eq)*

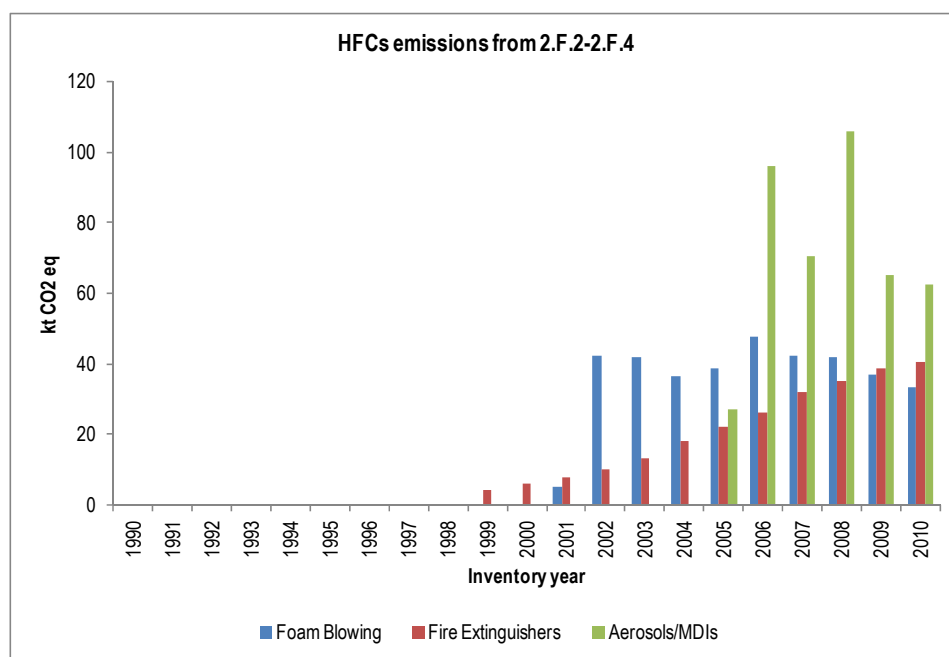


Figure 4.15 *HFCs emissions from Foam blowing, Fire extinguishers and Aerosols/MDIs for the period 1990-2010 (in kt CO₂ eq)*

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).

In this year the specific category has received priority in the Improvement Plan. Apart from the update of data providers, which has been already described above, additional QA/QC procedures involved the update of all data and 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 judgements.

4.14.5 Recalculations

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

Main recalculation include the following:

- Update of activity data for the whole time-series for 2.F.1 due to change of methodology. In specific, in the previous years it has been considered that each year's f gases penetration value for operation equipment refers to the total of equipment introduced in the system. This contradicted the fact that the penetration of the previous years had been already considered, therefore the number of equipment units of the previous years was already given. Additionally the previous methodology made difficult the removal of equipment surpassing lifetime, since there was no indication on the introduction year. The current estimations are based on the fact that the annual F-gases penetration percentages refer to the annual introduction of new equipment.
- Update of activity data concerning A/C and commercial refrigeration equipment from ICAP's sectoral study and from the provision of ElStat data.
- Update of the refrigerant blends used per application on the basis of data provided by the National Association of Refrigeration and Importing Companies. The resulted distribution is presented in **Figure 4.12** and refers to 11 blends instead of the 3 blends reported in the previous years.
- Change of EFs in order to be in the default ranges provided by the IPCC GPG and Guidelines. Source specific information on the EFs changes is provided in the CRF. The new values are presented in **Table 4.23** above.
- Some estimates of disposal emissions have been performed for the first time (namely Domestic and Transport Refrigeration).
- Update of the methodology used for the estimation of emissions from Aerosols. The new methodology takes account of the average charge of 70g/piece, as provided by the respective company.

The difference between the previous and the current estimates and the impact on total emissions is presented in **Table 4.29**.

It should be noted that even in the cases where equipment data have not been updated, the recalculation impact can be important, due to the higher GWP of the blends used instead of the R134a. This is more apparent in the first years of the timeseries because the total emissions are not so high in absolute values, due to the lower penetration of f-gases in the equipment sold. As a result the % difference has higher values for years 1995-2000 than in the more recent years.

Table 4.29 Recalculations of F-gases from ODS substitutes [1999-2009]

Year	1993	1994	1995	1996	1997	1998	1999	2000	
F Gases Emissions									
Difference (%)	NA	NA	476.72%	276.99%	136.65%	64.58%	36.32%	15.24%	
Impact on total Emissions (incl LULUCF, %)	0.00%	0.01%	0.04%	0.07%	0.09%	0.10%	0.10%	0.07%	
Impact on total Emissions (excl LULUCF, %)	0.00%	0.01%	0.04%	0.07%	0.09%	0.09%	0.09%	0.07%	
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
F Gases Emissions									
Difference (%)	-0.11%	-6.57%	-6.09%	-10.99%	8.54%	11.05%	24.54%	20.76%	32.48%
Impact on total Emissions (incl LULUCF, %)	0.00%	-0.05%	-0.07%	-0.14%	0.12%	0.17%	0.40%	0.39%	0.65%
Impact on total Emissions (excl LULUCF, %)	0.00%	-0.05%	-0.07%	-0.14%	0.12%	0.17%	0.39%	0.38%	0.64%

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:

- Regarding the f-gases equipment, a form has been sent to the companies producing, importing and exporting refrigeration and A/C equipment, based on the list provided in the Sectoral Studies of ICAP, as it has been already mentioned above. Although some companies have replied (about 22% so far), the procedure seems to be time-consuming because of the complexity of the issue and the size of the time-series. In addition many companies have communicated that the data are imported so they have requested additional information by the equipment manufactures, requiring more time for their collection. In any case it is to be expected that the data provided can be used mainly as indicative of the f-gases use in the refrigeration and A/C equipment, since there is no completeness guarantee, since, according to experts, there must be more companies selling this kind of

equipment to end users while many of them are provided the equipment from the internal market. In any case, the collected data will continue to be used as appropriate.

- Any additional information provided by the National Association of Refrigeration Importing and Trading Companies will be used as appropriate in the next submission.
- Data have been also sought by the Appliances Recycling SA regarding the recovery of f-gases. Any collected data will be used as appropriate.
- Finally the Inventory Team has already contacted the Panhellenic Association of Insulating Companies to examine the possibility of acquiring information on the imports of foam products in Greece.
- 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.

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 – 2010. 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 4.30**. Emissions in 2010 have been increased by 71.26% from 1990, whereas they have increased by 16.82% from 2008. The contribution of emissions from electrical equipment is insignificant (lower than 0.00 % for the whole time-series).

Table 4.30 *SF₆ emissions (in kg) from electrical equipment for the period 1990 - 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transmission						115	118	120	122	125
Distribution						35	36	36	36	37
Total	128	132	136	140	144	150	154	156	158	162

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Transmission	130	132	140	140	148	230	310	375	280	175	217
Distribution	37	38	38	38	39	40	40	40	35	45	40
Total	167	170	178	178	187	270	350	415	315	220	257

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. 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 pressurized 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 may have risen 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.

4.15.4 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

The value of 2009 has been updated based on new data provided by the PPC. The difference from the previous estimate is 4.76% and the impact on total emissions (incl/excl LULUCF) is 0.00%

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 2010 were 316.17kt (0.27% of the total GHG emissions in Greece, without *LULUCF*), while NMVOC emissions have been estimated at 54.32 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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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

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 1990-2010 of the 3D1 and 3D3 were estimated.

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 19.2% between 1990 and 2010 (**Figure 6.1**), with an average annual rate of decrease of 0.96%. 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 – 2010. 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).

GHG emissions estimated from *Agriculture* in the current submission have been recalculated for the years 2007, 2008 and 2009 because of the updated activity data of annual quantities of synthetic fertilizers consumed in the country as well as of the animals' population for the year 2008 and of the agricultural production per crop for 2009. However, the new estimations show small deviations in comparison with the estimations of the previous submission.

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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N ₂ O	7803	7664	7451	6600	6400	6679	6779	6630	6632	6490	6271
CH ₄	3680	3659	3635	3620	3635	3658	3701	3705	3715	3705	3685
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
N ₂ O	6174	6106	6037	6113	5810	5657	5880	5528	5244	5596	
CH ₄	3686	3723	3728	3734	3745	3731	3723	3695	3695	3686	

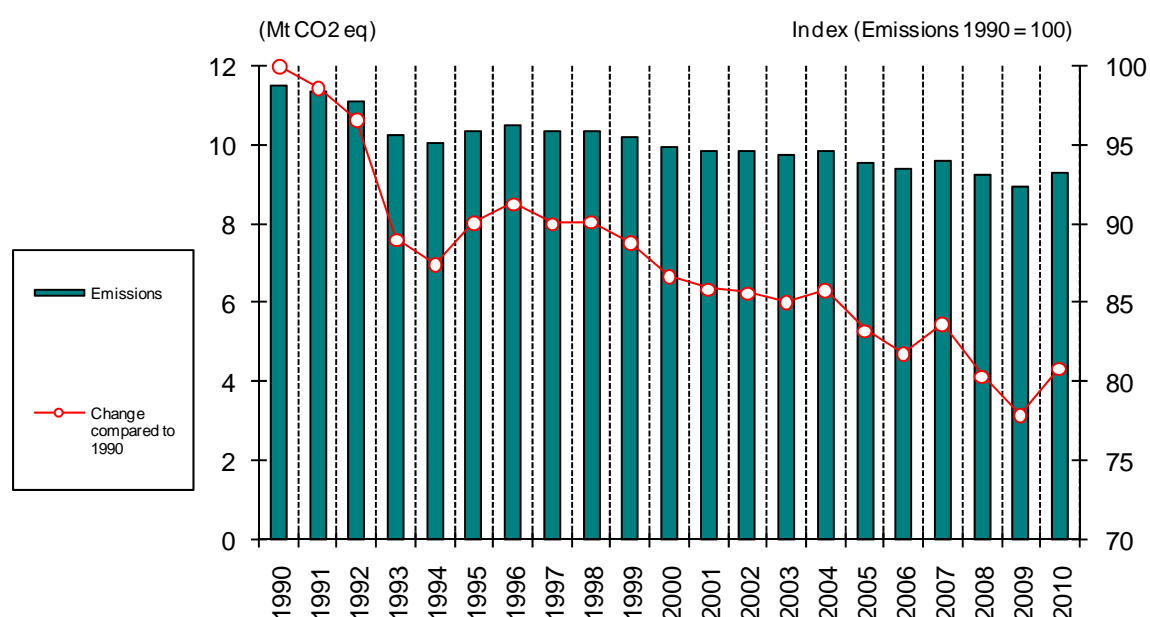


Figure 6.1 *Total GHG emissions (in kt CO₂ eq) from Agriculture for the period 1990 – 2010*

Nitrous oxide represents the main GHG from *Agriculture*, with a contribution ranging from 58% to 68%. Nitrous oxide emissions in 2010 decreased by 28.3 compared to 1990 levels with an average annual rate of decrease estimated at 1.41%.

Agricultural soils are the main source of emissions from *Agriculture* (**Figure 6.2**), accounting for 55% - 65% of the total emissions from the sector.

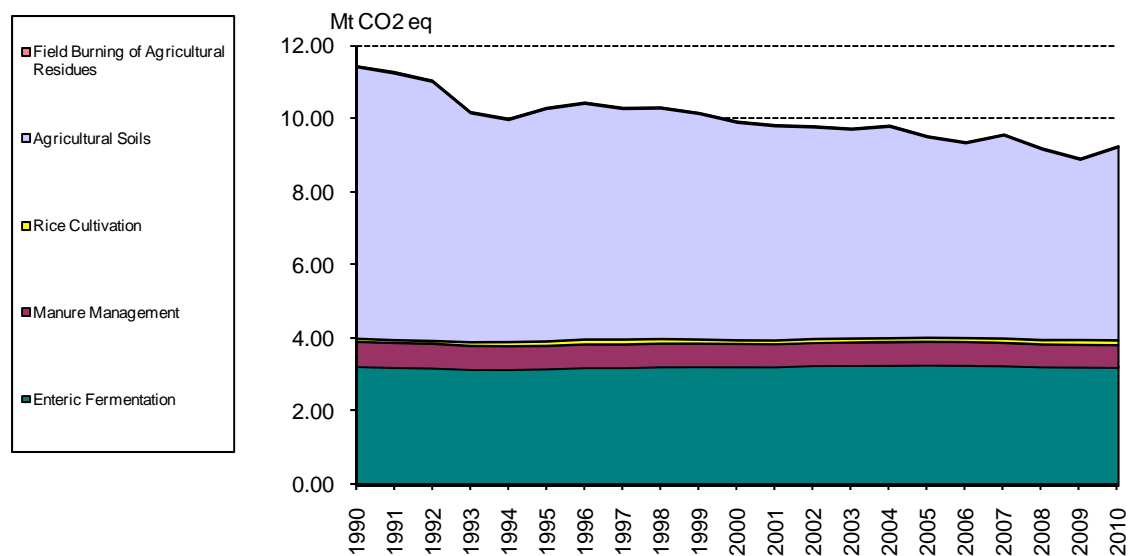


Figure 6.2 GHG emissions (in kt CO₂ eq) from Agriculture per source category, for the period 1990 – 2010

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 2010 and on agricultural production per crop for 2010 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**.

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 70% 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 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.

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	☒	
Direct emissions	N ₂ O	☒	☒
Animal production	N ₂ O	☒	☒
Indirect emissions	N ₂ O	☒	☒

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 2010 account for 35% of total GHG emissions from *Agriculture* and for 2.7% of total national emissions (excluding *LULUCF*). The average annual rate of decrease of emissions from enteric fermentation for the period 1990 – 2010, is estimated at 0.03% (decrease by 0.69% in 2010 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 – 2010

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ emissions (kt)	154.58	153.49	152.63	150.85	150.81	151.58	153.12	153.16	154.29	154.42	154.31
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH ₄ emissions (kt)	154.18	155.83	156.06	156.12	156.48	156.17	155.58	154.20	153.84	153.52	

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:

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

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NE_{ma}/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NE_{ga}/DE is the similar ratio for growth.

The number of dairy cattle used for the calculation of methane emissions is a three-year average centred at the year of reference and it is presented in **Table 6.6** for the period 1990-2010. In the same table the annual average milk production (for 365 days) is presented while milk production yield during suckling estimated at 0.6 kg/day (estimated for 365 days). The data for population of dairy cattle was updated in the current submission following the results of a survey of ELSTAT.

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%, digestibility of feed at 60% and methane conversion rate at 6% as suggested by IPCC Good Practice Guidance. 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 ($C_a = 0$).

Table 6.6 *Number of dairy cattle in 1000s (three-year average) and milk production yield in kg/head/day, for the period 1990 – 2010*

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†	
Dairy cattle (1000s)	168	158	152	153	153	153	148	141	136	135	
Milk prod. yield (kg/head/day)	11.57	12.72	12.52	13.12	14.02	13.74	13.90	14.69	15.14	15.25	

† Provisional data

Finally, in **Table 6.7** information regarding gross energy (Gei) and emissions factors (EFs) for the whole of period 1990-2010 is presented.

Table 6.7 *Gross energy (GE) and emissions factor (EF) for dairy cattle for the period 1990 - 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GE (MJ/head/day)	224	225	231	243	245	254	252	255	262	262	264
EF (kg CH ₄ /head/yr)	88.1	88.6	90.7	95.8	96.5	100.1	99.0	100.3	103.2	103.1	103.9
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	
GE (MJ/head/day)	266	278	276	282	291	288	290	298	303	304	
EF (kg CH ₄ /head/yr)	104.7	109.3	108.5	111.0	114.7	113.5	114.2	117.4	119.2	119.7	

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 1990-2010.

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 2010. Portion of female cattle, >2 year old, giving birth is estimated at 0.9 while milk production yield estimated at 0.1 kg/day (estimated for 365 days) and milk production yield during suckling estimated at 1.0 kg/day (estimated for 365 days). Milk fat content is estimated at 4%, digestibility of feed at 60% and methane conversion rate at 6%, as suggested by IPCC Good Practice Guidance. 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. ($C_a = 0.17$).

Table 6.8 *Number of other cattle (in 1000s) for each sub-category (three-year average), for the period 1990 – 2010*

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†	
< 1 year											
For slaughter as calves	53	58	66	69	71	70	67	74	76	78	
Females	56	57	61	60	59	60	59	53	50	49	
Males	56	59	63	65	64	67	61	52	47	47	
1-2 years											
Females	47	52	56	56	57	56	58	59	63	67	
Males	45	49	60	70	74	72	67	65	65	65	
> 2 year											
Females	142	161	171	174	180	180	187	181	190	190	
Males	12	13	13	13	13	14	15	17	18	18	
Total	411	450	490	506	517	519	515	501	509	515	

† Provisional data

Table 6.9 *Mean Weight, Gross energy (Gei), CH₄ conversion rate (Ym) value and emissions factor (EFs) for each subcategory of other cattle for 2010*

	Mean Weight (kg)	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) KgCH ₄ /head/yr
< 1 year				
For slaughter as calves	200	95.5	0.06	37.6
Females	180	100.9	0.06	39.7
Males	230	111.7	0.06	44.0
1-2 years				
Females	450	147.0	0.06	57.8
Males	500	160.2	0.06	63.0
> 2 year				
Females	550	165.8	0.06	65.4
Males	750	181.9	0.06	71.6
Average	419.8	141.4	0.06	55.63

Enteric fermentation of sheep

Methane emissions from the enteric fermentation of sheep are estimated according to the Tier 2 IPCC methodology, as it is described in the IPCC Good Practice Guidance. For the calculation of the net energy required for each animal sub-category and activity, the appropriate in each case factors suggested in the IPCC Good Practice Guidance were used. The calculation of the emission factors for each animal sub-category and activity is based on the following equation:

$$EF_i = \frac{GE_i \cdot Ym_i \cdot 365}{55.65}$$

where i is the activity, EF_i is the estimated emission factor for CH₄ (kg CH₄/head/yr), GE_i is the gross energy intake (MJ/head/day) and Ym is the methane conversion rate which is the fraction of the gross energy in feed converted to CH₄.

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

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

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

NE_{wool} is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NE_{ma}/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NE_{ga}/DE is the similar ratio for growth.

The characterization and classification of sheep was based on data from ELSTAT and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues. The estimation of sheep population for each sub-category is presented in **Table 6.10**.

Table 6.10 *Number of sheep (in 1000s) for each sub-category (three-year average), for the period 1990 – 2010*

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†	
Milking ewes											
Milk production	5476	5478	5418	5364	5329	5330	5363	5365	5352	5339	
Only suckling	412	412	408	404	401	401	404	404	403	402	
Other female sheep > 1 year											
old	765	766	757	750	745	745	750	750	748	746	
Males > 1 year old	412	412	408	404	401	401	404	404	403	402	
Female lambs	1594	1595	1577	1562	1552	1552	1561	1562	1558	1554	
Male lambs	399	399	394	390	388	388	390	391	390	389	
Total	9059	9062	8962	8874	8816	8818	8872	8875	8854	8832	
Born sheep	9005	9039	9038	9024	9008	8998	9002	9001	8999	8990	

† Provisional data

The average bodyweight of sheep at weaning is estimated at 15 kg while the average weights of female and male mature sheeps (>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 considered equal to 0.22 kg/day and 0.20 kg/day respectively estimated for 365 days, while 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 (Table 6.10).

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 (Gei), 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 2010.

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), CH_4 conversion rate (Y_m) value and emissions factor (EFs) for each subcategory of sheep for 2010*

	Gross Energy (Gei) MJ/day/head	Conversion rate (Y_m)	Emissions factors (EF) Kg CH_4 /head/yr
Female lamb	16.2	0.05	5.3
Female sheep - milking ewes	22.4	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	20.8	6.64	9.06

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.

Table 6.12 *Number of animals (in 1000s) by category (three-year average), for the period 1990 – 2010*

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†	
Buffalo	1.003	1.048	1.141	1.212	1.305	1.338	1.599	1.735	1.824	1.908	
Goats	5658	5652	5600	5517	5444	5409	5341	5279	5215	5155	
Horses	29	28	28	27	27	27	28	28	28	27	
Mules and ashes	90	84	79	74	69	66	60	55	51	46	
Swine	946	937	939	942	930	918	891	885	880	875	
Poultry	29937	29312	29936	30429	31251	31592	30896	30067	29110	29079	

† Provisional data

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.

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 2007, 2008, 2009 because of the updated activity data of the population of cattle for 2009 and 2010 and for the other animals for the 2008. Emissions for 2007 have been recalculated due to the use of three year average data for the population of animals, thus data of 2008 are used for the estimation of emissions for 2007. However, data for 2009 and 2010 for the rest of the animals, except of cattle, were not provided, thus new emissions will be estimated in the next submissions when updated data will be provided by ELSTAT. Similarly emissions of 2010 for cattle will be re-estimated when data for 2011 are available.

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	2007	2008	2009
Difference	0.170	-0.376	-0.149
Impact on total emissions (excl LULUCF)	0.004	-0.009	-0.004

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 2010 accounted for 3.4% and 3.2% of total GHG emissions from *Agriculture* respectively, and for 0.27% and 0.25% of total national emissions respectively (without *LULUCF*). CH₄ emissions in 2010 decreased by 6.8% compared to 1990 levels, with an average annual rate of decrease estimated at 0.34% for the period 1990 - 2009. N₂O emissions in 2010 decreased by 13.4% compared to 1990 levels, with an average annual rate of decrease estimated at 0.67%. CH₄ and N₂O emissions from manure management for the period 1990 – 2010 are presented in **Table 6.14**.

Table 6.14 CH₄ and N₂O emissions (in kt) from manure management, for the period 1990 – 2010

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄ (kt)	16.07	16.00	16.08	16.07	16.03	15.96	16.00	16.01	16.04	16.00	15.81
N ₂ O (kt)	1.10	1.08	1.07	1.00	0.97	0.95	0.98	0.97	0.97	0.96	0.95
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH ₄ (kt)	15.70	15.60	15.65	15.75	15.80	15.73	15.42	15.21	15.03	14.98	
N ₂ O (kt)	0.94	0.95	0.97	0.98	1.00	1.00	0.98	0.95	0.95	0.95	

6.3.2 Methodology

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 6.15** the parameters used for the estimation CH_4 emissions from manure management of dairy cattle, other cattle and sheep are presented for 2010. 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.

Table 6.15 *Parameters for the estimation CH_4 emissions from manure management of dairy cattle, other cattle and sheep for 2010*

	Dairy cattle	Other cattle	Sheep
DE, %	60	60	65
ASH, %	8	8	8
VS, kg/day	6.59	2.82	0.36
Bo , m^3/kg of VS	0.24	0.17	0.19
MCF	1.5	1.5	1.5
EF, kg/year/head	9.56	1.69	0.25

The shares of manure management systems per animal species for dairy cattle, other cattle and sheep are presented in **Table 6.16** along with the rest of animal type considering 100% conditions of temperate climate region for Greece. These values are estimated on the basis of proposed (IPCC

1997, Table 4-21) and country-specific values, depending on the availability of national data, and are kept constant for the period 1990 – 2010.

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 shares of manure management systems per animal species have already been presented in Table 6.16 considering 100% conditions of temperate climate for Greece.

Generally, 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. However, in some cases country-specific data was used based on the judgement of experts from several institutes, including the Agricultural University of Athens, the Ministry of Rural Development and Food, the Department of Animal Production at the School of Agricultural Technology (the Technological Educational Institute of Epirus) and the Office of Rural Development of the Prefecture of Thessaloniki. Greece continues efforts to improve the country-specific data.

Table 6.16 *Manure management systems*

Manure management systems	Anaerobic lagoon	Liquid system	Daily spread	Solid storage and dry lot	Pasture/ range/ paddock	Other system
Dairy cows	0%	0%	2%	90%	8%	0%
Other cattle	0%	0%	3%	62%	33%	2%
Buffalo	0%	0%	3%	62%	33%	2%
Poultry	0%	0%	0%	0%	72%	28%
Sheep	0%	0%	0%	0%	100%	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%	0%	100%	0%

Country-specific data for dairy cattle, other cattle, buffalo and swine was considered. Dairy cattle are mainly stall or housed and they are used for milk production. Only for a small share of their life

they are in pasture. Thus the manure produced from them is mainly managed in Solid storage and dry lot systems.

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.

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.

The allocation of manure to animal waste management systems of other animal, like sheep, goats and poultry is similar with this referring to Near East and Mediterranean category on IPCC (1997) guidelines. For example sheep and goats are in pasture in Greece.

The emission factors for N excretion and N_2O -N/N are those suggested by the IPCC Guidelines. N excretion for dairy cattle value referring to West Europe countries was used taking into account that the dairy milk production in Greece has increased to levels similar to those of Western Europe. Moreover, for other cattle and buffalo N excretion values for dairy cattle referring to West Europe countries were used. Since Greece is a Mediterranean country the Nex values that are recommended by the IPCC guidelines for the Mediterranean countries are used in the greek inventory for all the animals included sheep and swine with one exception, i.e. cattle.

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 0.1%. 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 and N₂O emissions from manure management have been recalculated for 2007, 2008, 2009 because of the updated activity data of the population of animals, as it was described above.

The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission the impact on total emissions (excl LULUCF) of recalculations are presented in **Table 6.17** for CH₄ and for N₂O.

Table 6.17 *Recalculations of CH₄ and N₂O emissions from manure management (%)*

Year	2007	2008	2009
CH₄			
Difference	-1.088	-2.447	-3.363
Impact on total emissions (excl LULUCF)	-0.003	-0.006	-0.009
N₂O			
Difference	-0.162	-2.669	-2.219
Impact on total emissions (excl LULUCF)	-0.0004	-0.0062	-0.0054

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 2010 account for 1.27% of total GHG emissions from *Agriculture* and for 0.1% of total national emissions (without *LULUCF*). CH₄ emissions increased by 70.2 % in 2010 compared to 1990, with an average annual rate of increase of 3.5% for the period 1990 - 2010. CH₄ emissions from rice cultivation for the period 1990 – 2010 are presented in *Table 6.18*.

Table 6.18 CH₄ emissions (in kt) from rice cultivation for the period 1990 – 2010

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†	
CH ₄	4.22	4.48	4.52	4.55	4.62	4.46	5.00	5.00	5.60	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 NSSG.

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 19% of total GHG emissions from *Agriculture* and for 1.49% of total national emissions (without *LULUCF*) in 2010. Emissions decreased in 2010 by 3.4% compared to 1990 levels, with an average annual rate of decrease of 0.17% for the period 1990 – 2010. Direct N₂O emissions from agricultural soils in 2010 accounted for 17.1% of total GHG emissions from *Agriculture* and for 1.35% of total national emissions (without *LULUCF*). Direct emissions in 2010 decreased by 42.4% compared to 1990 levels, with an average annual rate of decrease of 2.12% for the period 1990 - 2010. Finally, indirect N₂O emissions in 2010 accounted for 21% of total GHG emissions from agriculture and for 1.49% of total national emissions (without *LULUCF*). Indirect emissions in 2010 decreased by 32.48% compared to 1990 levels, with an average annual rate of decrease estimated at 1.6% for the period 1990 – 2010. Emissions from agricultural soils for the period 1990 – 2010 are presented in **Table 6.19**.

Table 6.19 N₂O emissions (in kt) from agricultural soils for the period 1990 – 2010

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Animal production	5.87	5.84	5.83	5.82	5.84	5.87	5.90	5.91	5.93	5.95	5.96
Direct emissions	8.91	8.74	8.34	6.83	6.46	6.95	7.10	6.82	6.79	6.53	6.13
Indirect emissions	9.25	9.02	8.76	7.61	7.33	7.74	7.86	7.65	7.67	7.47	7.16
Year	2001	2002	2003	2004	2005	2006	2007	2008†	2009†	2010†	
Animal production	5.96	5.96	5.92	5.87	5.84	5.82	5.80	5.76	5.71	5.68	
Direct emissions	5.96	5.82	5.71	5.90	5.37	5.08	5.51	4.95	4.46	5.13	
Indirect emissions	7.02	6.93	6.84	6.93	6.51	6.31	6.64	6.13	5.76	6.25	

† Provisional data

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 – 2010.

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 – 2010 are presented in *Table 6.20*.

Table 6.20 *Nitrogen input (in kt) and N₂O emissions (in kt) from pasture, range and paddock, for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	186.93	185.89	185.38	185.12	185.82	186.89	187.71	188.13	188.77	189.16	189.52
N ₂ O emissions	5.87	5.84	5.83	5.82	5.84	5.87	5.90	5.91	5.93	5.95	5.96
Year	2001	2002	2003	2004	2005	2006	2007	2008†	2009†	2010†	
N input	189.67	189.68	188.51	186.81	185.68	185.33	184.63	183.17	181.76	180.63	
N ₂ O emissions	5.96	5.96	5.92	5.87	5.84	5.82	5.80	5.76	5.71	5.68	

† Provisional data

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. As a part of the nitrogen contained in the fertilizer is volatilised 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 – 2010 are presented in **Table 6.21**.

Table 6.21 *Synthetic nitrogen applied (in kt) and N₂O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2010*

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	
N input	234.00	227.70	222.30	229.50	201.60	189.00	212.40	180.90	157.50	191.70	
N ₂ O emissions	4.60	4.47	4.37	4.51	3.96	3.71	4.17	3.55	3.09	3.77	

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 6.22** nitrogen input to soils from animal manure and subsequent N₂O emissions are presented, for the period 1990 – 2010.

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 NSSG.

Table 6.22 *Nitrogen input to soils from animal manure (in kt) and N₂O emissions (in kt) from animal manure used as fertilizers, for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	42.90	42.40	42.03	40.22	39.63	38.94	39.65	39.48	39.46	39.21	38.67
N ₂ O emissions	0.84	0.83	0.83	0.79	0.78	0.76	0.78	0.78	0.78	0.77	0.76
Year	2001	2002	2003	2004	2005	2006	2007	2008†	2009†	2010†	
N input	38.26	38.35	38.95	39.46	39.76	39.72	39.02	38.06	37.89	37.88	
N ₂ O emissions	0.75	0.75	0.77	0.78	0.78	0.78	0.77	0.75	0.74	0.74	

† Provisional data

N₂O emissions from N-fixing crops and crop residues for the period 1990 – 2010 are presented in **Table 6.23**.

Table 6.23 *N₂O emissions (in kt) from N-fixing crops and crop residues, for the period 1990 – 2010*

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†	
N-fixing crops	0.021	0.021	0.020	0.019	0.019	0.019	0.020	0.016	0.017	0.016	
Crop residues	0.506	0.493	0.474	0.512	0.525	0.485	0.470	0.552	0.517	0.524	

† 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 1990-2010 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 – 2010 are presented in **Table 6.24**.

Table 6.24 *Nitrogen input to soils from Sewage sludge used in Agriculture (in kg) and N₂O emissions (in t) for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N-Sewage sludge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N ₂ O emissions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010†	
N-Sewage sludge	0.0	0.0	0.0	781	830	1354	7.2	7.2	7.2	7.2	
N ₂ O emissions	0.0	0.0	0.0	15.35	16.30	26.59	0.14	0.14	0.14	0.14	

† Provisional data

Estimation of N₂O emissions from the organic soils (0.084 kt) was based on the cultivated area (6.7 kHa, constant for the entire period examined in North Greece) and the updated default emission factor suggested in the IPCC Good Practice Guidance for mid-latitude organic soils. Data for the areas of organic soils derive from a relevant research conducted by the Soil Science Institute of Athens (SSIA, 2001).

Indirect N₂O emissions from agricultural soils

Indirect N₂O emissions from agricultural soils derive from:

☞ Volatilisation of nitrogen included in synthetic fertilizers, animal manure (used as fertilizer) and sewage sludge (used also as fertilizer) as NO_x and NH₃, followed by atmospheric deposition as NO_x, HNO₃ and NH₄ on soils and surface waters and subsequent N₂O formation.

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

For all sources of N₂O emissions, the Tier 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 volatilizes as ammonia and nitrous oxides, while for leaching and runoff it reflects the fraction of nitrogen that leaks from synthetic fertilizers and animal manure. The amount of nitrogen deposited and the indirect N₂O emissions for the period 1990 – 2010 are presented in **Table 6.25**.

For the estimation of the fraction of nitrogen that volatilizes as NH₃ and NO_x from the input to soils due to the application of sewage sludge in agriculture, the default value suggested by the IPCC Good Practice Guidance, i.e. 20%, was used.

Table 6.25 *Deposited nitrogen (in kt) and indirect N₂O emissions (in kt) from agricultural soils, for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atmospheric deposition											
N deposited	90.51	88.58	86.58	77.78	75.67	78.71	79.76	78.20	78.42	76.94	74.57
N ₂ O emissions	1.42	1.39	1.36	1.22	1.19	1.24	1.25	1.23	1.23	1.21	1.17
Leaching/Runoff											
N deposited	199.37	194.07	188.38	162.72	156.41	165.47	168.08	163.34	163.83	159.35	152.36
N ₂ O emissions	7.83	7.62	7.40	6.39	6.14	6.50	6.60	6.42	6.44	6.26	5.99
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Atmospheric deposition											
N deposited	73.50	72.82	72.14	72.73	69.48	67.99	70.28	66.25	63.33	66.90	
N ₂ O emissions	1.15	1.14	1.13	1.14	1.09	1.07	1.10	1.04	1.00	1.05	
Leaching/Runoff											
N deposited	149.25	147.19	145.26	147.34	137.81	133.49	140.82	129.53	121.24	132.29	
N ₂ O emissions	5.86	5.78	5.71	5.79	5.41	5.24	5.53	5.09	4.76	5.20	

6.5.3 Uncertainties and time-series consistency

The combined uncertainty of N₂O emissions of direct emissions as % of total emissions is estimated by 5.4%. 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 N₂O emissions of indirect emissions as % of total emissions is estimated by 0.9%. The uncertainty associated with activity data is 20% according to uncertainty given by NSSG for the crop production while the uncertainty associated with emission factors is 50 % as it is estimated according to Good Practice Guidance.

The combined uncertainty of N₂O emissions of animal production as % of total emissions is estimated by 1.7%. 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 while the uncertainty associated with emission factors is 100 % as it is estimated according to Good Practice Guidance.

The results of uncertainty analysis are presented in Table 1.9. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

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 2007, 2008, 2009 because of the updated activity data of annual quantities of synthetic fertilizers consumed in the country as they are derived from the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers.

Moreover, N₂O emissions from agricultural soils have been recalculated for 2007, 2008, 2009 because of the updated activity data of the population of the animals for the 2008 and of the agricultural production per crop for 2009.

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 6.26**.

Table 6.26 *Recalculations of N₂O emissions from agricultural soils (%)*

Year	2007	2008	2009
Difference	-0.782	5.600	0.455
Impact on total emissions (excl LULUCF)	-0.032	0.211	0.018

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 2010 accounted for 0.45% of total GHG emissions from *Agriculture* and for 0.036% of total national emissions (without LULUCF). Emissions in 2010 increased by 13.6% compared to 1990 levels with an average annual rate of increase estimated at 0.7%. CH₄ and N₂O emissions from field burning of agricultural residues for the period 1990 – 2010 are presented in **Table 6.27**.

Table 6.27 *GHG emissions (in kt) from field burning of agricultural residues, for the period 1990 – 2010*

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	
CH ₄ emissions	1.42	1.38	1.27	1.42	1.43	1.32	1.28	1.54	1.48	1.45	
N ₂ O emissions	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	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

CH₄ and N₂O emissions from field burning of agricultural residues have been recalculated for 2009 because of the updated activity data of crop production. However, data for 2010 were not provided, thus new emissions will be estimated in next submissions when updated data will be provided by ELSTAT.

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 0.011% and 0.0000028 %, respectively, for CH₄, and 0.012% and 0.0000011%, respectively, for N₂O.

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. 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-use¹⁴ 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 five the 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 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 emissions / 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 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.

¹⁴ 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.

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 – 2010. During this period, the LULUCF sector offset on average 2.5% (1.7-3.3%) of the total national emissions (without LULUCF). The sink capacity of the LULUCF sector fluctuates between 2.2 Mt CO₂ eq. and 3.3 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.

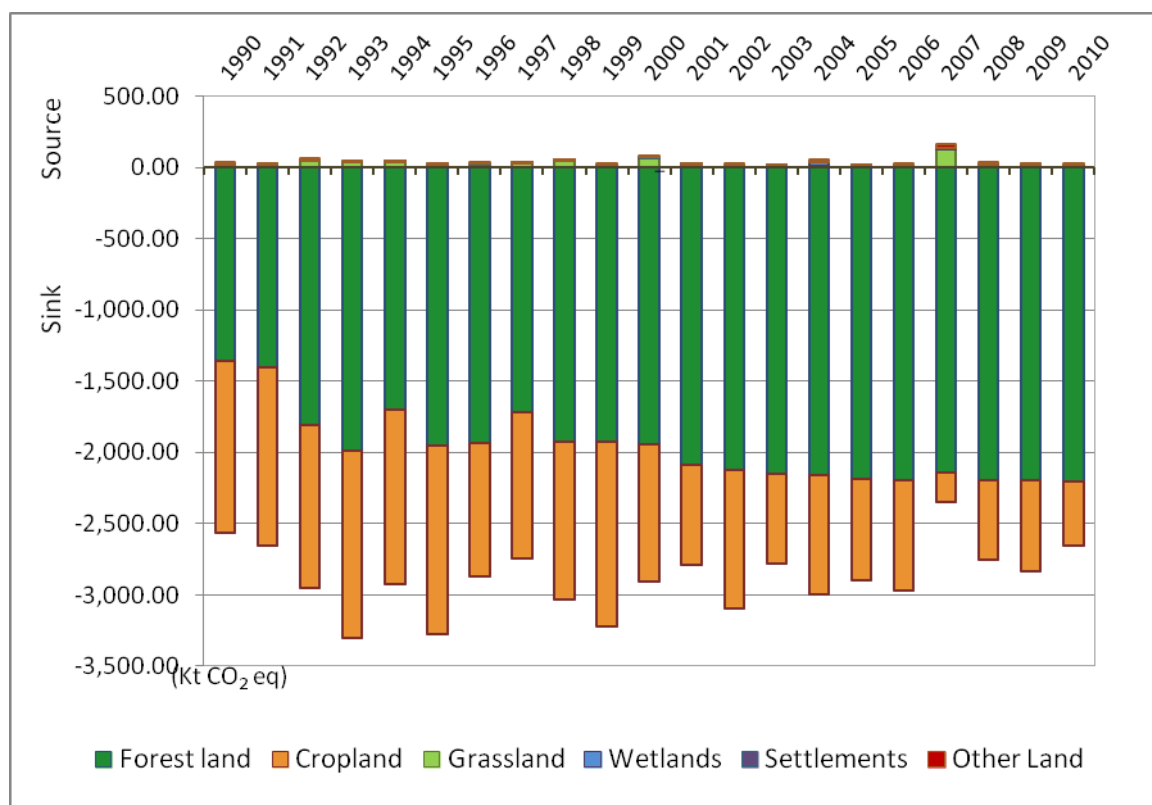


Figure 7.1 Net GHG emissions / removals (in kt CO₂ eq) from the Land Use, Land Use Change and Forestry sector by category for the period 1990 – 2010

CO₂ is the main greenhouse gas emitted and removed to / 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 categories act as net carbon sinks during the period 1990 – 2010. 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 1.4 Mt CO₂ eq in 1990 to 2.2 Mt CO₂ eq in 2010, i.e. an increase of about 60%.

Removals from Cropland, caused by changes in management practices and crop type, fluctuate between 0.2 - 1.3 Mt CO₂ eq yr⁻¹. Grassland category appears as a small source of CO₂ due to conversion of Forest land to Grassland and changes in vegetation type, as well as, source of CH₄ and N₂O due to emissions during 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 Change and Forestry sector by category and gas for the period 1990 – 2010*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Net CO ₂ emissions / removals (in kt)																					
A. Forest Land	-1,379	-1,412	-1,830	-2,012	-1,717	-1,970	-1,939	-1,731	-1,966	-1,933	-1,992	-2,101	-2,128	-2,152	-2,170	-2,189	-2,206	-2,206	-2,206	-2,206	-2,206
B. Cropland	-1,205	-1,251	-1,146	-1,311	-1,230	-1,315	-936	-1,025	-1,104	-1,296	-963	-699	-968	-630	-837	-717	-771	-206	-563	-642	-452
C. Grassland	0.04	0.27	0.06	0.45	0.50	2.45	0.02	0.10	0.04	0.33	0.02	0.02	0.04	2.02	0.43	0.02	0.06	0.07	0.42	1.96	0.44
D. Wetlands	0.00	NE,NO	0.00	NE,NO	0.02	NE,NO	0.26	0.46	1.94	NE,NO	2.10	0.21	1.91	0.87	23.86	0.27	1.19	0.20	0.00	NE,NO	NE,NO
E. Settlements	2.93	1.74	2.32	1.67	2.50	2.56	6.15	2.27	1.51	4.97	4.80	2.68	2.62	3.49	4.04	3.15	7.00	7.58	3.66	2.81	4.62
F. Other Land	10.78	4.45	14.53	6.47	6.83	5.92	11.17	10.51	9.23	8.27	12.76	10.69	12.81	8.97	12.03	5.05	10.97	20.43	13.46	6.63	3.28
CH ₄ emissions (in kt)																					
A. Forest Land	0.61	0.23	0.67	0.70	0.61	0.40	0.17	0.49	1.53	0.10	1.89	0.20	0.02	0.03	0.08	0.06	0.19	2.50	0.39	0.42	0.03
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	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	0.10	0.13	0.33	0.17	0.27	5.47	0.58	0.57	0.30
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	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	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
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	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
C. Grassland	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	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	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	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
TOTAL LULUCF (kt CO₂ eq)	-2,541	-2,639	-2,904	-3,270	-2,894	-3,253	-2,840	-2,712	-2,983	-3,210	-2,831	-2,770	-3,077	-2,763	-2,957	-2,891	-2,947	-2,199	-2,729	-2,814	-2,642

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 and the IPCC Good Practice Guidance for LULUCF.

Activity data and country specific emission / removal factors were obtained from the NSSG, 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 in Paragraphs 7.2 – 7.7.

Table 7.2 *Methodology for the estimation of emissions / removals from LULUCF*

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

T1, T2: IPCC methodology Tier 1 and Tier 2 respectively

CS: Country specific methodology and emission factor

D: IPCC default methodology and emission factor

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

Key categories

Key categories – a term introduced by 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	☑	☑
Land converted to Forest Land	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 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

Table 7.4 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 emission / removal 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	☑	NO	NO
B. Cropland			
1. Cropland remaining Cropland	☑	NO	NO
2. Land converted to Cropland	☑	NO	NO
C. Grassland			
1. Grassland remaining Grassland	NO	☑	☑
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 for information related to forest and grassland management systems applied in Greece per forest type, the fate of carbon stocks after disturbances and cross-checking. Information has already sought from the Ministry of Environment, Energy and Climate Change, the Forest Research Institute and other research institutes.
- Comparison of information regarding biomass densities, biomass increment and emissions factors with this of other neighbour countries.
- Cross checking information provided by the Forest office of each prefecture and by the regional Forest office regarding the area of wildfires.
- Estimations were checked with several calculation tools such as emissions trends and sum deviations.

The most important results of the internal audits are:

- Need to separate carbon stock changes in soils between the categories Cropland remaining Cropland and Cropland converted to Forest land.
- Estimation of carbon stock changes in dead organic matter and soil organic carbon in Forest land converted to other land uses.
- More detailed description in the NIR of methods used and better implementation of the Annotated NIR.
- Better use of Notation keys in the CRF tables.

7.1.5 Recalculations and improvements

In the current submission the following recalculations have been performed:

- Estimation and report of carbon stock changes in living biomass in Grasslands remaining Grasslands category due to vegetation management
- Update of activity data on areas under different tree crop types for the years 2000-2009 (for use in the Cropland remaining Cropland category)
- 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
- Fulfillment of the Land Use Change Database with values from all prefectures of Greece and for all the time series

- Recalculation of non-CO₂ emissions from wildfires in Forest lands remaining Forest land.

7.1.6 Representation of land areas

The various forms of land uses in 2010 are presented in *Figure 7.2*.

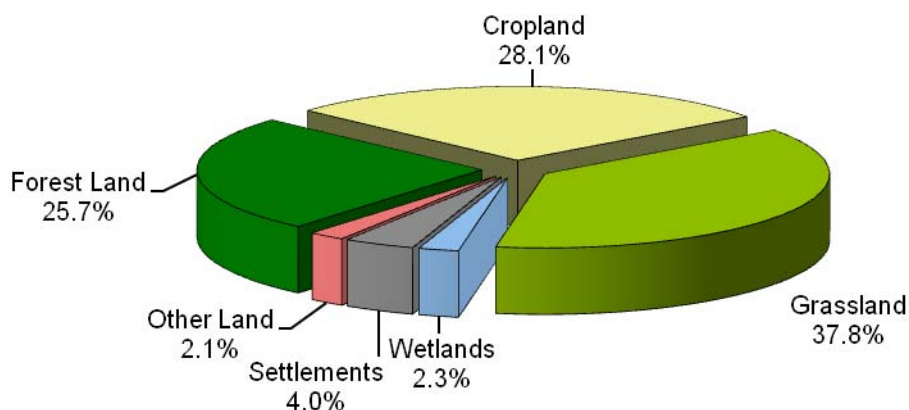


Figure 7.2 *Distribution of the area of Greece in 2009 by land-use category*

The information used for 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 (NSSG, annual census)
- the ‘Distribution of the Country’s Area by Basic Categories of Land Use’ of the Hellenic Statistical Authority (NSSG, decennial survey)
- the ‘Land Use Change Database’ recently developed by the Ministry of Environment, Energy and Climate Change, which until today comprise more than 19000 acts of land use change since 1990
- the ‘Forest Management Plans Database’, recently developed by the Ministry of Environment, Energy and Climate Change

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. **Table 7.5** is the land-use matrix for the period 1990-2010.

Table 7.5 *Land-Use Matrix for the period 1990-2010 (areas in kha).*

1990 2010	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	Total in 2010
Forest Land	3.355,26	33,25					3.388,51
Cropland	0,01	3.681,16	0,07				3.681,24
Grassland	0,23	229,80	4.789,20				5.019,22
Wetlands	0,08		1,40	299,60			301,08
Settlements	0,67		2,72		530,32	0,06	533,77
Other Land	2,93		3,77			265,22	271,92
Total in 1990	3359,186	3.944,20	4.797,15	299,6	530,32	265,28	13.195,74

Art. 3.3 Afforestation / Reforestation

Art. 3.3 Deforestation

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 Lands remained Forest Lands and Lands converted to Forest Lands have been assessed and reported under this category.

Carbon stocks increased during the period 1990 – 2010 due to biomass increment in Forest Land remaining Forest Land and in Land converted to Forest Land (afforestation of croplands), and the increment in soil organic carbon in areas afforested (reported though under Cropland remaining Cropland category for inventory methodological reasons). Non-CO₂ greenhouse gases released to the atmosphere during biomass burning. Estimates of emissions / removals in this category are presented in *Table 7.6*.

The sink capacity of Forest Land has increased from 1.37 Mt CO₂ eq in 1990 to 2.21 Mt CO₂ eq in 2010, i.e. an increase of 61.5%. This rising trend is attributed mainly to the reduction in fellings and the afforestation programmes started in 1994.

Table 7.6 *Net GHG emissions / removals (in kt) from Forest Land by subcategory and gas for the period 1990 – 2010*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest land remaining forest land											
CO ₂	-1,379.4	-1,412.5	-1,829.9	-2,011.8	-1,692.1	-1,911.6	-1,849.0	-1,578.8	-1,795.0	-1,720.3	-1,754.5
CH ₄	0.61	0.23	0.67	0.70	0.61	0.40	0.17	0.49	1.53	0.10	1.89
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	NO	NO	NO	NO	-25.06	-58.48	-89.81	-152.47	-171.26	-213.03	-237.86
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)	-1,365.2	-1,407.1	-1,814.3	-1,995.5	-1,703.0	-1,960.8	-1,935.0	-1,720.0	-1,930.8	-1,931.1	-1,948.7

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Forest land remaining forest land										
CO ₂	-1,850.5	-1,854.1	-1,861.4	-1,860.2	-1,855.0	-1,855.5	-1,855.5	-1,855.5	-1,855.5	-1,855.5
CH ₄	0.20	0.02	0.03	0.08	0.06	0.19	2.50	0.39	0.42	0.03
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Land converted to forest land										
CO ₂	-250.14	-274.17	-290.29	-309.39	-333.67	-350.63	-350.63	-350.63	-350.63	-350.63
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
Total (kt CO₂ eq)	-2,096.1	-2,127.8	-2,151.0	-2,167.8	-2,187.2	-2,201.8	-2,148.4	-2,197.1	-2,196.3	-2,205.4

NO: Not Occurring

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 1,205,761 ha, which corresponds to approximately 36% of the total forest land. The same definition of forest land is used in the Kyoto Protocol inventory, in order to maintain coherence and congruity 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 summary equation, which estimates the annual emissions or removals from FF with respect to changes in carbon pools, is given in the following equation:

$$\Delta C_{FF} = (\Delta C_{FF_{LB}} + \Delta C_{FF_{DOM}} + \Delta C_{FF_{Soils}})$$

where, ΔC_{FF} is the annual change in carbon stocks from forest land remaining forest land, t C yr⁻¹, $\Delta C_{FF_{LB}}$ is the annual change in carbon stocks in living biomass (includes above- and belowground biomass) in forest land remaining forest land, t C yr⁻¹, $\Delta C_{FF_{DOM}}$ 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 $\Delta C_{FF_{Soils}}$ 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 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 stock 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, tonnes C yr⁻¹, C_{t_2} is the total carbon in biomass calculated at time t_2 , tonnes C, C_{t_1} is the total carbon in biomass calculated at time t_1 , tonnes C.

The total carbon in biomass is calculated according 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 , tonnes C, V_{t_i} is the merchantable volume, m³ ha⁻¹, at time t_i , D is the basic wood density, tonnes dry matter m⁻³ merchantable volume, 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 C (t d.m.)⁻¹

CO₂ 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 1232 forest management plans (FMP) have been used, corresponding to 487 forest districts.

The merchantable volume, V , and the area covered by each forest class (subdivision of the forest area defined by the forest species) are obtained from the FMP. Appropriate IPCC default factors for root/shoot ratio R were selected for each forest species from table 3A.1.8 of 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.

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 only take place for fuel load management (mainly pine litter) in urban forests in a very small scale. Greenhouse gas emissions from this activity were therefore considered as negligible. Post logging burning of harvest residues is not practiced in Greece.

Table 7.7 *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.

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:

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

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, $B_{W_{\text{understorey}}}$ 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 LULUCF GPG respectively.

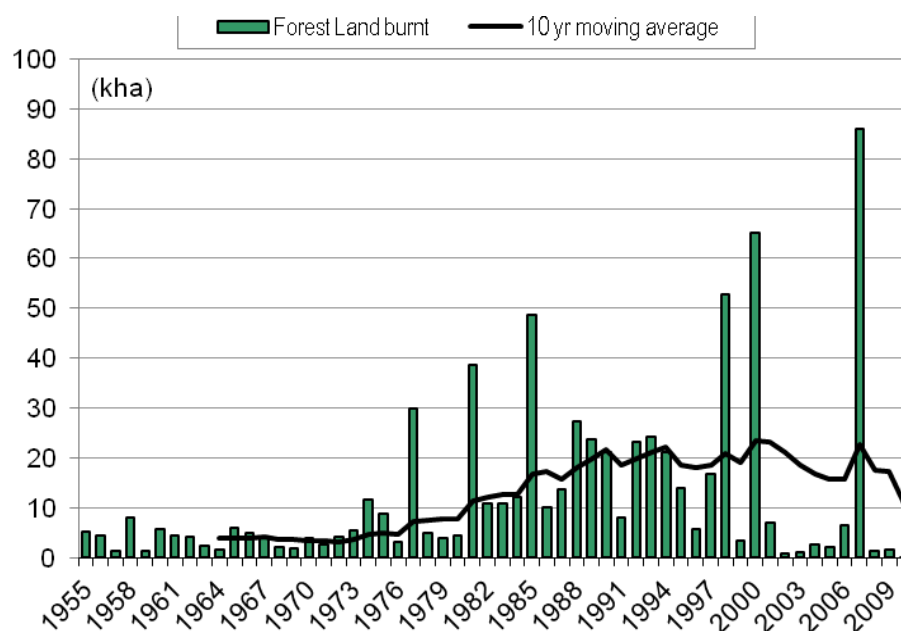


Figure 7.3 Areas of Forest Land burnt since 1955

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. 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.

Annual change in carbon stocks in living biomass was estimated using the default method described in the IPCC Guidelines (Method 1 of GPG LULUCF) and relies on the carbon flux approach (a mix of Tier 1 and Tier 2 method):

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

where, $\Delta C_{LFGROWTH}$ is the annual increase in carbon stocks in living biomass due to biomass growth in land converted to forest, t C yr⁻¹, $\Delta C_{LFCONVERSION}$ is the annual change in carbon stocks in living biomass due to actual conversion 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.

The annual increase in carbon stocks in living biomass due to biomass growth was calculated as:

$$\Delta C_{FFG} = [\sum_i (A_i \cdot G_{TOTAL_i}) \cdot CF]$$

where, A_i is the area of cropland converted to forest land, by forest type ($i = 1$ to 24), ha, G_{TOTAL_i} is the average annual increment rate in total biomass in units of dry matter, by forest type, t d.m. ha⁻¹ yr⁻¹, CF is the carbon fraction of dry matter, t C (t d.m.)⁻¹. Data on area afforested were obtained from the statistics of the Ministry of Environment, Energy and Climate Change (GDPDFNE, 2001), disaggregated by twenty four forest types. For the conversion of dry matter to carbon the IPCC default factor (CF = 0.5) was used throughout the inventory. The annual increment rate in total biomass (above and below ground, G_{TOTAL}) was derived from the annual aboveground biomass increment and the root- shoot ratio that applies to increments, according the equation:

$$G_{TOTAL} = G_w \cdot (1 + R)$$

where, G_w is the average annual aboveground biomass increment, t d.m. ha⁻¹ yr⁻¹ and R is the root-to-shoot ratio appropriate to increments. The annual aboveground biomass increment G_w was obtained from the net annual increment in volume suitable for industrial processing (I_v) by applying appropriate Biomass Expansion Factors (BEF):

$$G_w = I_v \cdot D \cdot BEF_1$$

where, I_v is the average net annual increment in volume suitable for industrial processing, m³ ha⁻¹ yr⁻¹, D is the basic wood density, t d.m. m⁻³ and BEF_1 is the biomass expansion factor for conversion of annual net increment to aboveground tree biomass increment. Appropriate IPCC default values for the average net annual increment in volume suitable for industrial processing (I_v), wood density (D), biomass expansion factor (BEF_1), annual aboveground biomass increment (G_w) and root-to-shoot ratio appropriate to increments (R) were selected from tables 3A.1.7, 3A.1.9-1, 3A.1.10, 3A.1.5 and 3A.1.8 of GPG LULUCF respectively.

The annual change in carbon stocks in living biomass due to actual conversion ($\Delta C_{LFCONVERSION}$) is estimated by the difference in biomass stocks immediately before and immediately after the conversion. This quantity was assumed to be negligible since the 96% of the cropland afforested consisted of annual crops and only 4% of tree or vine crops with significant biomass stock (GDPDFNE, 2001).

Decreases in carbon stocks due to biomass loss (ΔC_{LFLOSS}) are caused by commercial fellings, fuelwood gathering and disturbances. In lands afforested since 1994 harvest has not taken place yet. Hence, no decreases in carbon stocks due to biomass loss in land converted to forest land are reported.

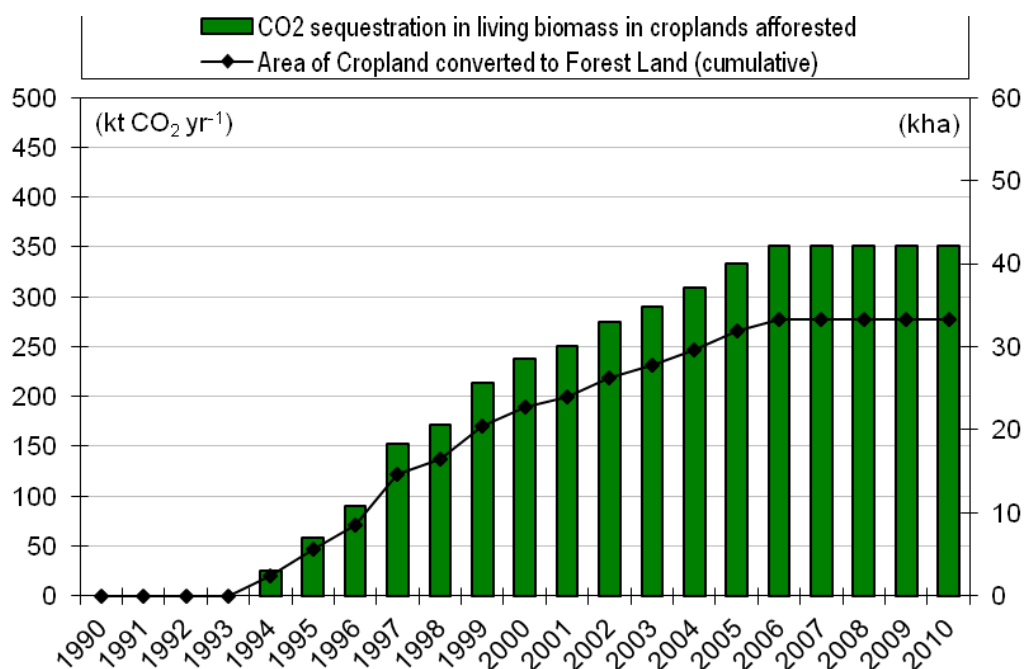


Figure 7.4 Carbon sequestration in living biomass and area of Croplands converted to Forest land during 1990-2010

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).

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:

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

where, $\Delta C_{LF_{Mineral}}$ is the annual change in carbon stocks in mineral soils for inventory year, t C yr⁻¹, SOC_{REF_i} 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, 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, because available data on areas of cropland were not available stratified by crop type, carbon stocks changes in these lands were estimated and reported aggregated in changes in soil carbon stocks in Cropland remaining Cropland. Further information is given in Paragraph 7.3.2. Croplands on organic soils have not been converted to forest land.

Soil carbon stock changes in cropland converted to Grassland and Forest Land, currently reported in the Cropland remaining Cropland category, will be attributed to the proper category.

7.3 Cropland (CRF Source Category 5B)

7.3.1 Category description

Carbon stock changes in Croplands remaining Croplands and in Lands converted to Croplands are estimated and reported in this category. Carbon stock changes in living biomass and soil in Croplands remaining Croplands were caused by changes in management practices and crop type. Soil carbon stock changes in cropland converted to Grassland and Forest Land (through abandonment or afforestation) are also reported in the Cropland category (due to inventory methodological reasons). 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 7.8*.

Table 7.8 *Net CO₂ emissions / removals (kt CO₂) from Cropland by subcategory for the period 1990 - 2010*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cropland remaining Cropland	-1,205	-1,251	-1,146	-1,311	-1,230	-1,316	-936	-1,025	-1,104	-1,297	-963
Biomass	-1,226	-1,272	-1,167	-1,332	-1,251	-1,336	-957	-1,046	-1,124	-1,317	-984
Dead Organic matter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soils	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65
Land converted to Cropland	0,03	0,17	0,14	0,32	0,06	0,17	0,13	0,02	0,04	0,12	0,06
Biomass	0,03	0,17	0,14	0,32	0,06	0,17	0,13	0,02	0,04	0,12	0,06
Dead Organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Soils	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Cropland	-1205	-1251	-1146	-1311	-1230	-1315	-936	-1025	-1104	-1296	-963

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cropland remaining Cropland	-699.56	-968.46	-630.60	-836.93	-716.60	-770.98	-205.90	-562.76	-642.09	-452.08
Biomass	-720.22	-989.11	-651.25	-857.58	-737.25	-791.64	-226.56	-583.41	-662.74	-472.73
Dead Organic matter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soils	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65
Land converted to Cropland	0,07	0,05	0,14	0,18	0,00	0,04	0,12	0,01	0,04	0,29
Biomass	0,07	0,05	0,14	0,18	0,00	0,04	0,12	0,01	0,04	0,29
Dead Organic matter	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Soils	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Cropland	-699	-968	-630	-837	-717	-771	-206	-563	-642	-452

Note: Emissions / removals from changes in soil carbon stocks in Cropland converted to Grassland and Forest land are also included

According to the Agricultural Statistics of the National Statistical Service 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 0.2-1.3 Mt CO₂ yr⁻¹ during the

period 1990 – 2010. Carbon sequestration in mineral soils is mostly attributed to the abandonment and afforestation of croplands - and not to changes in crop type - and accounts for an average removal of 224 kt CO₂ per year during the period 1990 – 2010. Cultivation of organic soils resulted in net emissions of 244 kt CO₂ yr⁻¹ during the same period, and therefore soils accounted for net emissions of 20 kt CO₂ yr⁻¹.

7.3.2 Methodology

Cropland includes all annual and perennial crops as well as temporary fallow land. The course of the area of different broad crop categories is illustrated in *Figure 7.5*.

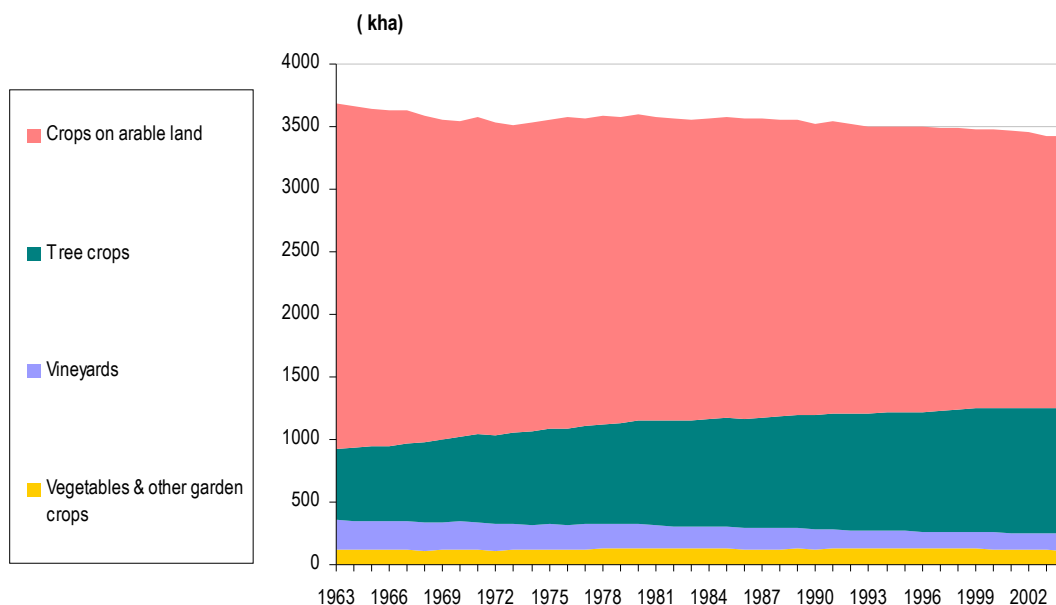


Figure 7.5 Areas of cropland in Greece since 1963 (fallow land excluded)

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 used:

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

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 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:

$$\Delta C_{CC_G} = \sum_i \sum_{j=k-(\lambda_i/2)-1}^k \frac{1}{\lambda_i/2} \cdot A_{\text{planted}_{ij}} \cdot G_{W_i} \cdot CF, \quad G_{W,i} = \frac{B_{M,i}}{(\lambda_i/2)}$$

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, t d.m. ha⁻¹ yr⁻¹, CF is the carbon fraction of dry matter, t C (t d.m.)⁻¹, k is the inventory year, B_{M_i} is the average biomass stock at maturity, by crop type, d.m. ha⁻¹ and λ_i is the average replacement cycle, by crop type, yr.

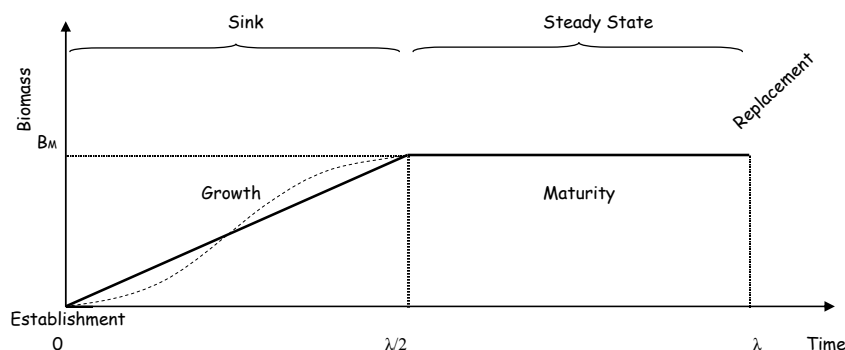


Figure 7.6 Assumed biomass accumulation in new plantations

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:

$$\Delta C_{CC_L} = \sum_i A_{eradicated_i} \cdot B_{M_i}$$

where, $A_{eradicated_i}$ is the area of crop eradicated, by crop type ($i = 17$), ha yr⁻¹ and B_{M_i} is the average biomass stock at maturity / replacement, by crop type, t d.m. ha⁻¹.

Data on areas planted and eradicated since 1963 were obtained by 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 7.9**.

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 ($\Delta C_{CC_{Soils}}$, tonnes C yr⁻¹) was estimated as the difference in the annual emissions from cultivated organic soils ($\Delta C_{CC_{Organic}}$, tonnes C yr⁻¹) from the annual change in organic carbon stocks in mineral soils ($\Delta C_{CC_{Mineral}}$, tonnes C yr⁻¹).

$$\Delta C_{CC_{Soils}} = \Delta C_{CC_{Mineral}} - \Delta C_{CC_{Organic}}$$

According to 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 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 7.9 *Average biomass stock at maturity and replacement cycle for 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 ¹⁵	71.5	50

Mineral soils

The default IPCC methodology that a certain concentration of carbon stock is associated with one crop type and management practice under a specific climate and soil type, and thus changes in soil carbon stocks occur when crop type or management practices are altered, was followed. The annual change in carbon stocks in mineral soils was estimated using a Tier1 method based on equation 3.3.4 of GPG LULUCF:

$$\Delta C_{CC_{\text{Mineral}}} = [\sum_i (SOC_0 \cdot A)_i - \sum_i (SOC_{(0-T)} \cdot A)_i] / T$$

$$SOC = SOC_{\text{REF}} \cdot F_{\text{LU}} \cdot F_{\text{MG}} \cdot F_I$$

where, SOC₀ is the soil organic carbon stock in the inventory year, t C yr⁻¹, SOC_(0-T) is the soil organic carbon stock T years prior to the inventory year, t C yr⁻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,

¹⁵ Olive groves constitute the majority of new plantations (approximately 90%) during 1990-2010. 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.

($i = 13$), 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.

The IPCC default inventory time period was used ($T = 20$). The high majority of agricultural soils in Greece are high activity clays (Yassoglou, 2004), and thus only one soil type was considered. 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). However, since land area data disaggregated by climatic type were not available, a weighted average value for reference soil organic carbon stock was selected for the whole of the country ($SOC_{REF} = 0.8 \cdot 38 + 0.2 \cdot 88 = 48\ tonnes\ C\ ha^{-1}$, Table 3.3.3 of GPG LULUCF). Similarly, one weighted average land use factor, management factor and input factor was assumed for each crop type, selected from table 3.3.4 of GPG LULUCF. The stock change factors used are presented in **Table 7.10**.

Table 7.10 *Stock change factors used for different crop types*

Crop Type	F_{LU}	F_{MG}	F_I
Cereals for grain	0.80	1.00	0.92
Edible pulse	0.80	1.00	1.08
Fodder seeds	0.80	1.00	1.08
Industrial plants	0.80	1.00	0.92
Aromatic plants	0.80	1.04	0.92
Fodder plants	0.80	1.04	0.92
Melons, watermelons & potatoes	0.80	1.00	1.35
Vegetables & other garden crops	0.80	1.00	1.35
Vines (grapes & raisins)	0.80	1.00	0.92
Citrus trees	0.80	1.08	0.92
Fruit trees	0.80	1.04	0.92
Nut & dried fruit trees	0.80	1.11	0.92
Olive & other trees	0.80	1.04	0.92

Carbon stocks in mineral soils were estimated to increase over the period 1990 – 2007 with an average annual rate of $61\ kt\ C\ yr^{-1}$. However, this value represents annual change in carbon stocks in minerals soils not only in Cropland remaining Cropland, but also in Cropland converted to Grassland and Cropland converted to Forest Land. This is because the methodology used to represent land areas is following Approach 1 (GPG LULUCF, Chapter 2), i.e. gives areas of crop types at two points in time, that do not allow determining the initial crop type of the area abandoned or afforested, and thus allow to report separately carbon stock changes in Cropland remaining Cropland and Cropland converted to Grassland or Forest land. It was assumed that soil organic carbon in the cropland abandoned or afforested recovered to the reference carbon stock SOC_{REF} . This is the Tier 1 assumption for both Land converted to grassland (F_{LU} , F_{MG} , $F_I = 1$) and

Land converted to Forest land ($SOC_{Ext\ Forest} = SOC_{Int\ Forest} = SOC_{REF}$). The aggregate area of cropland abandoned and cropland afforested was calculated as the difference between the total area of cropland in the inventory year and 20 years ago.

Organic Soils

Unlikely the situation with mineral soils, where carbon fluxes were estimated from changes in soil carbon stocks followed changes in crop type/management, emissions from organic soils are 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 and equation 3.3.5 of GPG LULUCF.

$$\Delta C_{CCOrganic} = A_{Organic} \cdot EF$$

where, $\Delta C_{CCOrganic}$ represents CO₂ 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⁻¹yr⁻¹.

All cultivated organic soils are found under warm temperate climate, hence one climate type was considered when choosing the emission factor (EF = 10 tonnes C ha⁻¹yr⁻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 C stocks associated with Forest land and Grassland conversion to Cropland are addressed in this category. The carbon emissions and removals in land use conversion to cropland result from the removal of existing and replacement with different vegetation. 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.

$$\Delta C_{LC_{LB}} = A_{Conversion} \cdot (L_{Conversion} + \Delta C_{Growth})$$

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

where, $\Delta C_{LC_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to cropland, tonnes C yr⁻¹, $A_{Conversion}$ is the annual area of land converted to cropland from some initial use, ha yr⁻¹, $L_{Conversion}$ is the carbon stock change per area for that type of conversion when land is converted to cropland, tonnes C ha⁻¹, ΔC_{Growth} is the carbon stocks from one year of growth of cropland vegetation after conversion, tonnes C ha⁻¹, C_{After} is the carbon stocks in biomass immediately after conversion to cropland, tonnes C ha⁻¹, C_{Before} is the carbon stocks in biomass immediately before conversion to cropland, tonnes 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). As a result of conversion, it is assumed that the dominant vegetation is removed entirely, thus $C_{After} = 0$. Carbon stocks increment from biomass growth following conversion – in the cases where a perennial, tree crop is established – is estimated and reported under the Cropland remaining Cropland category.

Carbon stock changes in DOM in Forest lands converted to Cropland have not been estimated. However, these are assumed to be negligible, since the total area of Forest land that has been converted to cropland during the period 1990-2010 is only 13ha. DOM in grasslands is assumed to be zero and, thus, no carbon stock changes in DOM have been estimated. Carbon stock changes in soil in lands converted to cropland were estimated and reported under the category Cropland remaining Cropland. 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.

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 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 lands converted to Grassland are reported, as well as non-CO₂ emissions from wildfires (**Table 7.11**). Changes in soil carbon stock in Cropland converted to Grassland are estimated and reported in the Cropland remaining Cropland category.

Table 7.11 Emissions / removals of greenhouse gases (in kt) from Grassland for the period 1990 - 2010

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	0,04	0,27	0,06	0,45	0,50	2,45	0,02	0,10	0,04	0,33	0,02
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 (in kt CO₂ eq)	15,50	13,35	39,69	28,23	29,46	14,72	13,23	19,99	39,10	4,74	61,15

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO ₂	0,02	0,04	2,02	0,43	0,02	0,06	0,07	0,42	1,96	0,44
CH ₄	0,53	0,10	0,13	0,33	0,17	0,27	5,47	0,58	0,57	0,30
N ₂ O	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00
Total (in kt CO₂ eq)	12,32	2,34	5,11	8,08	3,95	6,30	126,50	13,74	15,21	7,47

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 (grasses and forbs) 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 is 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:

$$\Delta C_{GGLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{GGLB} is the annual change in carbon stocks in living biomass, tonnes C yr⁻¹, A is the area of intervention, ha yr⁻¹, C_{After} is the carbon stocks in living biomass immediately after intervention, tonnes C ha⁻¹, C_{Before} is the carbon stocks in living biomass immediately before intervention, tonnes 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 tonnes 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 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 equation 3.4.8 of GPG LULUCF, $F_{MG} = F_I = 1$ and $\Delta C_{CCMineral} = 0$, 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 are addressed in this category.

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. 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, tonnes 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, tonnes C ha⁻¹, ΔC_{Growth} is the carbon stocks from one year of growth of grassland vegetation after conversion, tonnes C ha⁻¹, C_{After} is the carbon stocks in biomass immediately after conversion to grassland, tonnes C ha⁻¹, C_{Before} is the carbon stocks in biomass immediately before conversion to grassland, tonnes 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 tonnes 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).

According to Tier 1 approach, soil C stocks in both forest land and grassland (unmanaged land) are assumed equal to the reference level (i.e. land use, management and input factors equal 1), and

hence C stock changes in soil is zero. Croplands that have been abandoned and taken over by grassland were also considered in this section. It was assumed that biomass stocks do not change after conversion, and hence carbon stock changes in living biomass were zero. Carbon stock changes in soil were estimated and reported under the category Cropland remaining Cropland. All relevant information and methods used are presented in Section 7.3.2. No croplands on organic soils have been abandoned. Non-CO₂ emissions from wildfires on Lands converted to Grassland are reported under the category Grassland remaining Grassland.

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 reported¹⁶. 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.

Carbon stock changes in lands converted to flooded lands are caused by decomposition of living biomass in these areas. Carbon stock changes in soils and DOM in lands converted to Wetlands have not been estimated since no methodological guidance is provided by the GPG LULUCF. 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:

$$\Delta C_{LWLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{LWLB} is the annual change in carbon stocks in living biomass in land converted to wetland, tonnes C yr⁻¹, A is the area of land converted annually to wetland from some initial use, ha yr⁻¹, C_{After} is the carbon stocks in living biomass immediately after conversion to wetland, tonnes C ha⁻¹, C_{Before} is the carbon stocks in living biomass immediately before conversion to wetland, tonnes 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).

¹⁶ Parties do not have to prepare estimates of emissions and removals from Wetlands remaining Wetlands, although they may do so if they wish.

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 ‘Other Land’. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type.

7.6 Settlements (CRF Source Category 5E)

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories. Parties have to estimate and report carbon stock changes in living biomass in Land converted to Settlements¹⁷.

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, tonnes 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, tonnes C ha⁻¹, C_{Before} is the carbon stocks in living biomass immediately before conversion to settlement, tonnes C ha⁻¹.

The default assumptions of 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.

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.

Three types of land use changes to settlements have been indentified:

- Forest land converted to Settlements
- Grassland converted to Settlements, and
- Other land converted to Settlements

¹⁷ Parties do not have to prepare estimates of emissions and removals from Settlements remaining Settlements, although they may do so if they wish.

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).

For the category other land, it is assumed that carbon stocks in living biomass are equal to zero, and hence changes in carbon stocks in living biomass in other land converted to settlements are zero.

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 GPG LULUCF, changes in carbon stocks and non- CO_2 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 calculated and reported, since the act of conversion releases the carbon previously held on these lands.

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:

$$\Delta C_{\text{LOLB}} = A \bullet (C_{\text{After}} - C_{\text{Before}})$$

where, ΔC_{LOLB} is the annual change in carbon stocks in living biomass in land converted to other land, tonnes 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, tonnes C ha^{-1} , C_{Before} is the carbon stocks in living biomass immediately before conversion to other land, tonnes 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. ($C_{\text{After}} = 0$).

Actual areas converted annually have been used for each unit of land converted to ‘Other Land’. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type.

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

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 2010 GHG emissions from *Waste* decreased by 11.5% compared to 1990 levels (**Figure 8.1**), while the average annual rate of decrease of emissions for the period 1990 – 2010 is estimated at 0.57%.

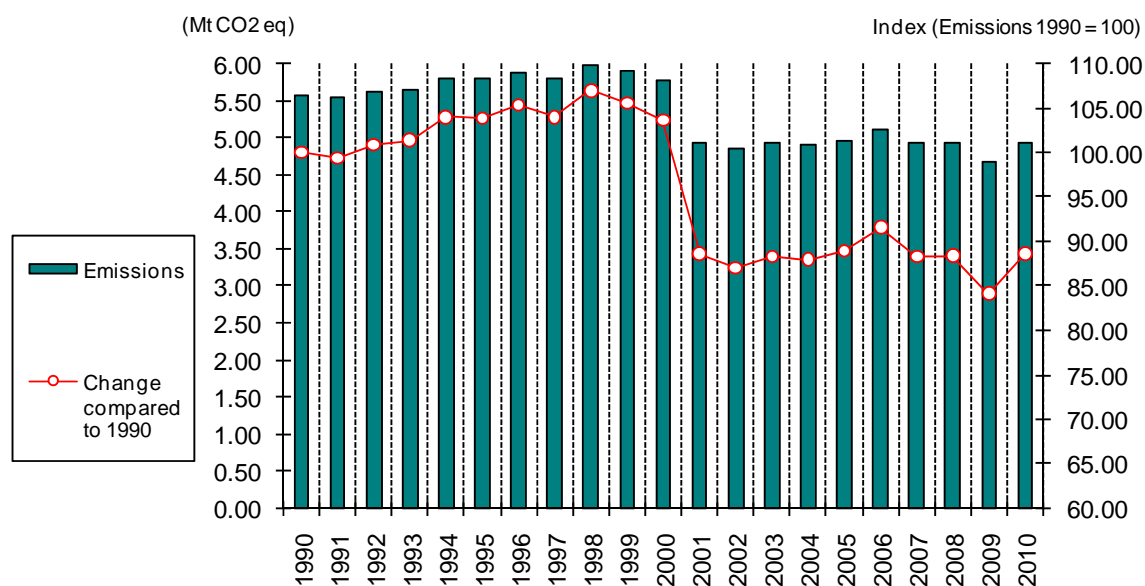


Figure 8.1 Total GHG emissions (in kt CO₂ eq) from Waste for the period 1990 – 2010

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 – 2010*

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	5242.8	5202.7	5281.3	5307.6	5449.1	5435.7	5521.3	5440.1	5603.5	5511.6	5398.4
N ₂ O	331.4	335.9	340.6	342.1	349.0	352.3	353.8	357.2	361.0	373.9	378.2
Total	5574.4	5538.9	5622.1	5650.0	5798.3	5788.3	5875.2	5797.5	5964.8	5885.7	5776.9
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CO ₂	0.22	0.48	0.85	1.05	1.93	2.41	3.13	3.68	3.60	3.19	
CH ₄	4561.2	4476.8	4538.3	4521.0	4573.3	4714.4	4525.6	4526.9	4286.9	4536.2	
N ₂ O	375.1	370.8	380.4	377.6	380.0	386.3	390.6	392.4	393.3	394.2	
Total	4936.5	4848.1	4919.5	4899.6	4955.3	5103.0	4919.4	4923.0	4683.8	4933.6	

Methane represents the major greenhouse gas from *Waste*, with a contribution which, however, decreased from 94.1% in 1990 to 92.0% in 2010. Overall, CH₄ emissions in 2010 decreased by 13.5% compared to 1990 levels, with an average annual rate of -0.67%.

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 40.0% in 1990 to 70.0% in 2010. On the contrary, GHG emissions from wastewater handling present a declining trend, with an average annual rate of -2.82% for the period 1990 – 2010. Emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2010; 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. In the present inventory the annual permanent population is calculated as the average of the population in the end of the current (examined) year and the previous one, contrary to the previous inventories in which the annual population used was the existed one at the end of each year.
- ⇒ 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.

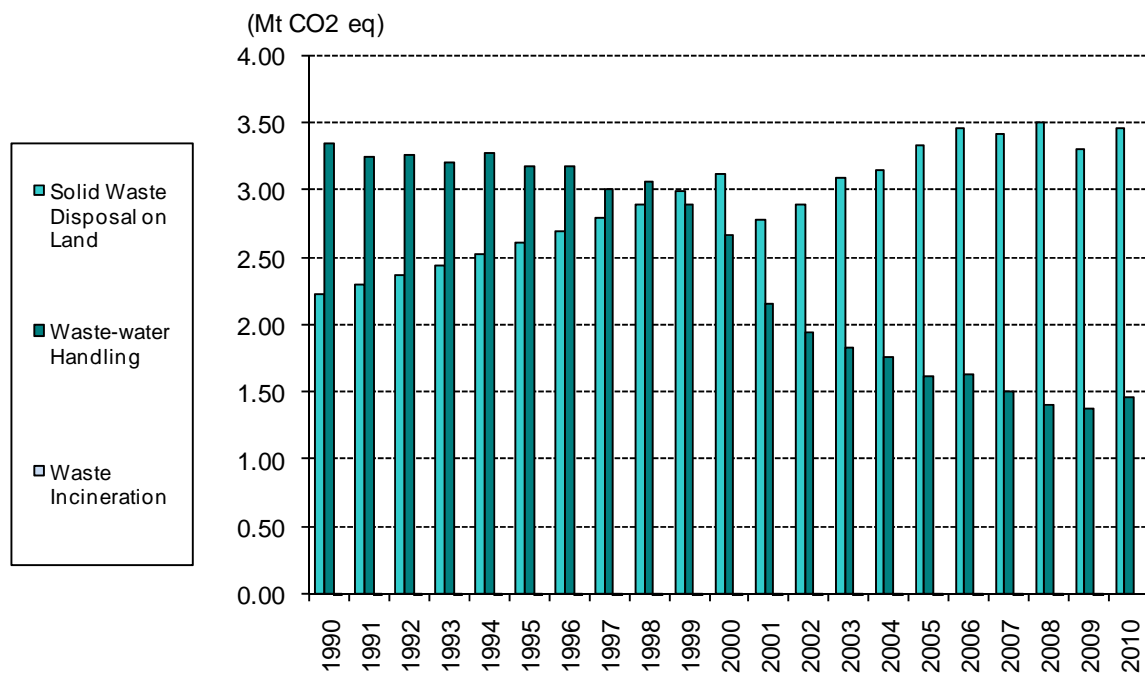


Figure 8.2 Greenhouse gases emissions (in kt CO₂ eq) from Waste per source category for the period 1990 – 2010

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.

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	CS	D	CS

T2: Tier 2 IPCC methodology

D: Default IPCC methodology / emission factor

CS: Country Specific

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 8.3 *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.

CH₄ emissions from industrial solid waste in managed and unmanaged SWDS were estimated and submitted for the first time during the 2011 centralized ERT review of EU inventory, while CH₄ emissions from construction and demolition waste in managed and unmanaged SWDS are being submitted for the first time in the current submission.

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	☒	☒
1. Hospital waste	☒	☒	☒
1. Other	☒	☒	☒

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. Emissions from the industrial solid waste and from construction and demolition solid waste disposed in managed and unmanaged SWDS are presented for the first time in the current submission. 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 2001-2010 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 2010 accounted for 70% of total GHG emissions from Waste and for 2.93% of total national emissions (without LULUCF). The average

annual rate of increase of emissions from solid waste disposal on land, for the period 1990 – 2010 is estimated at 2.8%. CH₄ emissions from managed and unmanaged solid waste disposal sites are presented in **Table 8.5**.

CH₄ emissions from managed SWDS in 2010 increased by 1801% compared to 1990 levels, while emissions from unmanaged SWDS decrease by 12.1%. This difference is due to the reduction of the number of the unmanaged SWDS in operation. Emissions from sewage sludge disposal in 2010 are 20 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	9.57	12.72	16.04	19.41	22.83	26.37	30.16	34.23	39.08
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	
Managed SWDS	22.49	27.39	35.36	38.04	46.70	52.67	51.85	58.09	51.80	63.09	
Unmanaged SWDS	103.5	103.6	104.0	103.5	102.8	102.0	100.2	98.1	93.8	89.7	
Sludge treatment	6.4	7.0	7.6	8.3	9.3	10.4	10.7	10.9	11.6	12.4	

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.

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 waste disposal sites which is planned to be eliminated until the end of 2011.

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 2001-2010 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 order to meet the recommendation of 2010 centralized ERT review for improvement of transparency in relation to Activity Data used for the estimations, the following are presented:

- Data concerning the period 1960-2000 were obtained from the report entitled “Quantification of objectives of directive 31/99 E.C. on landfill of wastes, 2001 (p. 195 of the National Inventory Report -Waste Sector)” which was composed by the General Directorate for the Environment, Environmental Planning Division, Solid waste management division of the Ministry of Environment, Energy and Climate Change. The data provided in this report were based on studies that were performed in various managed waste disposal sites of Greece. E.g. the respective study for the biggest managed disposal site of Greece located in Attica region was carried out by the National Technical University of Athens. The amount of waste disposed on managed disposal sites was estimated through sample weighting of the tracks that enter the disposal sites and it was correlated to the estimated population of the people served by these sites.
- The data concerning the period 2001-2008 were obtained by the report entitled “Report for the national strategy on the biodegradable waste management” which was composed by the same division of the MEECC. According to this report, the generation rate of solid waste quantities was considered to show an increase of 35 % for the period 2000 – 2020. This assumption was justified with data obtained from recent respective studies. Moreover, it has already been explained by the Solid waste management division of MEECC that the National Strategy for municipal wastes will be updated soon in the framework of the 2008/98/EC Dir.

In **Table 8.6** the estimated data on population served for the whole period 1960-2010 is presented.

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 8.6 *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	127.88	11433.00

On the basis of the above, the following MSW quantities for the years 1990 – 2010 were estimated (*Table 8.8*). For the period 2001-2010, confirmed data was 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 8.7 *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	1.244	2.100	1.254

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†			
Generated MSW	4.266	4.411	4.559	4.64	4.71	4.781	4.854	4.927	5.002	5.077	5.154	5.232			

†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.

During the 2011 centralized ERT review of Greek inventory, questions regarding the composition of municipal solid waste generated at national level were arisen concerning the distinguish of putrescibles waste between garden/park waste & other non-food putrescibles and food waste and the nature of the rest of the waste. In order to clarify these issues, Greece investigated the composition of municipal solid waste, searching for data in any scientific research that has been presented in Greek institutes, like universities etc. The result of this effort is the reconsideration of the composition of municipal solid waste generated as follows:

✎ The latest estimate at national level, MEECC (1998), is used as the basic information source. According to this estimate, municipal solid waste in 1997 in Greece consisted of Putrescibles in fraction 47%, Paper in 20%, Plastic 8.5%, Metals in 4.5%, Glass in 4.5 % and Rest in 15.5%.

✎ The share of wood and textiles is about 1% and 3.25%, respectively. These fractions were included in the “rest” fraction in the analysis, MEECC (1998), contrary to the consideration of previous submissions, where it was assumed that they are included in the putrescibles (fraction of 47%).

✎ The share of garden (yard) waste, park waste and other non-food organic putrescibles is about 1.5% (Panagiotakopoulos, 2002) and it also is included in the “rest” fraction of MEECC (1998) analysis.

According to these assumptions, municipal solid waste in 1997 in Greece consisted of food waste in fraction 47%, textiles in 3.25%, wood in 1%, garden (yard) waste, park waste and other non-food organic putrescibles in 1.5%, paper in 20%, plastic 8.5%, metals in 4.5%, glass in 4.5 % and rest in 9.75%. Rest fraction consisted of 3% soils and 6.75% other inorganic waste.

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 - 2010*

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
Soils	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Rest Other In.	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	
Food	45.80	45.50	45.20	44.90	44.60	44.30	44.00	43.70	43.40	43.10	
Non Food	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	
Wood	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	
Plastics	9.30	9.50	9.70	9.90	10.10	10.30	10.50	10.70	10.90	11.10	
Metals	4.10	4.00	3.90	3.80	3.70	3.60	3.50	3.40	3.30	3.20	
Glass	4.42	4.40	4.38	4.36	4.34	4.32	4.30	4.28	4.26	4.24	
Soils	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Rest Other In.	6.83	6.85	6.87	6.89	6.91	6.93	6.95	6.97	6.99	7.01	

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. For 2010, the percentage of MSW recycled is estimated at 19 %, significantly higher than this of 2000, which was about 8%, due to the recycle projects that are promoted in Athens. It was assumed that after the subtraction of recycled materials, the remaining quantities of municipal solid waste end up to various disposal sites (managed or unmanaged).

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 – 2010*

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	1.63
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
Soils	3.31	3.31	3.30	3.28	3.27	3.26	3.25	3.28	3.27	3.26	3.25
Rest Other In.	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	
Food	50.23	49.87	49.19	49.90	50.05	48.93	52.83	50.93	52.95	52.40	
Non Food	1.65	1.64	1.63	1.67	1.70	1.72	1.88	1.82	1.85	1.85	
Textiles	3.56	3.56	3.54	3.62	3.67	3.73	4.06	3.95	4.01	4.00	
Wood	0.86	0.86	0.86	0.88	0.90	0.91	1.00	0.98	1.00	1.00	
Paper	14.88	15.17	16.00	15.36	15.33	16.16	5.71	9.04	6.58	7.12	
Plastics	10.01	10.21	10.35	10.67	10.96	11.30	13.13	13.00	13.46	13.66	
Metals	4.25	4.12	3.97	3.77	3.57	3.45	4.36	4.12	4.06	3.92	
Glass	3.79	3.76	3.73	3.14	2.62	2.40	4.58	4.07	3.75	3.74	
Soils	3.29	3.29	3.26	3.34	3.39	3.44	3.75	3.64	3.70	3.69	
Rest Other In.	7.49	7.51	7.48	7.66	7.81	7.95	8.69	8.47	8.63	8.63	

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	398.64	952.81	117.68	71.63	28.65
2009	4147.06	484.84	26.60	3.11	109.21	43.69
2010	4224.49	545.78	27.10	3.50	114.08	45.63

According to the most recent data by the Ministry of Environment, Energy and Climate Change (MEECC) (10/2004), out of the various existing disposal sites, 71 fulfil the criteria set by the IPCC guidelines so as to be considered as managed. For each one 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**).

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, Thessalonica and Larissa). For two of these sites, Athens and Thessalonica, 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. Thus, the collection of data on the amount of biogas flared has not been yet possible for these sites and the estimation of biogas recovered was based on the assumption that for technical reasons, 60% of biogas released is finally recovered and flared.

For the SWDS of Athens and Thessalonica, in which almost 65% of total waste going to managed sites is disposed, data were collected by the National Energy Balance. In previous submissions, detailed measurements were used for SWDS of Athens for the years that they were provided. However, after the recommendations of the previous ERT review for further investigation regarding the amount of CH₄ recovered, official data from the National Energy Balance were used.

For the rest of the sites, where biogas is recovered without energy use, namely Patra and Larissa, the assumption that 60% of the biogas being released is finally recovered and flared is used. In **Table 8.12**, quantities of waste disposed in the 2 sites for which the CH₄ recovery is based on assumptions and the amount of methane obtained by the energy balance, are presented.

Table 8.12 *CH₄ recovery from biogas flaring in managed SWDS*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Waste landfilled in the SWDS of Patra. and Larissa (kt)	64.0	66.1	68.7	71.4	77.6	81.5	85.2	90.4	99.3	110.6	119.2
CH ₄ recovery in Patra and Larissa (kt) (estimated figures)	0.11	0.22	0.33	0.44	0.55	0.67	0.78	0.91	1.04	1.18	1.34
CH ₄ recovery in Athens and Thessalonica (kt) (National Energy Balance)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Waste landfilled in the SWDS of Patra. and Larissa (kt)	128.9	131.2	133.7	149.2	155.8	158.6	154.7	178.0	228.7	233.0	
CH ₄ recovery in Patra and Larissa (kt) (estimated figures)	1.50	1.66	1.82	1.99	2.18	2.35	2.47	2.63	2.85	3.07	
CH ₄ recovery in Athens and Thessalonica (kt) (National Energy Balance)	23.8	23.6	20.0	23.1	19.6	19.2	24.6	23.5	38.4	33.6	

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 2010. Thus, emissions from this source were not estimated in the previous inventory's submission, considering that industrial waste were included elsewhere, i.e. in MSW along with the waste coming from the households as well as from the commercial sector. This assumption was based on the facts that all solid waste in Greece are being disposed at the same managed and unmanaged SWDS and that the estimation of total waste disposed in solid waste disposal sites is performed at the sites through sample weighting of the tracks entering the disposal sites.

However, Greece, aiming to improve the completeness of its inventory, as well as to address the ERT recommendations of previous submissions, estimates the emissions from the industrial sector 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. GDP evolution of Greece for the period 1960-2009 was obtained by the work ‘The Greek Economy In The 20th Century’ of Prof. John Milios of National Technical University of Athens, while GPV of livestock was obtained from FAO.

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.

The waste types of “mixed waste residues” and “sorting waste residues” are considered to be of the same nature as the products of the manufacturing process. For example, mixed and sorting waste residues from paper and paper products manufacturing plants are considered as paper waste.

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 2010. Thus, emissions from this source were not estimated in the previous inventory's submission, considering that industrial waste were included elsewhere, i.e. in MSW along with the waste coming from the households as well as from the commercial sector.

However, in order to improve the completeness of the Greek inventory, emissions from this sector were estimated based on data provided by ELSTAT.

Figures for construction and demolition solid waste are provided by ELSTAT for the years 2006 and 2008, **Table 8.14**, considering that they consist of wood, plastic and glass. Thus, similar with industrial solid waste, the historical data necessary for the rest of the years were estimated by using relative drivers i.e. the Gross Value Added of construction sector. It is estimated that the GVA of the construction sector increased with an average annual rate of 6% until 2000, for the period 2001 – 2007 it increased with rate of 8% while for the final years a significant decrease is observed due to the economical crisis.

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

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 0.4 was used. Since 2002 due to a number of issues raised concerning the transfer and disposal of sludge in the managed waste disposal site of Athens most of the sewage sludge remains in the wastewater treatment facility of Athens stored under aerobic conditions with negligible methane production. Therefore a lower than the default value was applied as DOC_F for sludge.
- ↳ Fraction of methane in landfill gas (F): 50% (default value) for solid waste, 0.6 for sewage sludge.
- ↳ Oxidation factor (OX): 0.1 for managed SWDS, 0.0 for unmanaged SWDS (default values).

8.2.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 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 CH_4 emissions from unmanaged SWDS and managed SWDS for Industrial waste as % of total emissions are estimated by 0.02% and 0.01%, respectively. The combined uncertainty of CH_4 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 CH_4 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 CH_4 emissions from municipal sludge disposal on land as % of total emissions is estimated by 0.1%. The uncertainty associated with activity data is 20% according to Good Practice Guidance for poor quality data while the uncertainty associated with emission factors is 40 %.

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 and CH₄ biogas flared have been recalculated for the period 1990-2009 due to the recommendations of 2011 centralized ERT. Moreover, additional emissions were estimated by the subsector of Construction and demolition solid waste. 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 8.15**.

Table 8.15 *Recalculations of CH₄ emissions from solid waste disposal on land (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	17.27	17.39	19.09	19.61	20.09	20.68	21.25	21.79	23.51	30.59	31.21
Impact on total emissions (excl LULUCF)	0.312	0.325	0.357	0.381	0.391	0.407	0.419	0.424	0.446	0.569	0.583
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
Difference	13.03	16.95	20.52	23.05	31.35	31.20	33.42	38.49	30.55		
Impact on total emissions (excl LULUCF)	0.250	0.329	0.399	0.446	0.587	0.624	0.634	0.743	0.620		

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 2010 accounted for 0.90% of total GHG emissions and for 21.65% 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 2010 account for 0.33% of total greenhouse gases emissions and 7.97% 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 8.16** CH₄ and N₂O emissions from wastewater handling for the period 1990 – 2010 are presented.

Table 8.16 CH₄ and N₂O emissions (in kt) from wastewater handling

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Domestic and commercial wastewater	CH ₄	102.98	101.47	99.33	95.26	94.09	92.16	90.06	86.44	82.77	78.18	60.53
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	
Domestic and commercial wastewater	CH ₄	34.71	29.49	24.13	18.39	15.00	12.69	11.13	10.89	10.40	10.28	
Human sewage	N ₂ O	1.19	1.17	1.21	1.20	1.20	1.22	1.24	1.24	1.25	1.25	
Industrial wastewater	CH ₄	50.14	45.68	45.03	47.11	43.99	46.74	41.62	37.61	36.54	40.58	
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	

CH₄ emissions from domestic wastewater handling and industrial wastewater handling in 2010 decreased by 90% and 0.27%, 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 90.9% in 2010. N₂O emissions from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) increased by 19.0% compared to 1990 levels. N₂O emissions from industrial wastewater handling increased by 5.7% 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.

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 of the final ERT review 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

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 0.05 kg BOD/person/day (suggested value for Europe).

↳ **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 8.15** the degradable organic waste (as kt BOD) for the period 1990 – 2010, is presented.

The calculation of BOD from sludge removed and disposed on land (**Table 8.17**) 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 8.17 *BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2010*

Year	Wastewater	Sludge	Total
1990	180.66	6.51	187.18
1991	182.19	6.51	188.70
1992	184.58	6.51	191.09
1993	186.34	6.51	192.85
1994	188.15	6.51	194.66
1995	189.04	6.98	196.02
1996	190.24	6.98	197.22
1997	190.41	8.24	198.66
1998	191.83	8.02	199.85
1999	192.75	8.13	200.88
2000	192.60	8.96	201.57
2001	192.85	9.16	202.01
2002	192.05	10.49	202.54
2003	192.34	10.78	203.12
2004	192.45	11.27	203.72
2005	188.90	15.78	204.68
2006	188.59	17.02	205.61
2007	188.57	18.10	206.67
2008	189.08	18.39	207.48
2009	187.77	20.47	208.24
2010	187.64	21.02	208.65

Biochemical oxygen demand (BOD) for sludge is finally subtracted from total BOD and methane emissions are calculated based on the fraction of BOD that degrades anaerobically. The relevant data are included in the reports of the Ministry of Environment, Energy and Climate Change (MEECC) on the implementation of EU Directive 91/71 regarding the collection, treatment and disposal of municipal wastewater.

N₂O emissions from domestic wastewater handling

N₂O emissions from domestic wastewater handling are estimated as the indirect nitrous oxide emissions from human consumption of food and their subsequent treatment through wastewater handling systems are estimated by the following equation:

$$\text{N}_2\text{O emissions} = \text{Protein} \times P \times \text{Frac}_{\text{NPR}} \times \text{EF (N}_2\text{O-N/N)}$$

Data on protein consumption (*Protein*) are provided by FAO. The population (*P*) used, is the one presented in Table 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 (N₂O-N/N)*] are those suggested by the IPCC Guidelines.

In **Table 8.18** the consumption of protein (kg/person/year) for the period 1990 – 2010, is presented.

Table 8.18 *Annual protein consumption (in kg/person) for the period 1990 – 2010*

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	
Protein (kg/capita)	42.65	42.10	43.07	42.60	42.70	43.18	43.47	43.47	43.47	43.47	

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 – 2010.
- ↳ Calculation of wastewater generated, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice Guidance in case where country specific data were not collected per industrial sector (m³ of wastewater/t product).
- ↳ Calculation of degradable organic fraction of waste, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice

Guidance in case where country specific data were not collected (kg COD/m³ wastewater) for each sector / sub-sector.

↳ The distribution between aerobic and anaerobic treatment of industrial wastewater for each industrial sector was estimated on the basis of data derived from a project financed by the Ministry of Environment, Energy and Climate Change (MEECC) (2001b). The maximum methane production potential factors B_0 and the methane conversion factors for aerobic and anaerobic treatment, which were used for the final estimation of methane emissions, are similar to those used for domestic wastewater handling.

It must be mentioned that for the first time in the current submission, country specific data were collected, thus additional industrial sectors with 100 % aerobic treatment of their wastewater were included in the estimation. In the previous submission, in case where 100% of sector was served by aerobic treatment, it was not taken into account, considering zero emissions. The additional sectors included in the wastewater were additional subsectors of food and beverage, and the sectors of paper and pulp, organic chemicals, soap and detergents, plastic and resins, paints and Petroleum Refinery in the already existing sectors of food and beverage, and in the sugar and textiles sectors.

In **Table 8.19** the degradable organic waste generated by each sector (as COD) for the period 1990 – 2010, is presented.

Table 8.19 *Total industrial wastewater in COD (in kt) produced from each industrial sector for the period 1990 – 2010*

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	
Food and beverage	265.54	237.05	231.90	245.87	224.20	236.17	205.24	173.86	178.85	205.12	
Paper and pulp	4.46	4.72	4.94	5.15	5.62	5.54	5.21	5.11	4.93	4.50	
Organic chemicals	0.35	0.35	0.35	0.35	0.40	1.59	1.61	13.38	9.47	11.26	
Other	33.23	33.31	35.29	34.52	36.28	38.65	40.98	37.59	30.49	27.84	

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 – 2010 is presented in **Table 8.20**.

Table 8.20 *TOW (in COD kt) removed as sludge from industrial wastewater handling for the period 1990 – 2010*

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	
COD (kt)	172.94	157.04	156.18	163.40	153.41	161.73	145.87	133.31	129.46	144.32	

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 – 2010 is presented in **Table 8.21**.

Table 8.21 *Waste water production from the industrial sector (1000000m³) for the period 1990 – 2010*

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	
Waste water	89.79	83.67	85.72	87.63	84.59	89.62	86.63	81.79	73.98	76.53	

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 0.03%. 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

CH₄ and N₂O emissions from commercial wastewater handling and CH₄ emissions from sludge generated industrial wastewater have been recalculated because of the use of country specific factors for each industrial sector for the period 1990-2009. Moreover, additional industrial sectors with 100 % aerobic treatment of their wastewater were included in the estimation.

N₂O emissions from domestic wastewater have been recalculated because of the availability of updated values for the annual protein consumption (in kg/person) in Greece.

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 8.22*.

Table 8.22 *Recalculations of CH₄ and N₂O emissions from domestic and commercial wastewater handling (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH ₄											
Difference	6.41	5.55	5.72	4.98	5.24	4.35	4.40	5.66	4.65	2.74	3.08
Impact on total emissions (excl LULUCF)	0.173	0.146	0.149	0.129	0.135	0.107	0.106	0.120	0.098	0.054	0.054
N ₂ O											
Difference	0.931	0.462	-0.264	0.413	-1.567	-1.413	-0.743	-1.802	-1.078	0.152	1.785
Impact on total emissions (excl LULUCF)	0.003	0.001	-0.001	0.001	-0.005	-0.005	-0.002	-0.006	-0.003	0.000	0.005
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
CH ₄											
Difference	2.80	3.67	10.18	5.78	9.01	9.14	10.15	18.08	17.48		
Impact on total emissions (excl LULUCF)	0.038	0.044	0.102	0.057	0.075	0.079	0.076	0.119	0.118		
N ₂ O											
Difference	1.603	0.414	2.765	1.667	0.742	1.862	2.549	2.595	2.397		
Impact on total emissions (excl LULUCF)	0.005	0.001	0.008	0.005	0.002	0.005	0.007	0.008	0.007		

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, for the first time in the current submission, emissions from the incineration of biogenic agricultural residues produced in slaughterhouses and from the incineration of small amounts of industrial chemical waste are estimated. These estimations were performed in order to meet the recommendations of previous ERT review referred to data provided by the Hellenic Statistical Authority as waste incinerated without energy recovery in Greece. These data were obtained by individual researches of ELSTAT and they were not considered as official data in the previous submissions. However, after the ERT recommendations, data were collected and emissions were accounted, taking into consideration the additional information provided by the experts from ELSTAT concerning the nature of these wastes.

Finally, concerning the ‘other waste’ listed in ELSTAT publications as waste incinerated with energy recovery, in order to meet the recommendations of 2011 ERT review for improvement of information provided, it must be mentioned that emissions from these activities are reported in the Energy sector. More specifically, emissions are reported in the source categories of manufacturing industries and construction and other sectors (i.e. commercial, residential and agriculture). Other waste constitutes mainly from agricultural residues. Therefore, they are accounted in the CRF Tables 1A.(a)s2 and 1A.(a)s4 under biomass. However, for the estimation of these emissions, activity data in TJ from the energy balance of Greece was used.

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 country specific emission factors for all categories.

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 and 2008, 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:

$$\text{CO}_2 \text{ emissions} = \text{CW} \times \text{CCW} \times \text{FCF} \times \text{EF} \times 44/12$$

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:

$$CH_4 \text{ emissions} = CW \times EF_{CH_4} \text{ and}$$

$$N_2O \text{ emissions} = CW \times EF_{N_2O}$$

while the emissions factors' values were 0.06 kg CH_4 / tn waste and 0.1 kg N_2O / tn waste for the CH_4 and for the N_2O , respectively, for all the waste incinerated.

In **Table 8.23** the amount of waste incinerated and emissions released for the period 1990 – 2010 are presented.

8.4.3 Uncertainties and time-series consistency

The combined uncertainty of CO_2 emissions of waste incineration sector as % of total emissions is estimated by 0.003%. The combined uncertainty of CH_4 emissions of waste incineration sector as % of total emissions is estimated by 0.000004%. The combined uncertainty of N_2O emissions of waste incineration sector as % of total emissions is estimated by 0.001%.

The uncertainty associated with activity data is 5% while the uncertainty associated with emission factors for all gases is 100% according to Good Practice Guidance.

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 8.23 *Waste amounts (in tn) and emissions (in tn) for the period 1990 – 2010*

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 (Agricultural 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 (Chemical 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	
Clinical waste	180	492	939	1170	2231	2700	3666	4323	4222	3734	
CO ₂	150	411	785	978	1865	2257	3065	3614	3529	3122	
CH ₄	0.011	0.030	0.056	0.070	0.134	0.162	0.220	0.259	0.253	0.224	
N ₂ O	0.018	0.049	0.094	0.117	0.223	0.270	0.367	0.432	0.422	0.373	
Biogenic (Agricultural residues)	3935	3935	3935	3935	3935	2943	2943	24599	24599	24599	
CH ₄	0.236	0.236	0.236	0.236	0.236	0.177	0.177	1.476	1.476	1.476	
N ₂ O	0.394	0.394	0.394	0.394	0.394	0.294	0.294	2.460	2.460	2.460	
Other (Chemical waste)	25	25	25	25	25	54	25	25	25	25	
CO ₂	70	70	70	70	70	150	70	70	70	70	
CH ₄	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	
N ₂ O	0.003	0.003	0.003	0.003	0.003	0.005	0.003	0.003	0.003	0.003	

8.4.5 Recalculations

CO₂, CH₄ and N₂O emissions from waste incineration sector have been recalculated because of the inclusion of emissions from additional subsectors, these from the incineration of biogenic

agricultural residues produced in slaughterhouses and from the incineration of small amounts of industrial chemical waste.

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 8.24*.

Table 8.24 *Recalculations of CO₂, CH₄ and N₂O emissions waste incineration (%)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂											
Difference	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30
Impact on total emissions (excl LULUCF)	0.000066	0.000067	0.000066	0.000066	0.000065	0.000063	0.000062	0.000059	0.000056	0.000056	0.000055
CH ₄											
Difference	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Impact on total emissions (excl LULUCF)	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000004	0.000004	0.000004	0.000004	0.000004
N ₂ O											
Difference	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Impact on total emissions (excl LULUCF)	0.000117	0.000117	0.000116	0.000117	0.000114	0.000112	0.000109	0.000104	0.000099	0.000099	0.000097
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
CO ₂											
Difference	46.30	16.94	8.87	7.12	3.73	6.67	2.27	1.93	1.97		
Impact on total emissions (excl LULUCF)	0.000054	0.000055	0.000053	0.000053	0.000051	0.000114	0.000052	0.000053	0.000056		
CH ₄											
Difference	2200	805	422	338	177	111	81	570	583		
Impact on total emissions (excl LULUCF)	0.000004	0.000004	0.000004	0.000004	0.000004	0.000003	0.000003	0.000024	0.000025		
N ₂ O											
Difference	2200	805	422	338	177	111	81	570	583		
Impact on total emissions (excl LULUCF)	0.000096	0.000096	0.000093	0.000093	0.000090	0.000070	0.000068	0.001	0.001		

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 (mainly the recent centralized review held from 29 August to 3 September 2011).

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.1.A	Public Electricity and Heat Production \ Gaseous Fuels	CO ₂ / CH ₄ / N ₂ O	AD Updated AD
1.AA.1.B	Petroleum Refining \ Gaseous fuels	CO ₂	A Emissions from H ₂ production were reallocated to IP sector.
1.AA.3.B	Road Transportation \ Gaseous Fuels \ Natural Gas	CO ₂	EF CS EF was used.
1.AA.3.B	Road Transportation \ Liquid fuels \ Gasoline and Diesel	CH ₄ / N ₂ O	EF A recalculation of the whole timeseries was carried out with new updated emission factors
1.AA.3.E	Other Transportation (please specify) \ Pipeline transport \ Gaseous Fuels	CO ₂ / CH ₄ / N ₂ O	AD updated AD
1.B.2.B.3	Fugitive Emissions from Fuels \ Oil and Natural Gas \ Transmission	CO ₂ / CH ₄	AD Updated AD (length of transmission system)
1.B.2.B.4	Fugitive Emissions from Fuels \ Oil and Natural Gas \ Distribution	CH ₄	AD Updated AD (length of transmission system)
1.C1.B	International Bunkers \ Marine \ Gas/Diesel Oil	CH ₄ / N ₂ O	EF CH ₄ and N ₂ O emissions from liquid fuels marine bunkers were performed, which are based on EFs from the Revised 1996 IPCC Guidelines.
1.C1.B	International Bunkers \ Marine \ Residual Fuel Oil	CH ₄ / N ₂ O	EF CH ₄ and N ₂ O emissions from liquid fuels marine bunkers were performed, which are based on EFs from the Revised 1996 IPCC Guidelines.
1.C1.B	International Bunkers \ Marine \ Lubricants	CH ₄ / N ₂ O	EF CH ₄ and N ₂ O EFs from tables 1.7 and 1.8 of the IPCC Reference Manual (under the oil column) for lubricant use are applied
2.C.3	Aluminium Production	CO ₂	M Country specific methodology.
2.C.3	Aluminium Production	PFCs / CF ₄ / C ₂ F ₆	O Error in working files
2.F	Consumption of Halocarbons and SF ₆	HFCs / HFC-32 / HFC-125 / HFC-134a	O Emissions estimated for the first time, Updated data
2.F	Consumption of Halocarbons and SF ₆	SF ₆	O Updated data from PPC, Distribution department
2.IIA.F.1.1	Domestic Refrigeration	HFC-134a	O Emissions from disposal included for the first time (lifetime 15 years), update of penetration percentages
2.IIA.F.1.2	Commercial Refrigeration	HFCs-PFCs	AD Updated data regarding new blends, equipment data
2.IIA.F.1.2	Commercial Refrigeration	HFCs-PFCs	EF Use of EFs in the IPCC default range.
2.IIA.F.1.3	Transport Refrigeration	HFCs	O Emissions from disposal estimated for the first time (equipment lifetime 8 years)
2.IIA.F.1.3	Transport Refrigeration	HFCs	AD Updated data regarding the blends used.
2.IIA.F.1.5	Stationary Air-Conditioning	HFCs	AD Updated data regarding the blends used.
2.IIA.F.1.5	Stationary Air-Conditioning	HFCs	EF Use of EFs in the IPCC default range.
2.IIA.F.1.6	Mobile Air-Conditioning	HFC-134a	O Updated data provided by Association of Motor Vehicle Importers Representatives.
2.IIA.F.1.6	Mobile Air-Conditioning	HFC-134a	EF Use of updated default value (GPG).

2.IIA.F.4.2	Other \ HFC-134a	HFC-134a	M	Use of average actual charge per piece
2.F.8	Electrical Equipment \ SF6	SF6	O	Updated data from PPC, Distribution department,
4.A	Enteric Fermentation	CH ₄	AD	Updated Activity Data
4.B	Manure Management	CH ₄ / N ₂ O	AD	Updated Activity Data
4.D	Agricultural Soils	N ₂ O	AD	Updated Activity Data
4.F	Field Burning of Agricultural Residues	CH ₄ / N ₂ O	AD	Updated Activity Data
5.A.1	Forest land remaining Forest land	CO ₂	AD	Inclusion of the more recent data on biomass stocks from latest Forest Management Plans recalculates previous values, according to the stock change method
5.A.1	Forest land remaining Forest land	CH ₄ / N ₂ O	AD	Updated activity data on areas burnt by wildfires
5.B.1	Cropland remaining Cropland	CO ₂	AD	Updated activity data (cultivated areas)
5.B.2	Land converted to Cropland	CO ₂	AD NS	Updated activity data (fulfillment of the Land Use Change database)
5.C.1	Grassland remaining Grassland	CO ₂	AD NS	Updated activity data
5.C.2	Land converted to Grassland	CO ₂	AD NS	Updated activity data (fulfillment of the Land Use Change database)
5.D.2	Land converted to Wetlands	CO ₂	AD NS	Updated activity data (fulfillment of the Land Use Change database)
5.E.2	Land converted to Settlements	CO ₂	AD NS	Updated activity data (fulfillment of the Land Use Change database)
5.F.2	Land converted to Other Land	CO ₂	AD NS	Updated activity data (fulfillment of the Land Use Change database)
6.A.1	Managed Waste Disposal on Land	CH ₄	AD	Updated Activity Data
6.A.1	Managed Waste Disposal on Land	Recovery/CH ₄	AD	Updated Activity Data
6.A.3	Construction and Demolition Waste	CH ₄	NC	Emissions estimated for the first time
6.B.1	Industrial Wastewater \ Wastewater	CH ₄ / N ₂ O	M, AD	Updated Activity Data, Use of country specific factors
6.B.1	Industrial Wastewater \ Sludge	CH ₄	M, AD	Updated Activity Data
6.B.2.2	Human sewage	N ₂ O	AD	Updated Activity Data
6.C	Waste Incineration	CO ₂ / CH ₄ / N ₂ O	NC	Emissions estimated for the first time

E: Correction of errors. M: Change or refinement of methodology. NS: new sources. A: allocation to different sectors, AD: Update of Activity Data

9.1.2 KP-LULUCF inventory

Table 9.2 *Overview of recalculations on preparation of KP-LULUCF inventory*

IPCC source / sink categories		Gas	Explanation	
KP.A.2	Deforestation	CO ₂	AD	Updated activity data (fulfillment of the Land Use Change database)
			AD	Inclusion of the more recent data on biomass stocks from latest Forest Management Plans recalculates previous values, according to the stock change method
KP.B.1	Forest Management	CO ₂		Correction of errors in 2008 while filling in the required information in the CRF tables

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								-83.17	-173.51	-60.85	
Fuel Combustion Activities								-83.17	-173.51	-60.85	
Energy Industries								-83.17	-173.51	-60.85	
Man. Ind. and Con.											
Transport											
Other Sectors											
Fug. Emis. from Fuels											
Oil and Natural Gas											
Industrial processes	-6.57	-6.69	-6.72	-6.48	-6.06	-5.74	-5.74	77.35	167.10	53.83	-7.14
Mineral Products											
Chemical Industry								83.17	173.51	60.85	
Metal Production	-6.57	-6.69	-6.72	-6.48	-6.06	-5.74	-5.74	-5.82	-6.41	-7.02	-7.14
Land Use, Land-Use Change and Forestry	-47.40	-50.83	-50.14	-56.59	-57.15	-55.59	-55.76	119.22	121.32	116.93	-0.98
Forest Land	-52.07	-52.07	-52.07	-59.18	-59.18	-59.18	-59.18	116.05	116.05	124.75	100.04
Cropland		0.01	0.03	0.03	0.02	0.08	0.03			0.10	-99.30
Grassland	0.03	0.05	0.06	0.45	0.01	-0.55	0.02	0.02	0.04	0.01	0.02
Wetlands			0.00		0.02		0.19	0.46	1.94		2.10
Settlements	0.63	0.39	0.40	0.15	0.50	0.35	0.77	0.64	0.26	0.42	0.19
Other Land	4.01	0.79	1.43	1.97	1.47	3.71	2.41	2.05	3.03	-8.36	-4.04
Waste	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Waste Incineration	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
TOTAL	-53.90	-57.45	-56.79	-63.00	-63.14	-61.27	-61.43	113.47	114.98	109.98	-8.04

Table 9.3b *Recalculation of CO₂ emissions (differences compared to previous submission, in kt)*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Energy		-10.04	-14.52	-15.36	-33.98	-21.72	-19.21	490.44	-127.17
Fuel Combustion Activities		-10.04	-14.52	-15.36	-33.98	-21.72	-19.21	490.44	-127.17
Energy Industries		-9.75	-14.21	-15.06	-33.62	-21.34	-18.78	400.14	-139.23
Man. Ind. and Con.								90.65	
Transport		-0.29	-0.32	-0.31	-0.36	-0.38	-0.43	-0.35	8.60
Other Sectors									3.45
Fug. Emis. from Fuels									0.00
Oil and Natural Gas									0.00
Industrial processes	-7.11	2.56	7.21	7.74	57.57	19.74	11.17	103.87	263.38
Mineral Products					31.12	6.45	0.54		
Chemical Industry		9.75	14.21	15.06	33.62	21.34	18.78	107.69	265.65
Metal Production	-7.11	-7.19	-6.99	-7.31	-7.17	-8.05	-8.16	-3.82	-2.27
Land Use, Land-Use Change and Forestry	332.70	142.59	140.89	114.38	159.84	190.80	725.51	348.89	206.61
Forest Land	100.04	100.04	100.04	100.04	100.04	100.04	100.04	100.04	100.04
Cropland	246.45	37.47	37.48	-15.10	59.56	86.38	624.89	238.38	95.16
Grassland	0.02	0.02	-0.01	0.06	0.02	0.01	0.01	0.37	1.96
Wetlands	0.08	0.02	0.10	22.92	0.09	0.61	0.00	0.00	
Settlements	0.70	0.67	1.94	2.54	-0.30	1.10	-0.85	2.61	2.81
Other Land	-14.59	4.37	1.33	3.91	0.43	2.65	1.41	7.49	6.63
Waste	0.07	0.07	0.07	0.07	0.07	0.15	0.07	0.07	0.07
Waste Incineration	0.07	0.07	0.07	0.07	0.07	0.15	0.07	0.07	0.07
TOTAL	325.66	135.17	133.65	106.83	183.50	188.97	717.54	943.27	342.89

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	10.80	11.36	11.60	12.01	12.52	12.91	13.07	13.34	13.85	14.61	15.17
Fuel Combustion Activities	10.80	11.36	11.60	12.01	12.52	12.91	13.07	13.34	13.85	14.61	15.17
Energy Industries											
Man. Ind. and Con.											
Transport	10.80	11.36	11.60	12.01	12.52	12.91	13.07	13.34	13.85	14.61	15.17
Other Sectors											
Other											
Fug. Emis. from Fuels											
Solid fuel											
Oil and Natural Gas											
Agriculture											
Enteric Fermentation											
Manure Management											
Field Burning of Agricultural Residues											
Land Use, Land-Use Change and Forestry	1.94	0.74	2.13	2.22	1.94	1.28	0.53	1.55	4.85	0.31	5.98
Forest Land	1.94	0.74	2.13	2.22	1.94	1.28	0.53	1.55	4.85	0.31	5.98
Grassland											
Waste	509.55	492.83	536.52	536.00	567.50	564.51	591.76	641.61	671.21	768.93	809.45
Solid Waste Disposal on Land	327.84	339.97	378.69	399.92	421.60	446.70	472.72	499.80	550.81	701.79	741.25
Waste-water Handling	181.71	152.86	157.82	136.07	145.89	117.81	119.04	141.80	120.39	67.14	68.19
Waste Incineration	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL	522.29	504.93	550.25	550.23	581.96	578.70	605.36	656.49	689.91	783.85	830.60

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
Energy	15.76	16.19	16.35	16.37	16.31	15.83	15.37	15.44	18.52
Fuel Combustion Activities	15.76	16.19	16.35	16.37	16.31	15.83	15.37	15.44	15.07
Energy Industries								0.10	0.05
Man. Ind. and Con.								0.00	
Transport	15.76	16.19	16.35	16.37	16.31	15.83	15.37	15.34	14.97
Other Sectors									0.05
Other									
Fug. Emis. from Fuels									3.45
Solid fuel									
Oil and Natural Gas									3.45
Agriculture							1.99	-20.22	-15.80
Enteric Fermentation							5.55	-12.21	-4.82
Manure Management							-3.56	-8.01	-10.99
Field Burning of Agricultural Residues									0.00
Land Use, Land-Use Change and Forestry	0.63	0.06	0.09	0.24	0.20	0.60	7.90	1.23	-1.61
Forest Land	0.63	0.06	0.09	0.24	0.20	0.60	7.90	1.23	-0.94
Grassland									-0.67
Waste	368.90	475.92	659.73	664.48	898.22	928.85	958.26	1131.07	919.24
Solid Waste Disposal on Land	320.28	420.02	525.49	589.30	795.84	824.30	856.22	975.09	772.56
Waste-water Handling	48.61	55.89	134.23	75.17	102.37	104.55	102.03	155.95	146.64
Waste Incineration	0.0050	0.0050	0.0050	0.0050	0.0050	0.0038	0.0037	0.0310	0.0310
TOTAL	385.29	492.17	676.17	681.08	914.73	945.28	983.52	1127.51	920.35

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	23.01	23.84	26.27	29.34	32.11	32.53	33.97	36.79	39.49	42.99	32.71
Fuel Combustion Activities	23.01	23.84	26.27	29.34	32.11	32.53	33.97	36.79	39.49	42.99	32.71
Energy Industries											
Manufacturing Industries and Construction											
Transport	23.01	23.84	26.27	29.34	32.11	32.53	33.97	36.79	39.49	42.99	32.71
Other Sectors											
Agriculture											
Manure Management											
Agricultural Soils											
Field Burning of Agricultural Residues											
Land Use, Land-Use Change and Forestry	0.20	0.07	0.22	0.23	0.20	0.13	0.05	0.16	0.49	0.03	0.61
Forest Land	0.20	0.07	0.22	0.23	0.20	0.13	0.05	0.16	0.49	0.03	0.61
Grassland											
Waste	3.1774	1.6672	-0.7786	1.5303	-5.4320	-4.9248	-2.5240	-6.4282	-3.8120	0.6901	6.7548
Waste-water Handling	3.05	1.54	-0.90	1.41	-5.55	-5.05	-2.65	-6.55	-3.93	0.57	6.63
Waste Incineration	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
TOTAL	26.39	25.58	25.71	31.10	26.87	27.73	31.50	30.52	36.17	43.72	40.07

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
Energy	33.46	34.41	34.92	35.43	33.94	36.30	38.04	40.35	63.68
Fuel Combustion Activities	33.46	34.41	34.92	35.43	33.94	36.30	38.04	40.35	63.68
Energy Industries								2.32	0.07
Manufacturing Industries and Construction								-0.04	
Transport	33.46	34.41	34.92	35.43	33.94	36.30	38.04	38.07	34.10
Other Sectors									29.51
Agriculture							-44.38	268.70	15.68
Manure Management							-0.50	-8.11	-6.71
Agricultural Soils							-43.89	276.81	22.38
Field Burning of Agricultural Residues									0.00
Land Use, Land-Use Change and Forestry	0.06	0.01	0.01	0.02	0.02	0.06	0.80	0.12	-0.16
Forest Land	0.06	0.01	0.01	0.02	0.02	0.06	0.80	0.12	-0.10
Grassland									-0.07
Waste	6.0394	1.6494	10.3549	6.3132	2.9216	7.1496	9.7983	10.67	9.95
Waste-water Handling	5.92	1.53	10.23	6.19	2.80	7.06	9.71	9.90	9.19
Waste Incineration	0.12	0.12	0.12	0.12	0.12	0.09	0.09	0.76	0.76
TOTAL	39.57	36.06	45.28	41.77	36.88	43.51	4.26	319.84	89.14

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				2.71	6.61	42.75	71.89	102.12	107.29	110.28	70.67
PFC	-100.01	-100.09	-97.15	-59.59	-35.68	-31.81	-27.47	-61.97	-75.49	-45.18	-46.61
SF6											
TOTAL	-100.01	-100.09	-97.15	-56.88	-29.07	10.94	44.42	40.15	31.80	65.10	24.06
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
HFC	-13.92	-80.02	-106.31	-207.00	129.17	197.05	476.27	473.60	787.15		
PFC	-22.25	-21.52	-7.55	-4.23	-3.16	3.92	16.03	13.04	33.74		
SF6									0.24		
TOTAL	-36.17	-101.54	-113.85	-211.23	126.01	200.96	492.30	486.64	821.12		

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 2011 inventory with the present inventory (in Mt CO₂ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂ emissions											
2011 submission	83.31	83.02	84.73	84.07	86.35	86.81	88.92	93.77	98.68	98.08	103.22
2012 submission	83.30	83.02	84.72	84.06	86.34	86.80	88.92	93.76	98.67	98.07	103.21
Change (%)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH ₄ emissions											
2011 submission	9.80	9.77	9.84	9.82	9.97	10.00	10.21	10.06	10.27	10.08	9.99
2012 submission	10.32	10.28	10.39	10.37	10.55	10.58	10.81	10.72	10.95	10.87	10.82
Change (%)	-5.31	-5.16	-5.57	-5.58	-5.82	-5.77	-5.93	-6.51	-6.67	-7.77	-8.25
N ₂ O emissions											
2011 submission	10.25	9.95	9.80	8.92	8.74	9.01	9.23	9.01	8.95	8.85	8.53
2012 submission	10.28	9.98	9.83	8.95	8.77	9.03	9.26	9.04	8.99	8.90	8.57
Change (%)	-0.26	-0.26	-0.26	-0.35	-0.31	-0.31	-0.34	-0.34	-0.40	-0.49	-0.46
F-gases emissions											
2011 submission	1.20	1.37	1.17	1.77	2.24	3.35	3.85	4.21	4.74	5.48	4.43
2012 submission	1.10	1.27	1.07	1.71	2.21	3.36	3.89	4.25	4.78	5.55	4.45
Change (%)	-8.32	-7.28	-8.30	-3.22	-1.30	0.33	1.15	0.95	0.67	1.19	0.54
Total emissions											
2011 submission	104.57	104.12	105.53	104.58	107.30	109.17	112.21	117.05	122.64	122.49	126.17
2012 submission	105.01	104.55	106.00	105.10	107.88	109.78	112.88	117.77	123.38	123.38	127.05
Change (%)	0.42	0.41	0.45	0.49	0.53	0.56	0.60	0.61	0.61	0.72	0.70
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009		
CO ₂ emissions											
2011 submission	105.58	105.22	109.36	109.64	113.38	111.93	114.45	110.11	104.34		
2012 submission	105.57	105.22	109.35	109.64	113.41	111.93	114.44	110.71	104.47		
Change (%)	0.01	0.01	0.01	0.01	-0.02	0.00	0.01	-0.54	-0.13		
CH ₄ emissions											
2011 submission	9.64	9.55	9.40	9.43	9.23	9.25	9.06	8.86	8.81		
2012 submission	10.03	10.05	10.07	10.11	10.15	10.19	10.03	9.99	9.73		
Change (%)	-3.99	-5.15	-7.19	-7.22	-9.90	-10.22	-10.77	-12.71	-10.47		
N ₂ O emissions											
2011 submission	8.36	8.28	8.19	8.20	7.91	7.69	7.91	7.19	6.97		
2012 submission	8.40	8.31	8.24	8.24	7.94	7.73	7.91	7.51	7.06		
Change (%)	-0.47	-0.44	-0.55	-0.51	-0.47	-0.57	-0.04	-4.44	-1.28		
F-gases emissions											
2011 submission	4.08	4.31	4.12	4.30	4.04	2.10	2.17	2.57	2.61		
2012 submission	4.04	4.20	4.01	4.09	4.16	2.30	2.66	3.05	3.43		
Change (%)	-0.89	-2.36	-2.76	-4.91	3.12	9.56	22.70	18.96	31.46		
Total emissions											
2011 submission	127.65	127.36	131.07	131.58	134.56	130.96	133.58	128.74	122.72		
2012 submission	128.03	127.78	131.67	132.08	135.66	132.15	135.05	131.26	124.69		
Change (%)	0.30	0.33	0.46	0.38	0.82	0.91	1.10	1.96	1.60		

9.2.2 KP-LULUCF inventory

Table 9.8 *Comparison of the 2011 inventory with the present inventory (in Kt CO₂ eq.)*

Year	2008	2009
KP.A.2. Deforestation		
2011 submission	3.88	NE
2012 submission	10.42	6.97
Change (%)	168.59	-
KP.B.1. Forest Management		
2011 submission	-2,044.82	-1,944.71
2012 submission	-1,846.51	-1,845.7
Change (%)	-9.70	-5.09

9.3 Implications for emissions trends

9.3.1 GHG inventory

Total GHG emissions of years 1990-2009 (without LULUCF) in the current submission are a little higher than the emissions reported in the 2011 submission. The emission trends in Greece for the period 1990 – 2009 (without LULUCF) according to the inventories submitted in 2011 & 2012 are shown in **Figure 9.1**. Emission trends 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 – 2009 in the present inventory is calculated to be similar compared to the one that had been calculated in the previous inventory (1.32% and 1.22%, respectively).

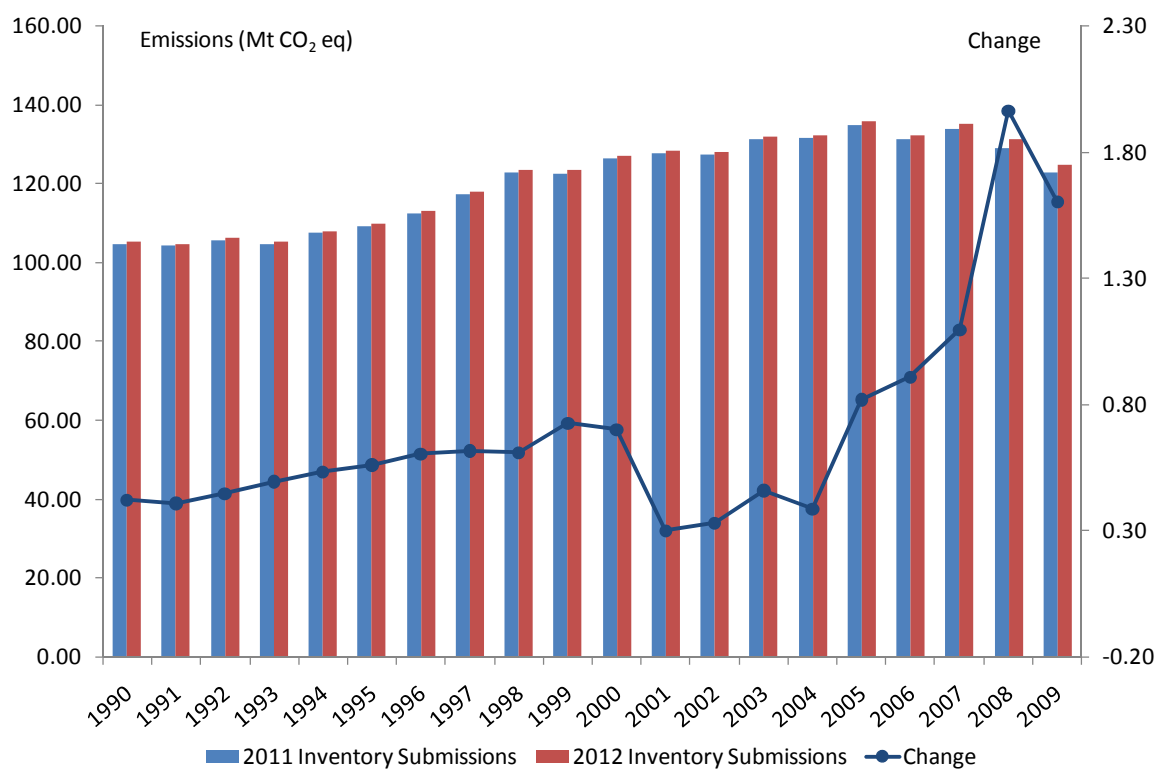


Figure 9.1 *GHG emissions trends in Greece for the period 1990 – 2009 (without LULUCF) according to the inventories submitted in 2011 & 2012*

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,

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 emissions from categories that were reported as NE in the previous submission and for which methods exist in the Revised 1996 IPCC guidelines and/or the IPCC good practice guidance have been calculated and reported in this submission for the whole time-series 1990-2009. Additionally, the improvement of the completeness of the GHG emissions inventory is being 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, in **Table 9.11** an overview of the responses to the outcomes of the 2011 review of Greek GHG inventory is presented. Since at the time of the writing of this report the 2011 ERT review report was not finalized (draft), the numbering of the ERT suggestions and the text may change. For the same reason the recommendations concerning LULUCF were not included in the table.

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			
4. Other Sectors			
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas			
2. Industrial Processes			
A. Mineral Products	√	√	Emissions from soda ash use are included for the first time
B. Chemical Industry	√	√	Rallocation of H2 production from Energy Sector
C. Metal Production	√	√	Highly detailed country specific methodology for CO2 emissions from Aluminium production.
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6	√	√	The distribution of blends has been re-evaluated using information collected by the gas importers. The annual F-gases penetration percentages refer to the annual introduction of new equipment.
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			
A. Enteric Fermentation			
B. Manure Management			
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			
B. Cropland			
C. Grassland			
D. Wetlands			
E. Settlements			
F. Other Land			
G. Other			
6. Waste			
A. Solid Waste Disposal on Land	√	√	Inclusion of Emissions from the construction and Demolition Waste based on data by ELSTAT
B. Waste-water Handling	√	√	Use of country specific factors for the estimation of COD from industrial wastewater
C. Waste Incineration	√	√	Inclusion of Emissions from the incineration of additional waste based on data by ELSTAT
D. Other			
7. Other (as specified in Summary 1.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 2011 review of Greek KP-LULUCF inventory*

Category	Review	Response by Greece
KP-LULUCF	93. Decision 15/CMP.1 requires information to be provided on whether factoring out is implemented by the Party. During the review, Greece stated that no factoring out was implemented. The ERT recommends that the Party include this information in its next annual submission.	Done, please see NIR section 10.3.1.3.
KP-LULUCF	94. The ERT noted that, in its 2011 submission, Greece did not provide sufficient verifiable information, as required by paragraph 6(e) of the annex to decision 15/CMP.1, to demonstrate that omitted pools, namely litter, dead wood and soils, are not net sources of emissions. Greece indicated in its NIR that the estimation of the carbon stock changes for these pools was a priority for its next annual submission. The ERT welcomes this upcoming improvement and recommends that Greece either estimate the carbon stock changes for these pools or provide the required evidence that these pools are not a net source if an estimate is not provided.	Partially done, please see NIR section 10.3.1.2.
KP-LULUCF	95. Greece has not made any recalculations for KP-LULUCF activities between the 2010 and 2011 submissions. The Party did, however, recalculate its removals for the forest land category under the Convention. As mentioned above, the ERT was not able to assess this recalculation or, therefore, to further assess whether it has an impact on KP-LULUCF activities. The ERT recommends that Greece improve transparency regarding this recalculation and recalculate relevant estimates for KP-LULUCF activities if warranted.	Done, please see NIR section 9.1.2.
KP-LULUCF	97. The previous ERT noted that data on deforestation had not been reported for 11 out of the country's 51 prefectures for the 2008 inventory year. The Party explained that the missing information would be provided in its 2011 submission. The ERT noted that the relevant AD were still missing from the 2011 submission and that data for 24 prefectures were missing for the 2009 inventory year. The ERT noted that the inability to identify deforested lands in these prefectures could result in an underestimation of the total area of deforested land. The ERT strongly recommends that Greece ensure the necessary capacity within the local Forest Services to acquire and report these data in accordance with the requirements of paragraph 20 of the annex to decision 16/CMP.1.	Done. The Land Use Change Database has been fulfilled with the missing values and emission estimates from deforestation from all prefectures are reported in the 2012 submission.
KP-LULUCF	99. The ERT noted that the category forest management has not been recalculated, whereas the category forest land remaining forest land has been recalculated for the Party's reporting on LULUCF under the Convention. No justification is provided in the NIR for this apparent inconsistency. The ERT reiterates the strong recommendation pertaining to transparency expressed in the forest land remaining forest land section of this report (see para. 71 above).	Forest Management activity under Art. 3.4 is equivalent with UNFCCC category Forest land remaining Forest land. However, an error in the 2008 inventory year while filling in the required information in the CRF tables resulted to this inconsistency. This has been resolved in the current submission.

Table 9.11 *Reporting on the outcomes of the 2011 review of Greek GHG inventory*

Category	Review	Response by Greece
General	18. ... the ERT reiterates the encouragement of the previous review reports that Greece use more country-specific information on uncertainties for categories for which IPCC default uncertainty values have been used.	Tables IV.1 – 3 have been updated, to include the effect of country specific information on uncertainties.
General	20. ... This information suggests that for all key categories, except for coal mining and handling and for wastewater handling, sector-specific QA/QC procedures exist. Therefore, the ERT recommends that Greece also implement sector-specific QA/QC procedures for these two key categories and for the LULUCF sector. In addition, the present ERT reiterates the recommendation in the previous review report that Greece provide additional information on its QA/QC procedures for the data supplied by external sources (in particular the European Union emissions trading scheme (EU ETS)).	Source-specific QA/QC and verification for coal mining is described in section 3.3.1.4. Details of the use of ETS reporting in energy sector's inventory calculations are provided in Annex II. Source-specific QA/QC and verification for wastewater handling is described in section 8.3.4.
Energy	31. The reporting on the energy sector is generally transparent and Greece has provided detailed information on the methodologies used, the descriptions of assumptions, the rationale for the recalculations and details of planned improvements in the sector. However, the ERT noted that the Party could further enhance transparency by providing, in the NIR, more background documentation on EFs (e.g. for other fuels in other sectors, and those based on data from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the 2006 IPCC Guidelines) and from the core inventory of air emissions (CORINAIR), including an explanation of their appropriateness to the national circumstances of Greece) and disaggregated AD (e.g. other fuels in other (manufacturing industries and construction), waste fuels for combustion by category, lubricant use by category, bituminous coal and lignite by category and biomass in residential). The ERT recommends that Greece enhance the transparency of its reporting by providing the above information in its next NIR.	Annex II was enriched with details of methodology and data for estimating CO ₂ and other GHG emissions from fossil fuel combustion, in order to improve transparency of the energy sector.
Energy	32. The present ERT agrees with the conclusion of the previous ERT that the Party has not provided sufficient information in its NIR to confirm whether the EU ETS data have been prepared and incorporated in the inventory submission in line with the IPCC good practice guidance. Since there is still a lack of relevant information provided in the 2011 NIR, the ERT raised questions during the review on the AD, EFs and methodological tier levels used by Greece for the calculation of emissions in the energy sector. In response to these questions, Greece provided more background information for clarification purposes. The ERT recommends that Greece provide detailed information (e.g. in an annex to the NIR) on the EU ETS data used, including an analysis of their completeness and consistency with the IPCC methodology, and on the verification procedure applied to ensure conservation of the fuel mass balance and completeness of the data and that the Party report on the progress made with regard to this issue in its next NIR..	Details of the use of ETS reporting in energy sector's inventory calculations are provided in Annex II.
Energy	33. The sectoral information in the report and in the CRF tables is generally correct and accurate. However, the ERT noticed some errors in the NIR (e.g. fugitive CH ₄ emissions from solid fuels for the years 2008 and 2009 in NIR table 3.1; the notation keys used to report fugitive CO ₂ emissions from solid fuels for the years 2000-2009, which should be reported as not occurring (.NO.) and not as included elsewhere, not occurring (.IE, NO.) in NIR table 3.1; and the EF for jet kerosene in civil aviation in NIR table 3.13) and in the CRF tables (e.g. the apparent energy consumption excluding non-energy use and feedstocks in CRF table 1.A(c); jet kerosene used in international aviation from 2003 to 2004 in CRF table 1.C; and CH ₄ and N ₂ O emissions from liquid fuels in railway transportation). The ERT recommends that Greece correct these data and enhance its QC procedures for its next annual submission.	Done.

Category	Review	Response by Greece
Energy	<p>36. The ERT noted that there are some inconsistencies between CRF tables 1.A(d) and 1.A(c). In table 1.A(d), non-energy use of natural gas is reported as 8.2 PJ but in table 1.A(c), only 3.9 PJ is subtracted. For liquid fuels, table 1.A(d) reports 25 PJ, while the difference in table 1.A(c) is only 15 PJ. Greece explained these differences in response to questions raised by the ERT during the review. The ERT recommends that the Party includes these explanations in its next NIR. The ERT also noted that some fuels used as feedstock and for non-energy use are still accounted for in the energy sector (e.g. natural gas used for hydrogen production and some amounts of naphtha, lubricants and other petroleum), which leads to low implied emission factors (IEFs) for CO₂, CH₄ and N₂O emissions in relevant sectors. Furthermore, the additional information on the stored carbon of these fuels for feedstock and non-energy use in CRF table 1.A(d) is far from complete and consistent. According to the Revised 1996 IPCC Guidelines, all feedstock and nonenergy use should be reallocated to the industrial processes sector and not included in the energy sector. The ERT recommends that Greece exclude all fuels for feedstock and nonenergy use from the energy sector and report, in line with the Revised 1996 IPCC Guidelines, in CRF tables 1.A(b) and 1.A(d) all feedstocks and non-energy use of fuels (as identified in the national energy balance), the associated CO₂ emissions and the category/sector under which they are allocated in the inventory.</p> <p>37. The ERT found that CO₂ emissions from solid fuel combustion in ferroalloys production have been allocated to the industrial processes sector as reported in the NIR. However, the amount consumed has not been indicated in CRF tables 1.A(d), 1.A(b) and 1.A(c) (e.g. in table 1.A(d), the solid fuel used for feedstock and non-energy use is reported as .NO., which is not in line with the Revised 1996 IPCC Guidelines). Greece also regarded this as one of the reasons for the difference between the reference and the sectoral approach in the NIR, which should be not relevant if the corresponding information is correctly included in the CRF tables. The ERT recommends that Greece report, in line with the Revised 1996 IPCC Guidelines, in CRF tables 1.A(b) and 1.A(d) the feedstocks and non-energy use of solid fuels (as identified in the national energy balance), the associated CO₂ emissions and the category/sector under which they are allocated in the inventory and revise the relevant information in the NIR of the next annual submission.</p>	Inconsistencies in tables 1Ab, 1Ac and 1Ad have been corrected. A description of how "Apparent energy consumption" is calculated has been added in section 3.2.1. Table 3.9 was updated, accordingly. Natural gas used as feedstock for hydrogen production was reallocated to the IP sector.
Energy	38. The ERT noted that the net calorific values (NCVs) and carbon EFs for lignite are significantly different for energy industries and for manufacturing industries and construction. In response to a question raised by the ERT during the review, Greece provided detailed information explaining and justifying this difference, including the fact that the lignite is distributed from different mining fields. The ERT recommends that Greece include this information in its next NIR.	The following explanation was added in section 3.2.4.2: "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 both NCV and EF used in Industry are greater than the ones used for Electricity production".
Energy	39. The ERT noted that the CO ₂ IEF for liquid fuels in petroleum refining and in all subcategories under manufacturing industries and construction fluctuates with a general decreasing trend. In response to questions raised by the ERT, Greece explained that this is due to the change in the percentage of the fuels that compose the liquid fuel mix of these subcategories. The ERT recommends that Greece provide more detailed background information on the AD and EFs for all types of liquid fuels in these subcategories in its next NIR in order to improve the transparency of the reporting.	Annex II was enriched with details of methodology and data for estimating CO ₂ and other GHG emissions from fossil fuel combustion, in order to improve transparency of the energy sector.
Energy	40. The ERT noted that the carbon content reported for refinery gas (15.42 t C/TJ) is low compared to the IPCC default value (18.2 t C/TJ). In response to a question raised by the ERT during the review, Greece provided more detailed data on refinery gas and explained how the EF (including the carbon content) is computed. The ERT recommends that Greece include this explanation in its next NIR in order to improve the transparency of the inventory.	Table II.10.

Category	Review	Response by Greece
Energy	41. The ERT noted that the N ₂ O IEF for liquid fuels in agriculture, forestry and fisheries is much lower in 2009 (23.44 kg/TJ) compared with the values in previous years (26.94- 27.70 kg/TJ). In response to a question raised by the ERT during the review, Greece explained that three liquid fuels are used in this category (i.e. diesel and heavy fuel oil for boilers, and diesel and motor gasoline for off-road machinery). In 2009, the IEF decreased due to the reduction in diesel use and the change in the allocation of diesel use between offroad machinery and boilers. The ERT recommends that Greece provide more background information on the N ₂ O IEF for liquid fuels in agriculture, forestry and fisheries in its next NIR.	NIR section 3.2.4.5.2: An error of the working file of the year 2009 was corrected (concerning AD), and the emissions of CO ₂ , CH ₄ and N ₂ O from liquid fuels combustion were recalculated for the year 2009. The impact on total emissions was minor (around +33 kt GHG).
Energy	42. In 2009, the CO ₂ IEF for other fuels in other manufacturing industries (32.73 t/TJ) is much lower compared with the value in previous years (89.25-119.13 t/TJ). In response to a question raised by the ERT during the review, Greece explained that the other fuels in this category are alternative fuels (e.g. scrap tyres, cable coating, etc.) used in Greek cement plants and provided the AD and EFs for these fuels for further clarification. The ERT recommends that Greece include this information in its next NIR	Table II.11.
Industrial Processes	The ERT reiterates the recommendation that the Party report, in the CRF tables of its next annual submission, publicly available data on aluminium production in order to enable the assessment of the approximate level and trend of the IEFs for PFC emissions for a cross-country comparison and trend analysis.	Done.
Industrial Processes	The ERT notes that the information on HFC emissions from imported foams is not reflected in the NIR and recommends that Greece include a transparent explanation on the assumptions, methodologies, AD and EFs used to estimate HFC emissions from foam blowing in the next annual submission.	Done, reported in para 4.14
Industrial Processes	The ERT also notes that the import of foams containing HFCs can be covered not only by companies producing foams and recommends that the Party further investigate the import of HFC-containing foam products in Greece for the next annual submission.	It has been investigated but no safe conclusions can be used in the current submission. See also para 4.14.
Industrial Processes	The ERT recommends that Greece use this revised estimate for its future annual submissions and transparently document the methodologies, EFs and AD used for the calculations.	Done, para 4.5
Agriculture	23. In addition, the ERT identified a few inconsistencies between CRF table summary 3 and the NIR (e.g. CH ₄ emissions from manure management and N ₂ O emissions from agricultural soils). The Party clarified these issues during the review. The ERT also identified differences between CRF table 7 and the key category analysis in the NIR due to the disaggregation of key categories in the NIR (e.g. stationary combustion and LULUCF), which is not reflected in CRF table 7. The ERT recommends that the Party correct these errors in its next annual submission.	Done, please see CRF table summary 3 and NIR section 6.1.2.
Agriculture	55. The inventory for the agriculture sector is complete and includes estimates of all gases and for all categories. 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 enteric fermentation estimate for other cattle, in order to enhance transparency. The inventory is complete for all categories and gases and the time series is consistent. Uncertainty estimates have been provided for all categories and extensive QA/QC procedures have been implemented in the development and review of the emission estimates.	All the AD used for the tier 2 enteric fermentation estimate for other cattle is presented in NIR section 6.2.2.
Agriculture	57. A notable improvement in the Party's inventory was the use of an IPCC tier 2 method to estimate emissions from cattle, as recommended in the previous review report. While the description provided for dairy cattle is sufficient, further information could be provided on the AD used for the enteric fermentation emission estimates for other cattle. As enteric fermentation is a key category, the move to a tier 2 approach is an important improvement to the Party's inventory.	All the AD used for the tier 2 enteric fermentation estimate for other cattle is presented in NIR section 6.2.2.

Category	Review	Response by Greece
Agriculture	61. In response to the recommendations from previous review reports, Greece now uses the Western Europe value for N excretion (Nex) from dairy cattle due to the similarity of the production practices. For non-dairy cattle, the Nex values range from 42 kg/head/year to 45 kg/head/year across the time series, which is in the lower range of the values recommended in the Revised 1996 IPCC Guidelines. However, because Greece is a Mediterranean country with production practices different from those in Western Europe for these animal types, the ERT considers that the use of these values is justified. The sheep and swine Nex values are also lower than those recommended in the Revised 1996 IPCC Guidelines for Western Europe but, again, because Greece is a Mediterranean country, these values are justified. The ERT encourages Greece to provide further explanation in future NIRs as to why these values have been selected.	Done, please see NIR section 6.3.2.
Agriculture	121. (c) Provide additional information on the AD used for the tier 2 enteric fermentation estimates for other cattle in the agriculture sector;	All the AD used for the tier 2 enteric fermentation estimate for other cattle is presented in NIR section 6.2.2.
Waste	11. In response to the list of potential problems and further questions raised by the ERT, Greece provided revised estimates for emissions from navigation and lubricant use (see paras. 44 and 45 below). Further, in response to questions raised during the review of the annual submission of the EU, Greece provided revised emission estimates for industrial waste disposal (see para. 84 below). The ERT encourages Greece to report, in its next annual submission, estimates for categories not yet addressed, in order to further improve the completeness and accuracy of its inventory.	Done, please see NIR section 8.2.2. , namely Chapter "Industrial solid waste". (For industrial waste disposal)
Waste	82. The Party has recalculated CH ₄ emissions from solid waste disposal on land by incorporating a revised DOCf and MCF for unmanaged SWDS and updated data for recycled waste for 2007 and 2008 and by using the IPCC tier 2 method for calculating flared CH ₄ , which resulted in an increase in emissions of 59.86 Gg CO ₂ eq (or 3.5 per cent) in the base year and of 213.40 Gg CO ₂ eq (or 9.5 per cent) in 2008. Additionally, Greece has recalculated CH ₄ emissions from domestic wastewater handling by incorporating updated data of produced amounts of sewage sludge for the period 1990–2008, which has resulted in a decrease in emissions of 248.42 Gg CO ₂ eq (or 8.1 per cent) in the base year and of 381.18 Gg CO ₂ eq (or 30.9 per cent) in 2008. Altogether, the recalculations resulted in a decrease in total sectoral emissions of 185.42 Gg CO ₂ eq (or 3.6 per cent) in the base year and of 167.78 Gg CO ₂ eq (or 4.3 per cent) in 2008. The ERT recommends that the Party include waste flows (including sludge flows) in its next NIR in order to increase transparency.	Done, please see NIR section 8.2.5.
Waste	84. Greece reports only MSW; however, based on information from the Hellenic Statistical Authority, large amounts of industrial and commercial waste are generated but are not included in the inventory. The Party explained that industrial and commercial waste is mainly recycled and the rest is disposed of at the same managed and unmanaged SWDS that are used for MSW. Additionally, it was mentioned by the Party that disposed industrial and commercial waste are included in the amount of MSW disposed. During the review of the annual submission of the EU, that ERT raised the same question and, in response to the list of potential problems and further questions raised by the ERT, Greece submitted revised estimates of the emissions from industrial waste for the entire time series. The revised estimates resulted in an increase in CH ₄ emissions from solid waste disposal on land of 39.49 Gg CO ₂ eq (or 2.1 per cent) in the base year and of 64.58 Gg CO ₂ eq (or 2.6 per cent) in 2009. The AD were obtained from the Hellenic Statistical Authority and, since industrial waste is disposed of at the same landfills as MSW, a similar method was used to estimate CH ₄ emissions. Most of the parameters used are IPCC default ones. The ERT considers that these revisions have been done in accordance with the IPCC good practice guidance and recommends that the Party include more information on industrial waste in its next NIR.	Done, please see NIR section 8.2.2, namely Chapters "Industrial solid waste" and "Construction and demolition solid waste".

Category	Review	Response by Greece
Waste	85. There are four landfill sites in Greece where CH ₄ is recovered. However, according to the Party, for three of the sites it has not been possible to obtain data but it has been assumed that 60 per cent of the CH ₄ at those sites is recovered. The Party explained that a recovery rate of 60 per cent is estimated at the SWDS in Athens where the CH ₄ is measured because it is used for energy production. Taking into consideration the fact that the other three landfill sites have been constructed with similar characteristics to that of Athens, it is estimated that the same fraction of CH ₄ is recovered at those sites. The ERT recommends that the Party further investigate the amount of CH ₄ recovered at the sites where it is flared with no energy recovery and provide a justification for the calculation of the amount of CH ₄ recovered in its next NIR.	Done, please see NIR section 8.2.2. , namely Chapter "Biogas flaring".
Waste	86. Greece does not differentiate between garden and park waste and other non-food putrescibles and food waste as all have been included in the general putrescibles. As the DOC value of these waste types differs, their allocation to the same category is not in line with the Revised 1996 IPCC Guidelines. The ERT reiterates the recommendation made in the previous review report that Greece estimate these waste types separately using appropriate DOC values.	Done, please see NIR section 8.2.2. , namely Chapters "Composition of generated municipal solid waste" and "Quantities and composition of MSW at disposal sites".
Waste	87. Greece has used a tier 1 method to calculate CH ₄ emissions from wastewater handling. However, wastewater handling is identified as a key category in the Greek inventory. According to the decision trees in the IPCC good practice guidance, the Party should use a tier 2 method for this key category. The Party explained that the use of a higher-tier method is limited by the lack of more detailed data. The ERT recommends that the Party make efforts to obtain the necessary data and encourages it to use a tier 2 method for the calculation of CH ₄ emissions from wastewater handling in its next annual submission.	Done, please see NIR section 8.3.2. ,namely Chapters "CH ₄ emissions from industrial wastewater handling" and "CH ₄ emissions from sludge generated industrial wastewater handling".
Waste	88. Greece has used the IPCC good practice guidance to estimate CO ₂ emissions, and a default methodology and country-specific EFs to estimate CH ₄ and N ₂ O emissions from the incineration of clinical waste. The Party mentioned in its NIR that there is no other incineration plant for any other type of waste, only the one for clinical waste. However, the ERT noted that the Hellenic Statistical Authority lists a significant amount of "other waste" without energy recovery and a larger amount of waste incinerated with energy recovery. The Party mentioned that the "other waste" is accounted for in the energy sector. The ERT recommends that Greece improve the information provided in the waste incineration subchapter in the NIR by including more detailed documentation on the waste incinerated with and without energy recovery.	Done, please see NIR sections 8.4.1 and 8.4.2.
Waste	110. Further, in response to questions raised during the review of the annual submission of the EU, Greece provided emission estimates for industrial waste disposal.	Done, please see NIR section 8.2.2. , namely Chapter "Industrial solid waste".
Waste	112. The Party's inventory is generally in line with the Revised 1996 IPCC Guidelines, the IPCC good practice guidance and the IPCC good practice guidance for LULUCF, with the following exceptions: the reporting of fuels in the reference approach related to feedstock and non-energy use of fuels; and the allocation of garden and park waste as well as other non-food putrescibles in the general putrescibles.	Done, please see NIR section 8.2.2. , namely Chapters "Composition of generated municipal solid waste" and "Quantities and composition of MSW at disposal sites". (For the allocation of garden and park waste as well as other non-food putrescibles in the general putrescibles)
Waste	121. (e) Investigate the amount of CH ₄ recovered from landfills and implement the tier 2 method for CH ₄ emissions from wastewater handling in the waste sector.	Done, please see NIR section 8.3.2. , namely Chapters "CH ₄ emissions from industrial wastewater handling" and "CH ₄ emissions from sludge generated industrial wastewater handling".
LULUCF	66. As already noted in the previous review report, Greece does not provide a transparent explanation in its NIR regarding the recalculations for the LULUCF sector. The ERT recommends that Greece dedicate a section of its NIR to explain the recalculations in this sector and that it adequately complete CRF table 8(b).	Done, please see NIR chapter 7.1.5.
LULUCF	67. Net emissions/removals from wetlands, settlements and other land were reported as "NO" or "NE" (not estimated). The following subcategories were also reported as "NO": land converted to grassland; and CO ₂ emissions from grassland remaining grassland. Greece followed the recommendation of the previous review report regarding the provision of information in the documentation box for categories where AD are reported and emissions are not occurring (e.g. wetlands). However, Greece failed to implement these recommendations regarding the improvement of	Greece, in the current submission, in order to improve the completeness of the reporting, fulfilled the Land Use Change database, reported on the missing categories, and provided estimates of carbon stock changes for the grassland remaining grassland category. Furthermore, improved transparency, the use of notation keys and the information provided in the

Category	Review	Response by Greece
	completeness, in particular regarding the provision of estimates for carbon stock changes in dead organic matter and regarding the enhancement of transparency for the subcategories reported as "NO", by indicating in the documentation boxes where the relevant information can be found in the NIR. The ERT reiterates the recommendations of the previous review report that Greece improve the completeness and transparency of its reporting in its next annual submission.	documentation boxes.
LULUCF	68. In its 2010 submission, Greece indicated that it was developing a new mapping system based on remotely sensed data, which would enable the Party to provide more complete information on land-use changes. However, no mention of this upcoming system is made in its 2011 submission. The ERT encourages Greece to provide information regarding the status of this ongoing effort in its next annual submission.	Greece was planning to initiate a project in order to map the missing land use changes, namely grasslands and croplands converted to forest land, but it is still unclear if this project is going to be implemented or not. Within the Grassland remaining Grassland category, there are some grasslands that have been afforested through natural succession, however these lands have not been identified, and hence, they are still reported under Grasslands remaining Grasslands. This is a conservative approach. Similarly, abandoned croplands have been afforested through natural succession, but since information on this conversion is missing, no biomass stock growth is assumed in these areas and they are reported in the cropland converted to grassland category.
LULUCF	70. The QA/QC procedures implemented in the LULUCF sector and their corresponding findings are not documented in the NIR. During the review, Greece provided the key findings of the procedures. The main findings were related to the correct use of the annotated NIR and of the notation keys "NO" and "NE". Nevertheless, the ERT noted that these two issues have still not been corrected in the 2011 submission. The ERT recommends that Greece document the QA/QC procedures for the LULUCF sector in its next annual submission and that it correct its next annual submission in accordance with the findings of the QA/QC procedures. The ERT encourages Greece to document its follow-up	Done, please see NIR chapter 7.1.4.
LULUCF	77. The carbon stock changes in grassland remaining grassland are reported as "NO", which is justified in the NIR by the fact that management practices have not changed in the last 20 years. During the review, Greece indicated that it would provide evidence for this absence of change in its next annual submission. The ERT welcomes this upcoming improvement in transparency.	The Tier 1 assumption that is no change in biomass stocks in grassland remaining grassland was followed in previous submissions, since grasslands in Greece are extensively managed, without significant management improvements (e.g. species changes, irrigation, fertilisation) and management practices applied are generally static. In 2012 submission, activity data on vegetation management acts have been compiled and carbon stock changes in these lands have been estimated and reported. As expected the impact of these interventions is minor (0,01-0,45 KtCO ₂ yr ⁻¹ during 1990-2010).
LULUCF	79. The previous ERT recommended that Greece provide information in its NIR on how fire emissions are distinguished between managed and unmanaged forest land. During the review, the Party explained that it did not have data to distinguish between these land types and therefore used a weighted average. The ERT reiterates the recommendation that the Party include this information in the NIR.	Done, please see NIR section 7.2.2.1. , namely Chapter "Forest land remaining Forest land".

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 congruity 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 in 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 with 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 for the UNFCCC inventory are used for the Kyoto Protocol reporting. 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. Afforestation of land occurred by natural regeneration is not yet estimated due to lack of activity data. Deforestation data are obtained from the Land Use Change Database recently 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 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)}

From previous inventory year To current 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		3,88						3,88
Article 3.4 activities	Forest Management (if elected)		0,00	1.205,76					1.205,76
	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	0,04	0,00	0,00	0,00	0,00	11.952,81	11.952,85
Total area at the end of the current inventory year		33,25	3,92	1.205,76	0,00	0,00	0,00	11.952,81	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. As reported in table NIR 1, carbon stock changes from the dead organic matter and from soils have not been assessed yet. This is planned for the next submission.

Table 10.2 *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⁾		
							N ₂ O	N ₂ O	N ₂ O	CO ₂	CO ₂	CH ₄	N ₂ O
Article 3.3 activities	Afforestation and Reforestation	R	R	NR	NR	NR	NO			NO	NO	NO	NO
	Deforestation	R	R	NR	NR	NR			NO	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 10.3 ***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

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 activity include croplands that have been afforested by planting. These croplands contain no dead organic matter and therefore the litter and the dead wood pools cannot be a source. 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. Carbon stock increment in soil in areas afforested have been estimated according to the Tier 1 methodology, however due to methodological reasons explained in NIR par.7.3 these estimations cannot be separated from carbon stock changes in Cropland remaining Cropland category, and they are reported under this category.

Litter, soil organic carbon and dead wood are generally decreased in areas deforested and it cannot be demonstrated that these pools are not net sources. Activity data on deforestation areas are available in the Land Use Change database and estimates of carbon stock changes in these pools will be provided in the next submission. However, since area afforested is very small (0.039-0.483 Kha each year for the period 1990-2010), it is expected that carbon stock changes in these pools are also small.

Regarding the dead organic matter and soil in areas under Forest Management, the Tier1 approach that there is no change in carbon stocks was followed. 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, 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 of harvest residues, soil scarification or fertilization are not practiced. Therefore the assumption that there is no change in carbon stocks in these pools has been used without introducing significant error in the calculations.

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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

10.4 Article 3.3

10.4.1 Information that demonstrates that activities began on or after 1 January 1990 and before 31 December 2012 and 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

From the land use change database only legal deforestations are drawn to be included in the art. 3.3 Deforestation activity. Lands that have illegally lost their forest cover are not classified as deforested, but as areas that temporary lost their vegetation. These areas are reforested either naturally or after the human intervention. Harvested or disturbed forest areas are not included in the land use change database.

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

Areas that have lost forest cover (through illegal harvest or burning or wildfire) are recorded at the relevant registry in the local Forest Service. Information on the size and geographical location of these areas is collected but is not readily available for use under the scope of the KP inventory. Greece is currently planning a mechanism to keep these areas under surveillance.

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 the forests that have a forest management plan started in 1990 or later have been included. These forests cover about the 35% 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. Afforestation/ Reforestation 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 10.4 (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			
Afforestation / Reforestation	CO ₂	Trend	Land converted to Forest Land
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 2011 (X-1) the respective software application has been used, which is included in this reporting submission (SEF_GR_2012_1_15-38-7 11-1-2012.xls).

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

Information to the public is provided in the registry interface through the corresponding Web site of the Ministry for the Environment:

<http://www.ypeka.gr/Default.aspx?tabid=775&language=el-GR>

<https://registry.ekpaa.gr/crrepekpaaproduct/en/index.htm>

Information to the public is provided also from CITL:

<http://ec.europa.eu/environment/ets/>

The information is provided through the Web site of UNFCCC:

http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php.

11.4 Calculation of the commitment period reserve (CPR)

The commitment period reserve for Greece has not changed since the initial report review (FCCC/IRR/2007/GRC, 28.12.2007) and amounts to 601,802,826 t CO₂ eq.

12. Information on changes in national system

As the UNFCCC secretariat has been informed, the UNFCCC Focal point of Greece was changed from Ms Afroditi Kotidou to Ms Irini Nikolaou (Address: Villa Kazouli, Kifisias 241, Athens, Greece, e-mail: i.nikolaou@prv.ypeka.gr, tel.: +30210 8089275, fax: +30210 8089239). Ms Afroditi Kotidou retired.

13. Information on changes in national registry

There are no changes in the national registry system since the last year's submission.

The registry software was upgraded by smart technologies GmbH (version 1.1.14.1a).

The national registry system is operated by the National Center of Environment and Sustainable development which is supervised by the Ministry of Environment, Energy and Climate Change (MEECC).

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)

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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 submission, namely 2011 submission. In answer to that encouragement Greece has 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 has been performed for the total of the time series (years 1990-2010) 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 2010*

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	39,679.67	33.55	33.55
Road Transportation	CO2	11,742.20	18,907.12	15.98	49.53
Other Sectors: Liquid fuels	CO2	8,006.48	8,593.67	7.27	56.79
Energy Industries: Liquid fuels	CO2	7,683.34	7,663.68	6.48	63.27
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	4,966.97	4.20	67.47
Energy Industries: Gaseous fuels	CO2	102.03	4,693.24	3.97	71.44
Cement Production	CO2	5,640.90	4,208.60	3.56	75.00
ODS substitutes	HFC	0.00	3,625.73	3.07	78.06
Solid waste disposal on land	CH4	2,225.69	3,467.99	2.93	81.00
Navigation	CO2	1,824.81	2,285.98	1.93	82.93
Indirect N2O from nitrogen used in agr.	N2O	2,868.92	1,937.03	1.64	84.57
Animal Production	N2O	1,821.24	1,759.90	1.49	86.05
Enteric fermentation: Sheep	CH4	1,655.96	1,679.97	1.42	87.47
Direct N2O from agr. soils	N2O	2,761.36	1,591.32	1.35	88.82
Civil Aviation	CO2	716.84	1,307.50	1.11	89.92
Coal Mining (surface)	CH4	1,095.27	1,192.85	1.01	90.93
Wastewater handling	CH4	3,017.06	1,068.16	0.90	91.84
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,061.54	0.90	92.73
Other Sectors: Gaseous fuels	CO2	0.00	911.45	0.77	93.50
Manufacturing Industries & Construction: Solid fuels	CO2	3,928.07	670.11	0.57	94.07
Enteric fermentation: Other	CH4	661.10	602.74	0.51	94.58
Enteric fermentation: Non Dairy Cattle	CH4	537.47	601.28	0.51	95.09
Ferroalloys	CO2	622.23	536.69	0.45	95.54
Limestone & Dolomite Use	CO2	582.80	457.50	0.39	95.93
Nitric Acid Production	N2O	1,109.04	428.39	0.36	96.29
Wastewater handling	N2O	331.24	393.31	0.33	96.62
Other Chemicals	CO2	0.00	362.13	0.31	96.93
Enteric fermentation: Dairy Cattle	CH4	391.75	339.85	0.29	97.22
Manure management	CH4	337.46	314.55	0.27	97.48
Ammonia Production	CO2	240.28	300.84	0.25	97.74
Manure management	N2O	341.77	295.84	0.25	97.99
Lime Production	CO2	431.97	229.96	0.19	98.18
Other Sectors: Liquid fuels	N2O	349.81	216.77	0.18	98.36
Aluminium Production	CO2	225.39	207.22	0.18	98.54
Road Transportation	N2O	145.27	190.14	0.16	98.70
Oil, Natural Gas and Other sources	CH4	91.59	188.13	0.16	98.86
Solvent and other product use	CO2	169.71	161.64	0.14	99.00
Solvent and other product use	N2O	138.63	154.53	0.13	99.13
Energy Industries: Solid fuels	N2O	134.19	147.76	0.12	99.25
Navigation	N2O	141.45	119.81	0.10	99.35
Rice Production	CH4	69.10	117.60	0.10	99.45
Iron and Steel Production	CO2	92.70	115.61	0.10	99.55
Road Transportation	CH4	100.74	86.88	0.07	99.62

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	66.72	0.06	99.68
Railways	CO ₂	202.69	63.00	0.05	99.73
Aluminium Production	PFCs	163.37	33.80	0.03	99.76
Field burning of agr.residues	CH ₄	27.06	30.47	0.03	99.79
Other Sectors: Biomass	N ₂ O	31.80	27.70	0.02	99.81
Energy Industries: Liquid fuels	N ₂ O	19.40	20.04	0.02	99.83
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	18.79	0.02	99.84
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	15.98	16.98	0.01	99.86
Other Mineral (Glass)	CO ₂	20.20	15.16	0.01	99.87
Civil Aviation	N ₂ O	7.71	13.98	0.01	99.88
Other Sectors: Solid fuels	CO ₂	119.43	13.97	0.01	99.89
Soda Ash Use	CO ₂	33.16	13.86	0.01	99.91
Manufacturing Industries & Construction: Biomass	N ₂ O	9.91	12.63	0.01	99.92
Field burning of agr.residues	N ₂ O	10.05	11.67	0.01	99.93
Oil, Natural Gas and Other sources	CO ₂	70.23	10.60	0.01	99.94
Other transportation	CO ₂	0.00	9.14	0.01	99.94
Railways	N ₂ O	24.40	7.68	0.01	99.95
Other Sectors: Liquid fuels	CH ₄	7.36	7.65	0.01	99.96
Energy Industries: Liquid fuels	CH ₄	6.57	6.79	0.01	99.96
Energy Industries: Solid fuels	CH ₄	6.06	6.67	0.01	99.97
Manufacturing Industries & Construction: Biomass	CH ₄	5.03	6.42	0.01	99.97
SF ₆ from electrical equipment	SF ₆	3.07	6.14	0.01	99.98
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	0.00	4.16	0.00	99.98
Navigation	CH ₄	2.70	3.74	0.00	99.99
Manufacturing Industries & Construction: Solid fuels	N ₂ O	17.74	3.23	0.00	99.99
Waste incineration	CO ₂	0.22	3.19	0.00	99.99
Energy Industries: Gaseous fuels	N ₂ O	0.05	2.64	0.00	99.99
Energy Industries: Gaseous fuels	CH ₄	0.04	1.79	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH ₄	3.10	1.56	0.00	100.00
Waste incineration	N ₂ O	0.13	0.88	0.00	100.00
Railways	CH ₄	2.40	0.76	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.00	0.51	0.00	100.00
Civil Aviation	CH ₄	0.26	0.46	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.00	0.43	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.00	0.40	0.00	100.00
Iron and Steel Production	CH ₄	0.21	0.38	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.00	0.35	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.00	0.21	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH ₄	0.82	0.15	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.00	0.09	0.00	100.00
Other transportation	N ₂ O	0.00	0.08	0.00	100.00
Other Sectors: Solid fuels	N ₂ O	0.71	0.07	0.00	100.00
Energy Industries: Biomass	CH ₄	0.00	0.06	0.00	100.00
Waste incineration	CH ₄	0.01	0.04	0.00	100.00

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Level Assessment	Cumulative total of column E
Oil, Natural Gas and Other sources	N ₂ O	0.20	0.03	0.00	100.00
Other transportation	CH ₄	0.00	0.00	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			118,286.73	100.00	

Table I.2 *Key categories analysis with LULUCF – Level assessment for 2010*

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Energy Industries: Solid fuels	CO ₂	39,679.67	32.80	32.80
Road Transportation	CO ₂	18,907.12	15.63	48.43
Other Sectors: Liquid fuels	CO ₂	8,593.67	7.10	55.54
Energy Industries: Liquid fuels	CO ₂	7,663.68	6.34	61.87
Manufacturing Industries & Construction: Liquid fuels	CO ₂	4,966.97	4.11	65.98
Energy Industries: Gaseous fuels	CO ₂	4,693.24	3.88	69.86
Cement Production	CO ₂	4,208.60	3.48	73.34
ODS substitutes	HFC	3,625.73	3.00	76.34
Solid waste disposal on land	CH ₄	3,467.99	2.87	79.20
Navigation	CO ₂	2,285.98	1.89	81.09
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	1,937.03	1.60	82.70
Forest Land remaining Forest Land	CO ₂	1,855.51	1.53	84.23
Animal Production	N ₂ O	1,759.90	1.45	85.68
Enteric fermentation: Sheep	CH ₄	1,679.97	1.39	87.07
Direct N ₂ O from agr. soils	N ₂ O	1,591.32	1.32	88.39
Civil Aviation	CO ₂	1,307.50	1.08	89.47
Coal Mining (surface)	CH ₄	1,192.85	0.99	90.46
Wastewater handling	CH ₄	1,068.16	0.88	91.34
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	1,061.54	0.88	92.22
Other Sectors: Gaseous fuels	CO ₂	911.45	0.75	92.97
Manufacturing Industries & Construction: Solid fuels	CO ₂	670.11	0.55	93.52
Enteric fermentation: Other	CH ₄	602.74	0.50	94.02
Enteric fermentation: Non Dairy Cattle	CH ₄	601.28	0.50	94.52
Ferroalloys	CO ₂	536.69	0.44	94.96
Limestone & Dolomite Use	CO ₂	457.50	0.38	95.34
Cropland remaining Cropland	CO ₂	452.08	0.37	95.72
Nitric Acid Production	N ₂ O	428.39	0.35	96.07
Wastewater handling	N ₂ O	393.31	0.33	96.39
Other Chemicals	CO ₂	362.13	0.30	96.69
Conversion to Forest Land	CO ₂	350.63	0.29	96.98
Enteric fermentation: Dairy Cattle	CH ₄	339.85	0.28	97.26
Manure management	CH ₄	314.55	0.26	97.52
Ammonia Production	CO ₂	300.84	0.25	97.77
Manure management	N ₂ O	295.84	0.24	98.02
Lime Production	CO ₂	229.96	0.19	98.21
Other Sectors: Liquid fuels	N ₂ O	216.77	0.18	98.39
Aluminium Production	CO ₂	207.22	0.17	98.56
Road Transportation	N ₂ O	190.14	0.16	98.72
Oil, Natural Gas and Other sources	CH ₄	188.13	0.16	98.87
Solvent and other product use	CO ₂	161.64	0.13	99.00
Solvent and other product use	N ₂ O	154.53	0.13	99.13
Energy Industries: Solid fuels	N ₂ O	147.76	0.12	99.25
Navigation	N ₂ O	119.81	0.10	99.35
Rice Production	CH ₄	117.60	0.10	99.45
Iron and Steel Production	CO ₂	115.61	0.10	99.55
Road Transportation	CH ₄	86.88	0.07	99.62
Other Sectors: Biomass	CH ₄	66.72	0.06	99.67

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Railways	CO2	63.00	0.05	99.73
Aluminium Production	PFCs	33.80	0.03	99.75
Field burning of agr.residues	CH4	30.47	0.03	99.78
Other Sectors: Biomass	N2O	27.70	0.02	99.80
Energy Industries: Liquid fuels	N2O	20.04	0.02	99.82
Manufacturing Industries & Construction: Other Fuels	CO2	18.79	0.02	99.83
Manufacturing Industries & Construction: Liquid fuels	N2O	16.98	0.01	99.85
Other Mineral (Glass)	CO2	15.16	0.01	99.86
Civil Aviation	N2O	13.98	0.01	99.87
Other Sectors: Solid fuels	CO2	13.97	0.01	99.88
Soda Ash Use	CO2	13.86	0.01	99.90
Manufacturing Industries & Construction: Biomass	N2O	12.63	0.01	99.91
Field burning of agr.residues	N2O	11.67	0.01	99.92
Oil, Natural Gas and Other sources	CO2	10.60	0.01	99.92
Other transportation	CO2	9.14	0.01	99.93
Railways	N2O	7.68	0.01	99.94
Other Sectors: Liquid fuels	CH4	7.65	0.01	99.94
Energy Industries: Liquid fuels	CH4	6.79	0.01	99.95
Energy Industries: Solid fuels	CH4	6.67	0.01	99.96
Manufacturing Industries & Construction: Biomass	CH4	6.42	0.01	99.96
Grassland remaining Grassland	CH4	6.38	0.01	99.97
SF6 from electrical equipment	SF6	6.14	0.01	99.97
Conversion to Settlements	CO2	4.62	0.00	99.97
Manufacturing Industries & Construction: Gaseous fuels	N2O	4.16	0.00	99.98
Navigation	CH4	3.74	0.00	99.98
Conversion to Other land	CO2	3.28	0.00	99.98
Manufacturing Industries & Construction: Solid fuels	N2O	3.23	0.00	99.99
Waste incineration	CO2	3.19	0.00	99.99
Energy Industries: Gaseous fuels	N2O	2.64	0.00	99.99
Energy Industries: Gaseous fuels	CH4	1.79	0.00	99.99
Manufacturing Industries & Construction: Liquid fuels	CH4	1.56	0.00	99.99
Waste incineration	N2O	0.88	0.00	99.99
Railways	CH4	0.76	0.00	100.00
Forest Land remaining Forest Land	CH4	0.67	0.00	100.00
Grassland remaining Grassland	N2O	0.65	0.00	100.00
Other Sectors: Gaseous fuels	N2O	0.51	0.00	100.00
Civil Aviation	CH4	0.46	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.43	0.00	100.00
Manufacturing Industries & Construction:Gaseous fuels	CH4	0.40	0.00	100.00
Iron and Steel Production	CH4	0.38	0.00	100.00
Other Sectors:Gaseous fuels	CH4	0.35	0.00	100.00
Conversion to Cropland	CO2	0.29	0.00	100.00
Conversion to Grassland	CO2	0.27	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.21	0.00	100.00

IPCC source categories	GHG	Current year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Grassland remaining Grassland	CO2	0.16	0.00	100.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.15	0.00	100.00
Energy Industries: Biomass	N2O	0.09	0.00	100.00
Other transportation	N2O	0.08	0.00	100.00
Forest Land remaining Forest Land	N2O	0.07	0.00	100.00
Other Sectors: Solid fuels	N2O	0.07	0.00	100.00
Energy Industries: Biomass	CH4	0.06	0.00	100.00
Waste incineration	CH4	0.04	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.03	0.00	100.00
Other transportation	CH4	0.00	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
Conversion to Wetland	CO2	0.00	0.00	100.00
TOTAL		120,961.35	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	CO ₂	35,207.38	33.53	33.53
Road Transportation	CO ₂	11,742.20	11.18	44.71
Other Sectors: Liquid fuels	CO ₂	8,006.48	7.62	52.34
Energy Industries: Liquid fuels	CO ₂	7,683.34	7.32	59.65
Cement Production	CO ₂	5,640.90	5.37	65.03
Manufacturing Industries & Construction: Liquid fuels	CO ₂	5,637.96	5.37	70.39
Manufacturing Industries & Construction: Solid fuels	CO ₂	3,928.07	3.74	74.14
Wastewater handling	CH ₄	3,017.06	2.87	77.01
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	2,868.92	2.73	79.74
Direct N ₂ O from agr. soils	N ₂ O	2,761.36	2.63	82.37
Solid waste disposal on land	CH ₄	2,225.69	2.12	84.49
Navigation	CO ₂	1,824.81	1.74	86.23
Animal Production	N ₂ O	1,821.24	1.73	87.96
Enteric fermentation: Sheep	CH ₄	1,655.96	1.58	89.54
Nitric Acid Production	N ₂ O	1,109.04	1.06	90.60
Coal Mining (surface)	CH ₄	1,095.27	1.04	91.64
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.89	92.53
Civil Aviation	CO ₂	716.84	0.68	93.21
Enteric fermentation: Other	CH ₄	661.10	0.63	93.84
Ferroalloys	CO ₂	622.23	0.59	94.43
Limestone & Dolomite Use	CO ₂	582.80	0.56	94.99
Enteric fermentation: Non Dairy Cattle	CH ₄	537.47	0.51	95.50
Lime Production	CO ₂	431.97	0.41	95.91
Enteric fermentation: Dairy Cattle	CH ₄	391.75	0.37	96.29
Other Sectors: Liquid fuels	N ₂ O	349.81	0.33	96.62
Manure management	N ₂ O	341.77	0.33	96.94
Manure management	CH ₄	337.46	0.32	97.27
Wastewater handling	N ₂ O	331.24	0.32	97.58
Ammonia Production	CO ₂	240.28	0.23	97.81
Aluminium Production	CO ₂	225.39	0.21	98.02
Railways	CO ₂	202.69	0.19	98.22
Solvent and other product use	CO ₂	169.71	0.16	98.38
Aluminium Production	PFCs	163.37	0.16	98.53
Road Transportation	N ₂ O	145.27	0.14	98.67
Navigation	N ₂ O	141.45	0.13	98.81
Solvent and other product use	N ₂ O	138.63	0.13	98.94
Energy Industries: Solid fuels	N ₂ O	134.19	0.13	99.07
Other Sectors: Solid fuels	CO ₂	119.43	0.11	99.18
Energy Industries: Gaseous fuels	CO ₂	102.03	0.10	99.28
Road Transportation	CH ₄	100.74	0.10	99.37
Iron and Steel Production	CO ₂	92.70	0.09	99.46
Oil, Natural Gas and Other sources	CH ₄	91.59	0.09	99.55
Other Sectors: Biomass	CH ₄	76.59	0.07	99.62
Oil, Natural Gas and Other sources	CO ₂	70.23	0.07	99.69
Rice Production	CH ₄	69.10	0.07	99.76
Soda Ash Use	CO ₂	33.16	0.03	99.79
Other Sectors: Biomass	N ₂ O	31.80	0.03	99.82
Field burning of agr. residues	CH ₄	27.06	0.03	99.84

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Level Assessment (Base Year)	Cumulative total
Railways	N ₂ O	24.40	0.02	99.87
Other Mineral (Glass)	CO ₂	20.20	0.02	99.89
Energy Industries: Liquid fuels	N ₂ O	19.40	0.02	99.90
Manufacturing Industries & Construction: Solid fuels	N ₂ O	17.74	0.02	99.92
Manufacturing Industries & Construction: Liquid fuels	N ₂ O	15.98	0.02	99.94
Field burning of agr.residues	N ₂ O	10.05	0.01	99.95
Manufacturing Industries & Construction: Biomass	N ₂ O	9.91	0.01	99.96
Civil Aviation	N ₂ O	7.71	0.01	99.96
Other Sectors: Liquid fuels	CH ₄	7.36	0.01	99.97
Energy Industries: Liquid fuels	CH ₄	6.57	0.01	99.98
Energy Industries: Solid fuels	CH ₄	6.06	0.01	99.98
Manufacturing Industries & Construction: Biomass	CH ₄	5.03	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	2.70	0.00	99.99
Railways	CH ₄	2.40	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
Civil Aviation	CH ₄	0.26	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
Oil, Natural Gas and Other sources	N ₂ O	0.20	0.00	100.00
Waste incineration	N ₂ O	0.13	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
Waste incineration	CH ₄	0.01	0.00	100.00
Energy Industries: Biomass	CH ₄	0.00	0.00	100.00
Energy Industries: Biomass	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CO ₂	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	CH ₄	0.00	0.00	100.00
Manufacturing Industries & Construction: Other Fuels	N ₂ O	0.00	0.00	100.00
Other transportation	CO ₂	0.00	0.00	100.00
Other transportation	CH ₄	0.00	0.00	100.00
Other transportation	N ₂ O	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CO ₂	0.00	0.00	100.00
Other Sectors: Gaseous fuels	CH ₄	0.00	0.00	100.00
Other Sectors: Gaseous fuels	N ₂ O	0.00	0.00	100.00
Other Chemicals	CO ₂	0.00	0.00	100.00

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Level Assessment (Base Year)	Cumulative total
ODS substitutes	HFC	0.00	0.00	100.00
TOTAL		105,005.46	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	CO ₂	35,207.38	32.71	32.71
Road Transportation	CO ₂	11,742.20	10.91	43.62
Other Sectors: Liquid fuels	CO ₂	8,006.48	7.44	51.06
Energy Industries: Liquid fuels	CO ₂	7,683.34	7.14	58.20
Cement Production	CO ₂	5,640.90	5.24	63.44
Manufacturing Industries & Construction: Liquid fuels	CO ₂	5,637.96	5.24	68.68
Manufacturing Industries & Construction: Solid fuels	CO ₂	3,928.07	3.65	72.33
Wastewater handling	CH ₄	3,017.06	2.80	75.13
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	2,868.92	2.67	77.79
Direct N ₂ O from agr. soils	N ₂ O	2,761.36	2.57	80.36
Solid waste disposal on land	CH ₄	2,225.69	2.07	82.43
Navigation	CO ₂	1,824.81	1.70	84.12
Animal Production	N ₂ O	1,821.24	1.69	85.81
Enteric fermentation: Sheep	CH ₄	1,655.96	1.54	87.35
Forest Land remaining Forest Land	CO ₂	1,379.37	1.28	88.63
Cropland remaining Cropland	CO ₂	1,205.41	1.12	89.75
Nitric Acid Production	N ₂ O	1,109.04	1.03	90.78
Coal Mining (surface)	CH ₄	1,095.27	1.02	91.80
HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.87	92.67
Civil Aviation	CO ₂	716.84	0.67	93.34
Enteric fermentation: Other	CH ₄	661.10	0.61	93.95
Ferroalloys	CO ₂	622.23	0.58	94.53
Limestone & Dolomite Use	CO ₂	582.80	0.54	95.07
Enteric fermentation: Non Dairy Cattle	CH ₄	537.47	0.50	95.57
Lime Production	CO ₂	431.97	0.40	95.97
Enteric fermentation: Dairy Cattle	CH ₄	391.75	0.36	96.34
Other Sectors: Liquid fuels	N ₂ O	349.81	0.33	96.66
Manure management	N ₂ O	341.77	0.32	96.98
Manure management	CH ₄	337.46	0.31	97.29
Wastewater handling	N ₂ O	331.24	0.31	97.60
Ammonia Production	CO ₂	240.28	0.22	97.82
Aluminium Production	CO ₂	225.39	0.21	98.03
Railways	CO ₂	202.69	0.19	98.22
Solvent and other product use	CO ₂	169.71	0.16	98.38
Aluminium Production	PFCs	163.37	0.15	98.53
Road Transportation	N ₂ O	145.27	0.13	98.66
Navigation	N ₂ O	141.45	0.13	98.80
Solvent and other product use	N ₂ O	138.63	0.13	98.93
Energy Industries: Solid fuels	N ₂ O	134.19	0.12	99.05
Other Sectors: Solid fuels	CO ₂	119.43	0.11	99.16
Energy Industries: Gaseous fuels	CO ₂	102.03	0.09	99.26
Road Transportation	CH ₄	100.74	0.09	99.35
Iron and Steel Production	CO ₂	92.70	0.09	99.44
Oil, Natural Gas and Other sources	CH ₄	91.59	0.09	99.52
Other Sectors: Biomass	CH ₄	76.59	0.07	99.59
Oil, Natural Gas and Other sources	CO ₂	70.23	0.07	99.66
Rice Production	CH ₄	69.10	0.06	99.72

IPCC source categories	GHG	Base year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Soda Ash Use	CO2	33.16	0.03	99.75
Other Sectors: Biomass	N2O	31.80	0.03	99.78
Field burning of agr.residues	CH4	27.06	0.03	99.81
Railways	N2O	24.40	0.02	99.83
Other Mineral (Glass)	CO2	20.20	0.02	99.85
Energy Industries: Liquid fuels	N2O	19.40	0.02	99.87
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	0.02	99.88
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	0.01	99.90
Grassland remaining Grassland	CH4	14.03	0.01	99.91
Forest Land remaining Forest Land	CH4	12.86	0.01	99.92
Conversion to Other land	CO2	10.78	0.01	99.93
Field burning of agr.residues	N2O	10.05	0.01	99.94
Manufacturing Industries & Construction: Biomass	N2O	9.91	0.01	99.95
Civil Aviation	N2O	7.71	0.01	99.96
Other Sectors: Liquid fuels	CH4	7.36	0.01	99.96
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	99.98
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	0.00	99.98
SF6 from electrical equipment	SF6	3.07	0.00	99.99
Conversion to Settlements	CO2	2.93	0.00	99.99
Navigation	CH4	2.70	0.00	99.99
Railways	CH4	2.40	0.00	99.99
Grassland remaining Grassland	N2O	1.42	0.00	100.00
Forest Land remaining Forest Land	N2O	1.31	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
Civil Aviation	CH4	0.26	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
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
Conversion to Cropland	CO2	0.03	0.00	100.00
Conversion to Cropland	CO2	0.03	0.00	100.00
Conversion to Grassland	CO2	0.01	0.00	100.00
Waste incineration	CH4	0.01	0.00	100.00
Conversion to Wetland	CO2	0.00	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

IPCC source categories	GHG	Base year (Gg CO ₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
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
Conversion to Forest Land	CO2	0.00	0.00	100.00
TOTAL		107,633.66	100.00	

Table I.5 Key categories analysis without LULUCF – Trend assessment for 2010

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
Road Transportation	CO2	11,742.20	18,907.12	0.04	0.15	0.15
Energy Industries: Gaseous fuels	CO2	102.03	4,693.24	0.03	0.13	0.27
Manufacturing Industries & Construction: Solid fuels	CO2	3,928.07	670.11	0.03	0.10	0.38
ODS substitutes	HFC	0.00	3,625.73	0.03	0.10	0.48
Wastewater handling	CH4	3,017.06	1,068.16	0.02	0.07	0.54
Cement Production	CO2	5,640.90	4,208.60	0.02	0.06	0.61
Direct N2O from agr. soils	N2O	2,761.36	1,591.32	0.01	0.04	0.65
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	4,966.97	0.01	0.04	0.69
Indirect N2O from nitrogen used in agr.	N2O	2,868.92	1,937.03	0.01	0.04	0.73
Energy Industries: Liquid fuels	CO2	7,683.34	7,663.68	0.01	0.03	0.76
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,061.54	0.01	0.03	0.79
Solid waste disposal on land	CH4	2,225.69	3,467.99	0.01	0.03	0.81
Other Sectors: Gaseous fuels	CO2	0.00	911.45	0.01	0.02	0.84
Nitric Acid Production	N2O	1,109.04	428.39	0.01	0.02	0.86
Energy Industries: Solid fuels	CO2	35,207.38	39,679.67	0.00	0.02	0.88
Other Sectors: Liquid fuels	CO2	8,006.48	8,593.67	0.00	0.02	0.89
Civil Aviation	CO2	716.84	1,307.50	0.00	0.01	0.90
Other Chemicals	CO2	0.00	362.13	0.00	0.01	0.91
Animal Production	N2O	1,821.24	1,759.90	0.00	0.01	0.92
Lime Production	CO2	431.97	229.96	0.00	0.01	0.93
Enteric fermentation: Sheep	CH4	1,655.96	1,679.97	0.00	0.01	0.94
Limestone & Dolomite Use	CO2	582.80	457.50	0.00	0.01	0.94
Navigation	CO2	1,824.81	2,285.98	0.00	0.01	0.95
Other Sectors: Liquid fuels	N2O	349.81	216.77	0.00	0.01	0.95
Ferroalloys	CO2	622.23	536.69	0.00	0.00	0.96
Railways	CO2	202.69	63.00	0.00	0.00	0.96
Enteric fermentation: Other	CH4	661.10	602.74	0.00	0.00	0.97
Aluminium Production	PFCs	163.37	33.80	0.00	0.00	0.97
Other Sectors: Solid fuels	CO2	119.43	13.97	0.00	0.00	0.97
Enteric fermentation: Dairy Cattle	CH4	391.75	339.85	0.00	0.00	0.98
Manure management	N2O	341.77	295.84	0.00	0.00	0.98
Oil, Natural Gas and Other sources	CH4	91.59	188.13	0.00	0.00	0.98
Manure management	CH4	337.46	314.55	0.00	0.00	0.98
Oil, Natural Gas and Other sources	CO2	70.23	10.60	0.00	0.00	0.99
Coal Mining (surface)	CH4	1,095.27	1,192.85	0.00	0.00	0.99
Aluminium Production	CO2	225.39	207.22	0.00	0.00	0.99
Navigation	N2O	141.45	119.81	0.00	0.00	0.99
Rice Production	CH4	69.10	117.60	0.00	0.00	0.99
Solvent and other product use	CO2	169.71	161.64	0.00	0.00	0.99
Road Transportation	CH4	100.74	86.88	0.00	0.00	0.99
Ammonia Production	CO2	240.28	300.84	0.00	0.00	0.99
Soda Ash Use	CO2	33.16	13.86	0.00	0.00	0.99
Road Transportation	N2O	145.27	190.14	0.00	0.00	0.99
Other Sectors: Biomass	CH4	76.59	66.72	0.00	0.00	1.00
Railways	N2O	24.40	7.68	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	18.79	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	3.23	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
Wastewater handling	N2O	331.24	393.31	0.00	0.00	1.00
Enteric fermentation:Non Dairy Cattle	CH4	537.47	601.28	0.00	0.00	1.00
Iron and Steel Production	CO2	92.70	115.61	0.00	0.00	1.00
Other transportation	CO2	0.00	9.14	0.00	0.00	1.00
Other Sectors: Biomass	N2O	31.80	27.70	0.00	0.00	1.00
Other Mineral (Glass)	CO2	20.20	15.16	0.00	0.00	1.00
Energy Industries: Solid fuels	N2O	134.19	147.76	0.00	0.00	1.00
Civil Aviation	N2O	7.71	13.98	0.00	0.00	1.00
Solvent and other product use	N2O	138.63	154.53	0.00	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	4.16	0.00	0.00	1.00
Waste incineration	CO2	0.22	3.19	0.00	0.00	1.00
SF6 from electrical equipment	SF6	3.07	6.14	0.00	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	2.64	0.00	0.00	1.00
Energy Industries: Liquid fuels	N2O	19.40	20.04	0.00	0.00	1.00
Railways	CH4	2.40	0.76	0.00	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	1.56	0.00	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.79	0.00	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	16.98	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.91	12.63	0.00	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.82	0.15	0.00	0.00	1.00
Other Sectors: Liquid fuels	CH4	7.36	7.65	0.00	0.00	1.00
Other Sectors: Solid fuels	N2O	0.71	0.07	0.00	0.00	1.00
Waste incineration	N2O	0.13	0.88	0.00	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.57	6.79	0.00	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.03	6.42	0.00	0.00	1.00
Navigation	CH4	2.70	3.74	0.00	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.51	0.00	0.00	1.00
Field burning of agr.residues	CH4	27.06	30.47	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.43	0.00	0.00	1.00
Manufacturing Industries & Construction:Gaseous fuels	CH4	0.00	0.40	0.00	0.00	1.00
Other Sectors:Gaseous fuels	CH4	0.00	0.35	0.00	0.00	1.00
Energy Industries: Solid fuels	CH4	6.06	6.67	0.00	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.21	0.00	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.20	0.03	0.00	0.00	1.00
Field burning of agr.residues	N2O	10.05	11.67	0.00	0.00	1.00
Civil Aviation	CH4	0.26	0.46	0.00	0.00	1.00
Iron and Steel Production	CH4	0.21	0.38	0.00	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.09	0.00	0.00	1.00
Other transportation	N2O	0.00	0.08	0.00	0.00	1.00
Other Sectors: Solid fuels	CH4	0.05	0.00	0.00	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.06	0.00	0.00	1.00
Waste incineration	CH4	0.01	0.04	0.00	0.00	1.00
Other transportation	CH4	0.00	0.00	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

IPCC source categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
TOTAL		105,005.46	118,286.73	0.27	1.00	

Table I.6 *Key categories analysis with LULUCF – Trend assessment for 2010*

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
Road Transportation	CO2	11,742.20	18,907.12	0.04332	0.15	0.15
Energy Industries: Gaseous fuels	CO2	102.03	4,693.24	0.03508	0.12	0.28
Manufacturing Industries & Construction: Solid fuels	CO2	3,928.07	670.11	0.02883	0.10	0.38
ODS substitutes	HFC	0.00	3,625.73	0.02778	0.10	0.48
Wastewater handling	CH4	3,017.06	1,068.16	0.01791	0.06	0.54
Cement Production	CO2	5,640.90	4,208.60	0.01653	0.06	0.60
Direct N2O from agr. soils	N2O	2,761.36	1,591.32	0.01169	0.04	0.64
Manufacturing Industries & Construction: Liquid fuels	CO2	5,637.96	4,966.97	0.01070	0.04	0.68
Indirect N2O from nitrogen used in agr.	N2O	2,868.92	1,937.03	0.00997	0.04	0.71
Manufacturing Industries & Construction: Gaseous fuels	CO2	0.00	1,061.54	0.00813	0.03	0.74
Energy Industries: Liquid fuels	CO2	7,683.34	7,663.68	0.00772	0.03	0.77
Solid waste disposal on land	CH4	2,225.69	3,467.99	0.00732	0.03	0.79
Other Sectors: Gaseous fuels	CO2	0.00	911.45	0.00698	0.02	0.82
Cropland remaining Cropland	CO2	-1,205.41	-452.08	0.00696	0.02	0.84
Nitric Acid Production	N2O	1,109.04	428.39	0.00631	0.02	0.86
Civil Aviation	CO2	716.84	1,307.50	0.00382	0.01	0.88
Other Sectors: Liquid fuels	CO2	8,006.48	8,593.67	0.00339	0.01	0.89
Other Chemicals	CO2	0.00	362.13	0.00277	0.01	0.90
Conversion to Forest Land	CO2	0.00	-350.63	0.00269	0.01	0.91
Forest Land remaining Forest Land	CO2	-1,379.37	-1,855.51	0.00229	0.01	0.92
Animal Production	N2O	1,821.24	1,759.90	0.00226	0.01	0.92
Lime Production	CO2	431.97	229.96	0.00197	0.01	0.93
Navigation	CO2	1,824.81	2,285.98	0.00173	0.01	0.94
Limestone & Dolomite Use	CO2	582.80	457.50	0.00153	0.01	0.94
Enteric fermentation: Sheep	CH4	1,655.96	1,679.97	0.00145	0.01	0.95
Other Sectors: Liquid fuels	N2O	349.81	216.77	0.00136	0.00	0.95
Railways	CO2	202.69	63.00	0.00127	0.00	0.96
Ferroalloys	CO2	622.23	536.69	0.00127	0.00	0.96
Aluminium Production	PFCs	163.37	33.80	0.00115	0.00	0.97
Enteric fermentation: Other	CH4	661.10	602.74	0.00110	0.00	0.97
Other Sectors: Solid fuels	CO2	119.43	13.97	0.00093	0.00	0.97
Enteric fermentation: Dairy Cattle	CH4	391.75	339.85	0.00078	0.00	0.98
Manure management	N2O	341.77	295.84	0.00069	0.00	0.98
Oil, Natural Gas and Other sources	CH4	91.59	188.13	0.00065	0.00	0.98
Oil, Natural Gas and Other sources	CO2	70.23	10.60	0.00053	0.00	0.98
Manure management	CH4	337.46	314.55	0.00051	0.00	0.98
Energy Industries: Solid fuels	CO2	35,207.38	39,679.67	0.00043	0.00	0.99
Aluminium Production	CO2	225.39	207.22	0.00036	0.00	0.99
Coal Mining (surface)	CH4	1,095.27	1,192.85	0.00033	0.00	0.99
Navigation	N2O	141.45	119.81	0.00031	0.00	0.99
Rice Production	CH4	69.10	117.60	0.00030	0.00	0.99
Solvent and other product use	CO2	169.71	161.64	0.00023	0.00	0.99
Ammonia Production	CO2	240.28	300.84	0.00023	0.00	0.99
Road Transportation	CH4	100.74	86.88	0.00021	0.00	0.99
Road Transportation	N2O	145.27	190.14	0.00020	0.00	0.99
Soda Ash Use	CO2	33.16	13.86	0.00018	0.00	0.99
Railways	N2O	24.40	7.68	0.00015	0.00	0.99
Other Sectors: Biomass	CH4	76.59	66.72	0.00015	0.00	1.00

IPCC source / sink categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessme nt (Absolute)	Contribution to trend (%)	Cumulative total
Wastewater handling	N2O	331.24	393.31	0.00015	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CO2	0.00	18.79	0.00014	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	N2O	17.74	3.23	0.00013	0.00	1.00
Forest Land remaining Forest Land	CH4	12.86	0.67	0.00011	0.00	1.00
Iron and Steel Production	CO2	92.70	115.61	0.00008	0.00	1.00
Grassland remaining Grassland	CH4	14.03	6.38	0.00007	0.00	1.00
Other transportation	CO2	0.00	9.14	0.00007	0.00	1.00
Conversion to Other land	CO2	10.78	3.28	0.00007	0.00	1.00
Other Sectors: Biomass	N2O	31.80	27.70	0.00006	0.00	1.00
Other Mineral (Glass)	CO2	20.20	15.16	0.00006	0.00	1.00
Enteric fermentation:Non Dairy Cattle	CH4	537.47	601.28	0.00004	0.00	1.00
Civil Aviation	N2O	7.71	13.98	0.00004	0.00	1.00
Manufacturing Industries & Construction: Gaseous fuels	N2O	0.00	4.16	0.00003	0.00	1.00
Energy Industries: Solid fuels	N2O	134.19	147.76	0.00003	0.00	1.00
Waste incineration	CO2	0.22	3.19	0.00002	0.00	1.00
SF6 from electrical equipment	SF6	3.07	6.14	0.00002	0.00	1.00
Energy Industries: Gaseous fuels	N2O	0.05	2.64	0.00002	0.00	1.00
Railways	CH4	2.40	0.76	0.00001	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	CH4	3.10	1.56	0.00001	0.00	1.00
Solvent and other product use	N2O	138.63	154.53	0.00001	0.00	1.00
Energy Industries: Liquid fuels	N2O	19.40	20.04	0.00001	0.00	1.00
Energy Industries: Gaseous fuels	CH4	0.04	1.79	0.00001	0.00	1.00
Manufacturing Industries & Construction: Biomass	N2O	9.91	12.63	0.00001	0.00	1.00
Forest Land remaining Forest Land	N2O	1.31	0.07	0.00001	0.00	1.00
Conversion to Settlements	CO2	2.93	4.62	0.00001	0.00	1.00
Manufacturing Industries & Construction: Liquid fuels	N2O	15.98	16.98	0.00001	0.00	1.00
Grassland remaining Grassland	N2O	1.42	0.65	0.00001	0.00	1.00
Manufacturing Industries & Construction: Solid fuels	CH4	0.82	0.15	0.00001	0.00	1.00
Waste incineration	N2O	0.13	0.88	0.00001	0.00	1.00
Manufacturing Industries & Construction: Biomass	CH4	5.03	6.42	0.00001	0.00	1.00
Other Sectors: Solid fuels	N2O	0.71	0.07	0.00001	0.00	1.00
Navigation	CH4	2.70	3.74	0.00001	0.00	1.00
Other Sectors: Liquid fuels	CH4	7.36	7.65	0.00001	0.00	1.00
Energy Industries: Liquid fuels	CH4	6.57	6.79	0.00000	0.00	1.00
Other Sectors: Gaseous fuels	N2O	0.00	0.51	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	N2O	0.00	0.43	0.00000	0.00	1.00
Manufacturing Industries & Construction:Gaseous fuels	CH4	0.00	0.40	0.00000	0.00	1.00
Other Sectors:Gaseous fuels	CH4	0.00	0.35	0.00000	0.00	1.00
Field burning of agr.residues	N2O	10.05	11.67	0.00000	0.00	1.00
Conversion to Grassland	CO2	0.01	0.27	0.00000	0.00	1.00
Conversion to Cropland	CO2	0.03	0.29	0.00000	0.00	1.00
Manufacturing Industries & Construction: Other Fuels	CH4	0.00	0.21	0.00000	0.00	1.00
Oil, Natural Gas and Other sources	N2O	0.20	0.03	0.00000	0.00	1.00

IPCC source / sink categories	GHG	Base year (Gg CO ₂ eq)	Current year (Gg CO ₂ eq)	Trend Assessme nt (Absolute)	Contribution to trend (%)	Cumulative total
Energy Industries: Solid fuels	CH4	6.06	6.67	0.00000	0.00	1.00
Civil Aviation	CH4	0.26	0.46	0.00000	0.00	1.00
Iron and Steel Production	CH4	0.21	0.38	0.00000	0.00	1.00
Grassland remaining Grassland	CO2	0.03	0.16	0.00000	0.00	1.00
Energy Industries: Biomass	N2O	0.00	0.09	0.00000	0.00	1.00
Other transportation	N2O	0.00	0.08	0.00000	0.00	1.00
Field burning of agr.residues	CH4	27.06	30.47	0.00000	0.00	1.00
Other Sectors: Solid fuels	CH4	0.05	0.00	0.00000	0.00	1.00
Energy Industries: Biomass	CH4	0.00	0.06	0.00000	0.00	1.00
Waste incineration	CH4	0.01	0.04	0.00000	0.00	1.00
Other transportation	CH4	0.00	0.00	0.00000	0.00	1.00
Other Chemicals	CH4	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
Conversion to Wetland	CO2	0.00	0.00	0.00000	0.00	1.00
TOTAL		102,507.45	114,088.67	0.28	1.00	

The results of the key categories analysis for the year 2010 are summed up in **Table I.7**. Finally in **Table I.8** the Table NIR.3 as contained in the annex to decision 6/CMP.3 can be found

Table I.7 *Source Category Analysis Summary for 2010*

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	Level, 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, Trend	T2
Civil Aviation	CH4	No		
Civil Aviation	N2O	No		
Navigation	CO2	Yes	Level, Trend	T1
Navigation	CH4	No		
Navigation	N2O	No		

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
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		
Other Sectors: Solid fuels	CO2	No		
Other Sectors: Solid fuels	CH4	No		
Other Sectors: Solid fuels	N2O	No		
Other Sectors: Gaseous fuels	CO2	Yes	Level, Trend	T2
Other Sectors: Gaseous fuels	CH4	No		
Other Sectors: Gaseous fuels	N2O	No		
Other Sectors: Biomass	CH4	No		
Other Sectors: Biomass	N2O	No		
Coal Mining (surface)	CH4	Yes	Level	T1
Oil, Natural Gas and Other sources	CO2	No		
Oil, Natural Gas and Other sources	CH4	No		
Oil, Natural Gas and Other sources	N2O	No		
INDUSTRIAL PROCESSES SECTOR				
Cement Production	CO2	Yes	Level, Trend	CS
Lime Production	CO2	No	Trend	CS
Limestone & Dolomite Use	CO2	No	Level, Trend	CS, T1
Soda Ash Use	CO2	No		
Other Mineral (Glass)	CO2	No		
Other Chemicals	CH4	No		
Other Chemicals	CO2	Yes	Trend	T1
Nitric Acid Production	N2O	Yes	Trend	D
Ammonia Production	CO2	No		
Iron and Steel Production	CO2	No		
Iron and Steel Production	CH4	No		
Ferroalloys	CO2	No	Level	CS
Aluminium Production	CO2	No		
Aluminium Production	PFCs	No		
HFC-23 Emissions from HCFC-22 Manufacture	HFC	No	Trend	NA
ODS substitutes	HFC	Yes	Level, Trend	CS, T2
SF6 from electrical equipment	SF6	No		
Solvent and other product use	CO2	No		
Solvent and other product use	N2O	No		
AGRICULTURE				
Enteric fermentation:Dairy Cattle	CH4	No		
Enteric fermentation:Non Dairy Cattle	CH4	No	Level	T2
Enteric fermentation: Sheep	CH4	Yes	Level, Trend	T2
Enteric fermentation: Other	CH4	Yes	Level	T1
Manure management	CH4	No		
Manure management	N2O	No		
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, Trend	D

Quantitative method used	Tier 1			
IPCC source categories	GHG	Key source category flag	If flag is yYes, Criteria for identification	Comments
Indirect N ₂ O from nitrogen used in agr.	N ₂ O	Yes	Level, Trend	T1a
Rice Production	CH ₄	No		
WASTE				
Solid waste disposal on land	CH ₄	Yes	Level	T2
Wastewater handling	CH ₄	Yes	Level, Trend	CS, D
Wastewater handling	N ₂ O	No		
Waste incineration	CO ₂	No		
LULUCF				
Forest Land remaining Forest Land	CO ₂	Yes	Level, Trend	T2
Forest Land remaining Forest Land	CH ₄			
Forest Land remaining Forest Land	N ₂ O			
Cropland remaining Cropland	CO ₂	Yes	Trend	T1, T2
Grassland remaining Grassland	CH ₄			
Grassland remaining Grassland	N ₂ O			
Conversion to Forest Land	CO ₂	Yes	Trend	T1
Conversion to Cropland	CO ₂			
Conversion to Grassland	CO ₂			
Conversion to Wetland	CO ₂			
Conversion to Settlements	CO ₂			
Conversion to Other land	CO ₂			

Table I.8 **Table NIR.3 for year 2010**

Information type	Unit	2010
Afforestation and Reforestation		
CO ₂		
Associated LULUCF category		Conversion to forest land
Category contribution > than smallest UNFCCC key category		Yes
Other identification criteria		
Comments		Trend assessment
Forest Management		
CO ₂		
Associated LULUCF category		Forest land remaining forest land
Category contribution > than smallest UNFCCC key category		Yes
Other identification criteria		
Comments		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, naphtha, HFO and natural gas, manufacturing industries (cement, lime ceramics etc) combusting coal, petcoke, HFO and alternative fuels (e.g. scrap tyres). For all these sources the EU ETS reports use only high tier methods. The EU ETS data have been applied for the years 2005 - 2010. 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	
CHP plants	1.A.2a – 1.A.2f	0101 – Public power / steam turbines, gas turbines, stationary engines
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	
Machinery	1.A.2f	
Mining	1.A.2f	
Food and tobacco	1.A.2e	
Paper. pulp	1.A.2d	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
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
Internal navigation	1.A.3d	080402 – National sea traffic within EMEP area

Energy balance sectors	IPCC source categories	CORINAIR activities
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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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	55,520
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	13	30	34
Exports	0	0	14	0	0	0	0	22	6	21	21	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
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
Transfers	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
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
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
CHP plants ¹⁸	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
BKB plants	350	351	203	178	214	191	157	169	133	124	236	265	345	419	422	411	266	188	39	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
INDUSTRY	515	432	379	552	406	408	503	418	362	235	381	172	156	195	195	224	345	313	304	29	22
Iron and steel	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
Non-ferrous metals ¹⁹	299	318	359	445	333	342	439	359	355	233	379	170	156	195	195	224	345	313	304	29	22
Non-metallic minerals	17	20	13	22	15	4	4	2	2	2	2	2	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
OTHER SECTORS	78	125	121	130	104	123	138	109	102	75	83	78	0	0	4	32	31	4	32	19	26
Agriculture	19	25	33	40	30	40	45	30	30	48	53	50	0	0	0	20	30	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
Residential	59	100	88	90	74	83	93	79	72	27	30	28	0	0	1	12	1	4	32	19	26
Non-specified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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

¹⁸ Fuel consumption in CHP plants is included in electricity plants.¹⁹ Accounted in Industrial Processes sector.

Table II.3 *Energy balance of natural gas in TJ (GCV) for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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	327
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
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
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	150,442
Transfers	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	105
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
Electricity 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
CHP plants ²⁰	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
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
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
Distribution losses	0	0	0	0	0	0	0	94	40	36	568	466	27	64	235	331	393	305	224	1,090	812
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
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
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
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
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
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
Transport equipment	0	0	0	0	0	0	0	9	74	62	46	81	55	66	68	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
Mining and Quarrying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213	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
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
Wood and wood products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	26	35	28	41	38	42
Construction	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

²⁰ 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
Non-specified	0	0	0	0	0	0	0	0	5	0	241	792	456	403	593	618	501	761	640	550	534
TRANSPORT	0	0	0	0	0	0	0	0	0	0	0	325	557	567	537	629	670	815	977	685	658
Road transport	0	0	0	0	0	0	0	0	0	0	0	284	449	495	493	552	582	667	660	685	658
Pipeline transport	0	0	0	0	0	0	0	0	0	0	0	41	108	72	44	77	88	148	317	16	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
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
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
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

Table II.4 *Energy balance of heavy fuel oil (in kt) for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
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
Stock changes	-80	-223	121	196	204	81	-72	7	-41	45	-32	25	-66	-36	159	-47	16	-261	219	-191	48
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
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
Statistical differences	-245	186	143	-14	-17	-178	139	60	-117	-89	-37	-72	-38	-68	-128	-62	-26	-163	-82	-24	-55
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
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
CHP plants ²¹	34	49	58	67	58	58	55	39	30	24	27	19	20	9	7	6	7	5	68	13	7
ENERGY SECTOR	266	279	260	210	273	274	295	294	320	313	372	358	397	351	416	442	482	465	448	422	427
Petroleum refineries	266	279	260	210	273	274	295	294	320	313	372	358	397	351	416	442	482	465	448	422	427
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
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
Iron and steel	101	96	97	86	78	47	21	16	18	8	18	19	20	17	13	4	5	5	4	3	3
Chemical industry	92	45	43	26	24	29	106	124	159	81	87	82	82	74	110	106	123	120	99	65	58
Non-ferrous metals	185	157	161	157	144	142	162	185	151	211	214	216	227	224	235	177	198	193	166	100	89
Non-metallic minerals	159	174	188	177	165	179	178	182	94	67	89	86	86	78	132	138	157	153	130	92	81
Transport equipment	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	4	4	3	2	2
Machinery	0	0	0	0	0	0	13	13	13	12	15	15	15	10	7	6	7	7	6	5	4
Mining	22	21	23	21	20	50	67	52	42	42	43	43	45	3	3	3	4	4	3	2	2
Food and tobacco	241	250	255	257	240	235	249	224	236	181	208	187	188	205	164	104	125	122	102	67	59
Paper, pulp	84	81	80	71	65	59	77	85	66	66	81	66	67	64	47	42	47	46	38	24	21
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
Construction	0	27	26	22	21	50	20	17	21	18	30	30	35	30	25	28	32	31	27	19	17
Textile and leather	111	93	108	91	82	88	140	137	101	79	92	81	77	68	60	54	46	42	36	22	19

²¹ 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
Non-specified	157	160	113	0	0	16	29	7	23	0	0	0	0	0	0	0	40	42	36	24	21
TRANSPORT	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359	350	292	630	462
Internal navigation	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359	350	292	630	462
OTHER SECTORS	62	79	78	55	40	21	28	28	28	28	28	34	35	36	44	47	60	59	52	35	0
Agriculture	0	20	21	15	15	10	15	15	15	15	15	18	18	19	21	23	31	30	30	20	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
Residential	36	35	38	25	15	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
NON-ENERGY USE	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 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
International marine bunkers	510	514	657	718	801	966	776	771	758	706	750	612	549	497	472	384	398	365	339	318	344
Stock changes	-169	162	99	-51	-32	67	-166	-133	-468	419	108	35	-251	129	-204	-271	-204	178	-180	353	-84
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
Transfers	0	0	0	-25	0	-171	-554	-667	-592	-646	-208	89	36	1	141	140	-20	32	78	-199	0
Statistical differences	7	-23	-47	-150	-2	-176	-177	-158	-244	-83	-98	-61	-16	-214	254	-59	-449	-453	-291	-270	-24
TRANSFORMATION	315	319	339	287	272	305	381	367	371	336	382	376	465	499	452	429	438	514	425	347	324
Electricity plants	314	312	338	287	272	305	381	367	371	336	382	376	465	499	448	424	427	507	415	399	308
CHP plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	11	7	10	8	16
ENERGY SECTOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	26	27	26	23	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	6384	5,712
INDUSTRY SECTOR	354	319	290	296	320	457	490	500	525	560	504	500	500	550	227	439	486	435	419	345	291
Iron and steel	41	20	20	26	28	18	5	11	12	20	13	13	15	17	1	1	1	1	1	1	1
Chemical industry	15	12	11	11	12	8	5	3	9	10	9	9	9	9	9	10	10	9	9	9	8
Non-ferrous metals	0	25	24	25	27	38	28	13	21	23	23	23	20	23	1	2	2	2	2	2	2
Non-metallic minerals	49	30	31	31	34	48	36	40	49	53	49	48	42	48	3	4	4	4	4	4	3
Transport equipment	0	2	2	2	2	12	12	7	15	17	16	15	15	16	15	17	18	18	17	17	15
Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mining	43	32	31	32	35	49	43	45	41	42	41	40	40	45	38	40	41	37	36	29	26
Food and tobacco	33	35	33	39	42	59	45	37	49	53	51	51	50	52	22	23	23	21	20	17	15
Paper, pulp	12	11	10	14	15	8	5	10	9	10	10	10	10	14	2	3	3	3	3	3	3
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
Construction	0	1	1	1	1	1	75	94	118	126	130	130	135	140	131	140	142	127	122	130	110
Textile and leather	17	16	15	20	22	18	10	3	5	8	10	10	7	8	5	5	4	3	3	3	3
Non-specified	144	135	112	95	102	198	224	235	195	195	150	150	156	177	0	194	238	210	202	130	105

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
Rail	63	49	47	48	52	43	45	42	42	40	40	40	40	40	40	40	41	37	36	30	20
Internal navigation	336	357	348	350	325	285	229	236	352	289	263	345	330	301	308	328	358	320	309	274	271
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
Agriculture	820	888	822	802	808	750	761	760	760	760	760	770	850	929	786	806	845	757	731	575	511
Commercial and public	145	167	155	150	160	165	200	192	195	195	203	270	278	300	285	365	371	332	321	233	207
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
Non-specified	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

Table II.6 *Energy balance of gasoline (in kt) for the period 1990 – 2010*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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
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
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
Stock changes	-45	59	-171	11	141	34	-4	-115	-69	169	-27	3	-122	53	11	1	-259	59	-32	192	-46
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
Transfers	0	0	0	0	0	0	42	4	28	17	22	167	153	166	121	99	140	76	161	27	410
Statistical differences	27	-36	-65	-23	-7	141	-119	-50	-19	0	-123	-7	-5	-6	-159	2	-100	-448	-131	8	65
TRANSFORMATION	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
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
<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>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>
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
OTHER SECTORS	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28	29	28	28	25
Agriculture	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28	29	28	28	25
Non specified	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

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*

Source 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 in 2010*

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 - 2010*

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

Table III.2 Reference approach for 2010

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	115.00	20,129.00	847.00		-178.00	19,575.00	42.75	NCV	836,831.25	20.00	16,736.63	NA	16,736.63	0.99	60,753.95	
		Orimulsion		NA	NA	NA		NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Natural Gas Liquids		2.27	NA	NA		NA	2.27	41.56	NCV	94.30	17.20	1.62	NA	1.62	0.99	5.89	
	Secondary Fuels	Gasoline	kt		371.00	1,372.00	NA	111.00	-1,112.00	43.96	NCV	-48,883.52	18.90	-923.90	NA	-923.90	0.99	-3,353.75	
		Jet Kerosene	kt		451.00	945.00	664.00	216.00	-1,374.00	44.59	NCV	-61,266.66	19.46	-1,192.28	NA	-1,192.28	0.99	-4,327.98	
		Other Kerosene			0.00	3.00	NA	3.00	-6.00	44.75	NCV	-268.50	19.60	-5.26	NA	-5.26	0.99	-19.10	
		Shale Oil			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Gas / Diesel Oil	kt		2,505.00	2,997.00	344.00	60.00	-896.00	43.00	NCV	-38,528.00	20.20	-778.27	NO	-778.27	0.99	-2,825.10	
		Residual Fuel Oil	kt		1,558.00	2,172.00	2,444.00	-103.00	-2,955.00	40.19	NCV	-118,761.45	21.10	-2,505.87	NA	-2,505.87	0.99	-9,096.30	
		Liquefied Petroleum Gas (LPG)	kt		9.00	352.00		20.00	-363.00	47.31	NCV	-17,173.53	17.20	-295.38	NO	-295.38	0.99	-1,072.25	
		Ethane			NA	NA		NA	NA	NA	NCV	NA	NA	NA	NO	NA,NO	NA	NA,NO	NA
		Naphtha	kt		79.00	425.00		57.00	-403.00	45.01	NCV	-18,139.03	20.00	-362.78	75.09	-437.87	0.99	-1,589.48	
		Bitumen	kt		NA	218.00		7.00	-225.00	40.19	NCV	-9,042.75	20.00	-180.86	216.22	-397.08	0.99	-1,441.39	
		Lubricants	kt		7.00	163.00	25.00	-2.00	-179.00	40.19	NCV	-7,194.01	20.00	-143.88	12.86	-156.74	0.99	-568.97	
		Petroleum Coke	kt		690.00	NA		-5.00	695.00	32.01	NCV	22,249.57	25.90	576.27	NA	576.27	0.99	2,091.87	
		Refinery Feedstocks	kt		992.00	NA		-760.00	1,752.00	41.32	NCV	72,389.14	20.00	1,447.78	NA	1,447.78	0.99	5,255.45	
		Other Oil				NA	0.00		-10.00	10.00	40.19	NCV	401.90	20.00	8.04	61.89	-53.85	0.99	-195.49
	Other Liquid Fossil												NA		NA	NA	NA		NA
	Other non-specified				NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
Liquid Fossil Totals												612,708.71		12,381.86	366.07	12,015.80		43,617.35	
Solid Fossil	Primary Fuels	Anthracite ⁽²⁾			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Coking Coal			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NO	NA,NO	NA	NA,NO	NA
		Other Bituminous Coal	kt		NA	617.00	0.00	343.00	274.00	25.13	NCV	6,886.26	26.70	183.87	NA	183.87	0.98	660.69	
		Sub-bituminous Coal			NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		Lignite	kt		56,520.00	34.00	NA	-1,128.00	57,682.00	5.50	NCV	317,123.25	34.75	11,020.04	NA	11,020.04	0.98	39,598.69	
		Oil Shale			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
	Secondary Fuels	Peat			NA	NA	NA		NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA
		BKB ⁽³⁾ and Patent Fuel				NA	NA	NA	0.00	0.00	0.00	NCV	0.00	25.80	0.00	NA	0.00	0.98	0.00
		Coke Oven/Gas Coke	kt			5.21	NA		NA	5.21	27.84	NCV	145.05	29.50	4.28	NA	4.28	0.98	15.38
	Other Solid Fossil												NA		NA	NA	NA		NA
Other non-specified				NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	NA	
Solid Fossil Totals												324,154.56		11,208.19	NA,NO	11,208.19		40,274.76	
Gaseous Fossil		Natural Gas (Dry)	TJ	294.30	134,039.29	NA		-159.30	134,492.89	1.00	NCV	134,492.89	15.16	2,039.06	73.47	1,965.59	1.00	7,207.17	
Other Gaseous Fossil												NA		NA	NA	NA		NA	
Other non-specified				NA	NA	NA	NA	NA	NA	NA	NCV	NA	NA	NA	NA	NA	NA	NA	
Gaseous Fossil Totals												134,492.89		2,039.06	73.47	1,965.59		7,207.17	
Total												1,071,356.15		25,629.12	439.54	25,189.58		91,099.27	
Biomass total												0.00		0.00	NA	0.00		0.00	
		Solid Biomass		0.00	0.00	NA		NA	0.00	0.00	NCV	0.00	0.00	0.00	NA	0.00	0.00	0.00	
		Liquid Biomass		0.00	NA	NA		NA	0.00	0.00	NCV	0.00	0.00	0.00	NA	0.00	0.00	0.00	
		Gas Biomass		0.00	NA	NA		NA	0.00	0.00	NCV	0.00	0.00	0.00	NA	0.00	0.00	0.00	

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
Railway	CH ₄	Activity data obtained from national energy balance.	IPCC default

IPCC Source category	Gas	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
		5% corresponds to the IPCC default uncertainty range.	
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."
Refrigeration and Air Conditioning Equipment	PFC	Assumption on HFCs penetration	Expert judgement , in default range
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	39,254.88	40,363.76	3	3	4.2	1.5	-0.0325	0.3844	-0.10	1.63	1.63
1A 1,2,4	Stationary Combustion - liquid fuels	CO ₂	21,327.77	21,224.32	3	3	4.2	0.8	-0.0244	0.2021	-0.07	0.86	0.86
1A 1,2,4	Stationary Combustion - gaseous fuels	CO ₂	102.03	6,666.23	3	2	3.6	0.2	0.0624	0.0635	0.12	0.27	0.30
1A2	Stationary Combustion - Other fuels	CO ₂	0.00	18.79	3	3	4.2	0.0	0.0002	0.0002	0.00	0.00	0.00
1A3	Road transport	CO ₂	11,742.20	18,907.12	5	5	7.1	1.1	0.0553	0.1801	0.28	1.27	1.30
1A3	Navigation	CO ₂	1,824.81	2,285.98	5	5	7.1	0.1	0.0024	0.0218	0.01	0.15	0.15
1A3	Civil Aviation	CO ₂	716.84	1,307.50	5	5	7.1	0.1	0.0048	0.0125	0.02	0.09	0.09
1A3	Railway	CO ₂	202.69	63.00	5	5	7.1	0.0	-0.0016	0.0006	-0.01	0.00	0.01
1A3	Other transportation	CO ₂	0.00	9.14	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	10.60	5	300	300.0	0.0	-0.0006	0.0001	-0.19	0.00	0.19
2A1	Cement Production	CO ₂	5,640.90	4,208.60	2	2	2.8	0.1	-0.0198	0.0401	-0.04	0.11	0.12
2A2	Lime Production	CO ₂	431.97	229.96	5	6	7.8	0.0	-0.0024	0.0022	-0.01	0.02	0.02
2A3	Limestone & Dolomite Use	CO ₂	582.80	457.50	10	5	11.2	0.0	-0.0018	0.0044	-0.01	0.06	0.06
2A42	Soda Ash Production and Use	CO ₂	33.16	13.86	10	5	11.2	0.0	-0.0002	0.0001	0.00	0.00	0.00
2A7	Other Mineral (Glass)	CO ₂	20.20	15.16	5	3	5.8	0.0	-0.0001	0.0001	0.00	0.00	0.00
2B1	Ammonia Production	CO ₂	240.28	300.84	3	6	6.7	0.0	0.0003	0.0029	0.00	0.01	0.01
2.B.5	Other Chemicals (Hydrogen Production)	CO ₂	0.00	362.13	3	3	4.2	0.0	0.0034	0.0034	0.01	0.01	0.02
2C1	Iron and Steel Production	CO ₂	92.70	115.61	5	5	7.1	0.0	0.0001	0.0011	0.00	0.01	0.01
2C2	Ferroalloys	CO ₂	622.23	536.69	7	7	9.9	0.0	-0.0015	0.0051	-0.01	0.05	0.05
2C3	Aluminium Production	CO ₂	225.39	207.22	2	2	2.8	0.0	-0.0004	0.0020	0.00	0.01	0.01
3	Solvent and other product use	CO ₂	169.71	161.64	5	300	300.0	0.4	-0.0003	0.0015	-0.08	0.01	0.08

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	3.19	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CO ₂	83,301.00	97,468.85									
1A 1,2,4	Stationary Combustion - all fuels	CH ₄	105.62	98.76	3	100	100.0	0.1	-0.0002	0.0009	-0.02	0.00	0.02
1A3	Road transport	CH ₄	100.74	86.88	4	40	40.2	0.0	-0.0002	0.0008	-0.01	0.00	0.01
1A3	Navigation	CH ₄	2.70	3.74	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH ₄	0.26	0.46	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Railway	CH ₄	2.40	0.76	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Other transportation	CH ₄	0.00	0.00	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	188.13	5	300	300.0	0.5	0.0008	0.0018	0.25	0.01	0.25
1B	Coal Mining	CH ₄	1,095.27	1,192.85	2	300	300.0	3.1	-0.0003	0.0114	-0.08	0.03	0.09
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	0.38	5	4	6.4	0.0	0.0000	0.0000	0.00	0.00	0.00
4A	Enteric fermentation	CH ₄	3,246.28	3,223.84	5	30	30.4	0.8	-0.0038	0.0307	-0.11	0.22	0.24
4B	Manure management	CH ₄	337.46	314.55	5	50	50.2	0.1	-0.0006	0.0030	-0.03	0.02	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	30.47	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	1,058.40	20	40	44.7	0.4	0.0094	0.0101	0.38	0.29	0.47
6A2	MSW (Unmanaged solid waste disposal)	CH ₄	1,910.60	1,608.52	20	72	74.7	1.0	-0.0050	0.0153	-0.36	0.43	0.56
6A3	Industrial waste (Managed Waste Disposal on Land)	CH ₄	1.34	34.37	20	40	44.7	0.0	0.0003	0.0003	0.01	0.01	0.02
6A3	Industrial waste (Unmanaged Waste Disposal on Land)	CH ₄	38.15	31.65	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	232.17	20	40	44.7	0.1	0.0022	0.0022	0.09	0.06	0.11

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	242.57	20	72	74.7	0.2	0.0002	0.0023	0.02	0.07	0.07
6A3	Municipal Sludge Disposal on Land	CH ₄	12.97	260.31	20	40	44.7	0.1	0.0023	0.0025	0.09	0.07	0.12
6B	Wastewater handling	CH ₄	3,017.06	1,068.16	30	100	104.4	1.0	-0.0219	0.0102	-2.19	0.43	2.23
6C	Waste incineration	CH ₄	0.01	0.04	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CH ₄	10,321.96	9,794.61									
1A1,2,4	Stationary Combustion - all fuels	N ₂ O	579.58	453.00	3	300	300.0	1.2	-0.0018	0.0043	-0.55	0.02	0.55
1A3	Road transport	N ₂ O	145.27	190.14	5	50	50.2	0.1	0.0003	0.0018	0.01	0.01	0.02
1A3	Navigation	N ₂ O	141.45	119.81	5	300	300.0	0.3	-0.0004	0.0011	-0.11	0.01	0.11
1A3	Civil Aviation	N ₂ O	7.71	13.98	5	300	300.0	0.0	0.0001	0.0001	0.02	0.00	0.02
1A3	Railway	N ₂ O	24.40	7.68	5	300	300.0	0.0	-0.0002	0.0001	-0.06	0.00	0.06
1A3	Other transportation	N ₂ O	0.00	0.08	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	0.03	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	428.39	2	20	20.1	0.1	-0.0077	0.0041	-0.15	0.01	0.15
3	Solvent and other product use	N ₂ O	138.63	154.53	5	300	300.0	0.4	0.0000	0.0015	0.00	0.01	0.01
4B	Manure management	N ₂ O	341.77	295.84	50	100	111.8	0.3	-0.0008	0.0028	-0.08	0.20	0.22
4D	Agricultural soils - direct emissions	N ₂ O	2,761.36	1,591.32	20	400	400.5	5.4	-0.0142	0.0152	-5.67	0.43	5.69
4D	Agricultural soils - indirect emissions	N ₂ O	2,868.92	1,937.03	20	50	53.9	0.9	-0.0120	0.0184	-0.60	0.52	0.80
4D	Animal Production	N ₂ O	1,821.24	1,759.90	50	100	111.8	1.7	-0.0026	0.0168	-0.26	1.19	1.21
4F	Field burning of agr. residues	N ₂ O	10.05	11.67	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
6B	Wastewater handling	N ₂ O	331.24	393.31	5	10	11.2	0.0	0.0002	0.0037	0.00	0.03	0.03
6C	Waste incineration	N ₂ O	0.13	0.88	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total N ₂ O	10,281.00	7,357.59									

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	50	50	70.7	0.0	-0.0100	0.0000	-0.50	0.00	0.50
2F1	Refrigeration and Air Conditioning Equipment	HFC	0.00	3,421.23	100	150	180.3	5.2	0.0326	0.0326	4.89	4.61	6.72
2F2	Foam Blowing	HFC	0.00	33.39	40	50	64.0	0.0	0.0003	0.0003	0.02	0.02	0.02
2F3	Fire Extinguishers	HFC	0.00	40.73	60	10	60.8	0.0	0.0004	0.0004	0.00	0.03	0.03
2F4	Aerosols/MDIs	HFC	0.00	62.57	15	5	15.8	0.0	0.0006	0.0006	0.00	0.01	0.01
Total HFC			935.06	3,557.92									
2C	PFC from Aluminium	PFC	163.37	33.80	3	6	6.7	0.0	-0.0014	0.0003	-0.01	0.00	0.01
2F1	PFC from Refrigeration and Air Conditioning Equipment	PFC	0.00	67.80	100	150	180.3	0.1	0.0006	0.0006	0.10	0.09	0.13
Total PFC			163.37	101.61									
2F	SF6 from electrical equipment	SF6	163.37	101.61	50	20	53.9	0.0	0.0000	0.0001	0.00	0.00	0.00
TOTAL			105,005.46	118,286.73				8.82					9.629

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	39,254.88	40,363.76	3	3	4.2	1.5	-0.0325	0.3844	-0.10	1.63	1.63
1A 1,2,4	Stationary Combustion - liquid fuels	CO ₂	21,327.77	21,224.32	3	3	4.2	0.8	-0.0244	0.2021	-0.07	0.86	0.86
1A 1,2,4	Stationary Combustion - gaseous fuels	CO ₂	102.03	6,666.23	3	2	3.6	0.2	0.0624	0.0635	0.12	0.27	0.30
1A2	Stationary Combustion - Other fuels	CO ₂	0.00	18.79	3	3	4.2	0.0	0.0002	0.0002	0.00	0.00	0.00
1A3	Road transport	CO ₂	11,742.20	18,907.12	5	5	7.1	1.1	0.0553	0.1801	0.28	1.27	1.30
1A3	Navigation	CO ₂	1,824.81	2,285.98	5	5	7.1	0.1	0.0024	0.0218	0.01	0.15	0.15
1A3	Civil Aviation	CO ₂	716.84	1,307.50	5	5	7.1	0.1	0.0048	0.0125	0.02	0.09	0.09
1A3	Railway	CO ₂	202.69	63.00	5	5	7.1	0.0	-0.0016	0.0006	-0.01	0.00	0.01
1A3	Other transportation	CO ₂	0.00	9.14	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	10.60	5	300	300.0	0.0	-0.0006	0.0001	-0.19	0.00	0.19
2A1	Cement Production	CO ₂	5,640.90	4,208.60	2	2	2.8	0.1	-0.0198	0.0401	-0.04	0.11	0.12
2A2	Lime Production	CO ₂	431.97	229.96	5	6	7.8	0.0	-0.0024	0.0022	-0.01	0.02	0.02
2A3	Limestone & Dolomite Use	CO ₂	582.80	457.50	10	5	11.2	0.0	-0.0018	0.0044	-0.01	0.06	0.06
2A42	Soda Ash Production and Use	CO ₂	33.16	13.86	10	5	11.2	0.0	-0.0002	0.0001	0.00	0.00	0.00
2A7	Other Mineral (Glass)	CO ₂	20.20	15.16	5	3	5.8	0.0	-0.0001	0.0001	0.00	0.00	0.00
2B1	Ammonia Production	CO ₂	240.28	300.84	3	6	6.7	0.0	0.0003	0.0029	0.00	0.01	0.01
2.B.5	Other Chemicals (Hydrogen Production)	CO ₂	0.00	362.13	3	3	4.2	0.0	0.0034	0.0034	0.01	0.01	0.02
2C1	Iron and Steel Production	CO ₂	92.70	115.61	5	5	7.1	0.0	0.0001	0.0011	0.00	0.01	0.01
2C2	Ferroalloys	CO ₂	622.23	536.69	7	7	9.9	0.0	-0.0015	0.0051	-0.01	0.05	0.05
2C3	Aluminium Production	CO ₂	225.39	207.22	2	2	2.8	0.0	-0.0004	0.0020	0.00	0.01	0.01

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
3	Solvent and other product use	CO ₂	169.71	161.64	5	300	300.0	0.4	-0.0003	0.0015	-0.08	0.01	0.08
5.A.1	Forest Land remaining Forest Land	CO ₂	-1,379.37	-1,855.51	5	34	34.0	-0.5	-0.0029	-0.0181	-0.10	-0.13	0.16
5.A.2	Conversion to Forest Land	CO ₂	0.00	-350.63	5	113	112.8	-0.3	-0.0034	-0.0034	-0.39	-0.02	0.39
5.B.1	Cropland remaining Cropland	CO ₂	-1,205.41	-452.08	12	53	54.0	-0.2	0.0089	-0.0044	0.47	-0.08	0.47
5.B.2	Conversion to Cropland	CO ₂	0.03	0.29	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.1	Grassland remaining Grassland	CO ₂	0.03	0.16	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.C.2	Conversion to Grassland	CO ₂	0.01	0.27	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.D.2	Land converted to Wetlands	CO ₂	0.00	0.00	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.E.2	Conversion to Settlements	CO ₂	2.93	4.62	10	50	51.0	0.0	0.0000	0.0000	0.00	0.00	0.00
5.F.2	Conversion to Other Land	CO ₂	10.78	3.28	10	50	51.0	0.0	-0.0001	0.0000	0.00	0.00	0.00
6C	Waste incineration	CO ₂	0.22	3.19	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
Total CO ₂			80,730.00	94,819.27									
1A 1,2,4	Stationary Combustion - all fuels	CH ₄	105.62	98.76	3	100	100.0	0.1	-0.0002	0.0009	-0.02	0.00	0.02
1A3	Road transport	CH ₄	100.74	86.88	4	40	40.2	0.0	-0.0002	0.0008	-0.01	0.00	0.01
1A3	Navigation	CH ₄	2.70	3.74	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH ₄	0.26	0.46	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Railway	CH ₄	2.40	0.76	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Other transportation	CH ₄	0.00	0.00	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	188.13	5	300	300.0	0.5	0.0008	0.0018	0.25	0.01	0.25
1B	Coal Mining	CH ₄	1,095.27	1,192.85	2	300	300.0	3.1	-0.0003	0.0114	-0.08	0.03	0.09
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	0.38	5	4	6.4	0.0	0.0000	0.0000	0.00	0.00	0.00
4A	Enteric fermentation	CH ₄	3,246.28	3,223.84	5	30	30.4	0.8	-0.0038	0.0307	-0.11	0.22	0.24
4B	Manure management	CH ₄	337.46	314.55	5	50	50.2	0.1	-0.0006	0.0030	-0.03	0.02	0.04

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
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	30.47	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	12.86	0.67	11	70	70.9	0.0	-0.0001	0.0000	-0.01	0.00	0.01
5.C.1	Grassland remaining Grassland	CH ₄	14.03	6.38	10	70	70.7	0.0	-0.0001	0.0001	-0.01	0.00	0.01
6A1	MSW (Managed solid waste disposal)	CH ₄	63.02	1,058.40	20	40	44.7	0.4	0.0094	0.0101	0.38	0.29	0.47
6A2	MSW (Unmanaged solid waste disposal)	CH ₄	1,910.60	1,608.52	20	72	74.7	1.0	-0.0050	0.0153	-0.36	0.43	0.56
6A3	Industrial waste (Managed Waste Disposal on Land)	CH ₄	1.34	34.37	20	40	44.7	0.0	0.0003	0.0003	0.01	0.01	0.02
6A3	Industrial waste (Unmanaged Waste Disposal on Land)	CH ₄	38.15	31.65	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	232.17	20	40	44.7	0.1	0.0022	0.0022	0.09	0.06	0.11
6A3	Construction and Demolition Waste (Unmanaged Waste Disposal on Land)	CH ₄	194.28	242.57	20	72	74.7	0.2	0.0002	0.0023	0.02	0.07	0.07
6A3	Municipal Sludge Disposal on Land	CH ₄	12.97	260.31	20	40	44.7	0.1	0.0023	0.0025	0.09	0.07	0.12
6B	Wastewater handling	CH ₄	3,017.06	1,068.16	30	100	104.4	1.0	-0.0219	0.0102	-2.19	0.43	2.23
6C	Waste incineration	CH ₄	0.01	0.04	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CH ₄	10,348.86	9,801.67									
1A1,2,4	Stationary Combustion - all fuels	N ₂ O	579.58	453.00	3	300	300.0	1.2	-0.0018	0.0043	-0.55	0.02	0.55
1A3	Road transport	N ₂ O	145.27	190.14	5	50	50.2	0.1	0.0003	0.0018	0.01	0.01	0.02
1A3	Navigation	N ₂ O	141.45	119.81	5	300	300.0	0.3	-0.0004	0.0011	-0.11	0.01	0.11
1A3	Civil Aviation	N ₂ O	7.71	13.98	5	300	300.0	0.0	0.0001	0.0001	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	%	%	%	%	%	%	%	%	%
1A3	Railway	N ₂ O	24.40	7.68	5	300	300.0	0.0	-0.0002	0.0001	-0.06	0.00	0.06
1A3	Other transportation	N ₂ O	0.00	0.08	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	0.03	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	428.39	2	20	20.1	0.1	-0.0077	0.0041	-0.15	0.01	0.15
3	Solvent and other product use	N ₂ O	138.63	154.53	5	300	300.0	0.4	0.0000	0.0015	0.00	0.01	0.01
4B	Manure management	N ₂ O	341.77	295.84	50	100	111.8	0.3	-0.0008	0.0028	-0.08	0.20	0.22
4D	Agricultural soils - direct emissions	N ₂ O	2,761.36	1,591.32	20	400	400.5	5.4	-0.0142	0.0152	-5.67	0.43	5.69
4D	Agricultural soils - indirect emissions	N ₂ O	2,868.92	1,937.03	20	50	53.9	0.9	-0.0120	0.0184	-0.60	0.52	0.80
4D	Animal Production	N ₂ O	1,821.24	1,759.90	50	100	111.8	1.7	-0.0026	0.0168	-0.26	1.19	1.21
4F	Field burning of agr. residues	N ₂ O	10.05	11.67	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	1.31	0.07	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	0.65	10	70	70.7	0.0	0.0000	0.0000	0.00	0.00	0.00
6B	Wastewater handling	N ₂ O	331.24	393.31	5	10	11.2	0.0	0.0002	0.0037	0.00	0.03	0.03
6C	Waste incineration	N ₂ O	0.13	0.88	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total N ₂ O	10,283.73	7,358.31									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	935.06	0.00	50	50	70.7	0.0	-0.0100	0.0000	-0.50	0.00	0.50
2F1	Refrigeration and Air Conditioning Equipment	HFC	0.00	3,421.23	100	150	180.3	5.2	0.0326	0.0326	4.89	4.61	6.72
2F2	Foam Blowing	HFC	0.00	33.39	40	50	64.0	0.0	0.0003	0.0003	0.02	0.02	0.02
2F3	Fire Extinguishers	HFC	0.00	40.73	60	10	60.8	0.0	0.0004	0.0004	0.00	0.03	0.03
2F4	Aerosols/MDIs	HFC	0.00	62.57	15	5	15.8	0.0	0.0006	0.0006	0.00	0.01	0.01
		Total HFC	935.06	3,557.92									
2C	PFC from Aluminium	PFC	163.37	33.80	3	6	6.7	0.0	-0.0014	0.0003	-0.01	0.00	0.01
2F1	PFC from Refrigeration and Air Conditioning Equipment	PFC	0.00	67.80	100	150	180.3	0.1	0.0006	0.0006	0.10	0.09	0.13

A	B	C	D	E	F	G	H	I	J	K	L	M
		Gg CO ₂ eq	Gg CO ₂ eq	%	%	%	%	%	%	%	%	%
	Total PFC	935.06	3,557.92									
2F	SF6 from electrical equipment	SF6	3.07	6.14	50	20	53.9	0.0	0.0000	0.0001	0.00	0.00
	TOTAL	102,464.09	115,644.92				9.050					9.904

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 2010 decreased by 2.36% compared to 1990 levels, with an average annual rate of decrease estimated at 0.12% for the period 1990 - 2010. Emissions of NO_x derive by 99.27% from the energy sector and especially from transport, which is responsible for the 46.77% of total NO_x emissions. In **Table V.1** NO_x emissions by source category for the period 1990 – 2010 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 2010 decreased by 53.35% approximately compared to 1990 levels, with an average annual rate of decrease estimated at 2.67% for the period 1990 – 2010. CO emissions derive by 89.36% from the energy sector and especially from transport, which is responsible for the 61.24% of total CO emissions. In **Table V.2** CO emissions by source category for the period 1990 – 2010 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 31.48% in 2010 compared to 1990, with an average annual rate of decrease estimated at 1.57%. NMVOC emissions derive by 53.28% from the energy sector and especially from transport, which is responsible for the 25.83% of total NMVOC emissions. In **Table V.3** NMVOC emissions by source category for the period 1990 – 2010 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 2010 decreased by 44.28% compared to 1990 levels, with an average annual rate of decrease estimated at 2.21% for the period 1990 - 2010. SO₂ emissions derive by 98.14% from the energy sector and mainly from the energy industries, which are responsible for the 76.24% of total SO₂ emissions. In **Table V.4** SO₂ emissions by source category for the period 1990 – 2010 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 87.48% was observed for the period 1990 – 2010. Emissions from Industrial processes decreased by 41% in 2010 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 – 2010*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL	329.6	339.5	346.4	344.0	352.0	331.6	335.6	348.8	371.6	368.9	362.9	384.4	385.3	395.0	401.0	418.7	415.0	418.3	394.6	382.2	321.8
Energy	326.7	336.4	343.5	341.1	349.1	329.0	333.0	346.2	368.7	366.5	359.5	382.0	382.9	392.7	398.6	416.3	412.8	414.2	392.0	379.9	319.5
Fuel combustion	326.3	336.0	343.0	340.6	348.7	328.5	332.5	345.7	368.2	366.0	359.0	381.6	382.4	392.2	398.2	415.9	412.2	413.5	391.3	379.2	319.1
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
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
Transport	184.0	186.3	187.8	188.8	191.4	181.5	178.8	186.5	205.7	206.2	186.0	197.5	191.9	191.1	196.6	190.0	195.5	191.0	181.9	193.9	150.5
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
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
Industrial processes	1.5	1.3	1.1	1.2	1.1	1.1	1.1	1.0	1.0	1.1	1.1	0.9	1.1	1.1	1.0	0.9	0.9	0.9	0.9	0.6	0.8
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
Ammonia production	0.3	0.3	0.2	0.1	NO	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2
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	0.2	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
Paper and pulp	0.1	0.0	0.0	0.0	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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
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
LULUCF	0.3	0.2	0.6	0.4	0.4	0.2	0.2	0.3	0.7	0.1	1.1	0.2	0.0	0.0	0.1	0.1	0.1	1.9	0.2	0.3	0.2
Forest and grassland conversion	0.3	0.2	0.6	0.4	0.4	0.2	0.2	0.3	0.7	0.1	1.1	0.2	0.0	0.0	0.1	0.1	0.1	1.9	0.2	0.3	0.2

Table V.2 CO emissions (in kt) by source category, for the period 1990 – 2010

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL	1143.3	1125.1	1094.4	1085.8	1063.2	962.1	954.9	957.6	973.9	956.8	959.9	919.1	857.5	813.1	811.8	722.8	741.2	748.5	630.4	600.4	533.3
Energy	1086.0	1060.4	1023.5	1021.0	997.4	906.7	901.9	898.8	900.2	906.0	872.2	861.4	804.8	762.1	755.2	667.0	685.9	630.9	566.6	542.6	476.5
Fuel combustion	1085.8	1060.1	1023.2	1020.7	997.2	906.4	901.7	898.6	900.0	905.7	871.9	861.2	804.5	761.8	755.0	666.8	685.6	630.6	566.2	542.2	476.3
<i>Energy industries</i>	36.4	34.8	36.8	37.0	38.8	37.2	36.2	39.7	42.3	42.5	46.0	46.8	46.2	47.0	48.7	48.8	45.5	49.0	47.0	45.6	43.6
<i>Industry</i>	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
<i>Transport</i>	878.9	849.9	801.0	806.3	788.4	701.4	695.0	691.9	693.8	690.8	642.0	639.3	600.0	579.0	566.8	501.2	519.2	455.4	405.8	385.6	326.6
<i>Other sectors</i>	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
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
Industrial processes	19.9	20.1	20.1	19.5	18.1	17.5	17.1	17.7	19.4	20.8	21.4	21.6	22.8	22.9	23.4	23.8	23.9	24.3	23.4	17.6	19.5
Glass production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia production	0.0	0.0	0.0	0.0	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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	3.7	2.0	3.1
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
Paper and pulp	0.2	0.2	0.2	0.1	0.1	0.2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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
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
LULUCF	10.4	6.7	20.0	15.7	15.5	7.6	6.2	11.2	26.2	2.4	37.2	6.1	1.0	1.4	3.5	2.0	3.8	66.4	7.9	9.1	6.8
Forest and grassland conversion	10.4	6.7	20.0	15.7	15.5	7.6	6.2	11.2	26.2	2.4	37.2	6.1	1.0	1.4	3.5	2.0	3.8	66.4	7.9	9.1	6.8

Table V.3 *NMVOC emissions (in kt) by source category. for the period 1990 – 2010*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL	269.1	271.3	268.7	267.9	266.1	259.6	260.0	261.5	267.0	269.7	265.5	262.7	257.9	245.4	245.6	221.1	230.9	219.7	227.7	212.1	184.4
Energy	187.0	185.5	182.4	181.4	180.3	171.0	171.4	172.0	173.1	172.5	163.2	160.9	154.1	148.8	143.4	134.3	133.9	129.1	119.1	114.4	98.2
Fuel combustion	164.8	163.9	159.6	159.4	156.9	145.7	145.5	145.5	145.7	146.0	134.7	132.7	124.9	118.8	114.4	102.6	100.7	94.2	85.5	81.0	67.4
<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
<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
<i>Transport</i>	139.1	137.5	132.8	133.5	131.5	120.7	120.0	120.0	120.5	120.1	106.9	105.6	99.1	94.0	90.0	79.4	77.0	70.2	61.8	59.8	47.6
<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
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
Industrial processes	25.5	27.5	28.8	30.3	31.6	36.9	37.6	38.1	42.5	43.5	49.0	49.4	51.3	44.0	49.6	33.7	43.3	36.8	54.6	43.4	31.8
Asphalt roofing	0.8	0.9	1.0	1.0	1.0	1.2	1.2	1.3	1.4	1.4	1.7	1.7	1.8	1.5	1.7	1.1	1.5	1.2	1.9	1.5	1.1
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
Glass production	0.6	0.6	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.5
Ammonia production	0.0	0.0	0.0	0.0	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Organic chemicals production	0.9	0.9	0.9	1.0	1.7	1.7	1.9	2.0	2.0	1.9	1.5	0.9	0.9	0.9	1.1	1.0	0.9	1.0	NA	NA	NA
Steel production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Paper and pulp	0.1	0.1	0.1	0.1	0.1	0.1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Food - Drinks	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.6	0.6	0.6	0.6	0.6	0.6
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

Table V.4 *SO₂ emissions (in kt) by source category. for the period 1990 – 2010*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
TOTAL	476	517	534	531	522	540	530	529	536	555	496	504	515	553	548	541	533	538	445	426	265
Energy	468	509	527	524	515	532	522	521	528	547	489	497	508	546	540	532	527	531	439	421	261
Fuel combustion	461	502	519	515	508	525	516	514	520	538	480	489	499	537	533	523	516	519	427	408	254
<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
<i>Industry</i>	94.5	91.2	89.7	78.5	65.7	70.7	79.6	79.5	70.7	59.0	68.6	67.4	69.3	64.2	63.4	56.9	58.5	62.5	18.8	11.8	11.9
<i>Transport</i>	39.0	39.0	41.3	38.6	43.0	32.3	30.9	37.9	52.7	56.6	21.6	28.9	25.3	26.8	31.9	28.0	30.6	27.7	23.5	47.0	34.4
<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
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
Industrial processes	8.6	8.1	7.2	6.8	7.2	8.0	7.8	8.1	8.1	8.2	7.4	7.3	7.4	7.4	7.5	8.9	6.5	6.5	6.1	4.6	4.9
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
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
Ammonia production	0.0	0.0	0.0	0.0	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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
Steel production	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Ferroalloys Production	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3
Aluminium production	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8
Paper and pulp	0.3	0.2	0.2	0.1	0.1	0.2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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.F.2.2 Cropland converted to Other Land	
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.D.2.2 Cropland converted to Wetlands	
Carbon	5 LULUCF	5.D.2.4 Settlements converted to Wetlands	
Carbon	5 LULUCF	5.D.2.5 Other Land converted to 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.F.2.2 Cropland converted to Other Land	
Carbon	5 LULUCF	5.A.2.2 Grassland converted to Forest Land	Lack of AD
Carbon	5 LULUCF	5.D.2.1 Forest Land converted to Wetlands	
Carbon	5 LULUCF	5.E.2.1 Forest Land converted to Settlements	
Carbon	5 LULUCF	5.F.2.1 Forest Land converted to Other Land	
Carbon	5 LULUCF	5.D.2.1 Forest Land converted to Wetlands	
Carbon	5 LULUCF	5.D.2.2 Cropland converted to Wetlands	

Sources and sinks not estimated (NE)			
GHG	Sector	Source/sink category	Explanation
Carbon	5 LULUCF	5.D.2.3 Grassland converted to Wetlands	Loss of carbon in Lands converted to Wetlands have not been estimated due to lack of sufficient data. However, this is expected to be relative small since peat extraction does not occur in the country and area flooded after 1990 is small.
Carbon	5 LULUCF	5.D.2.4 Settlements converted to Wetlands	
Carbon	5 LULUCF	5.D.2.5 Other Land converted to Wetlands	
Carbon	5 LULUCF	5.E.2.1 Forest Land converted to Settlements	
Carbon	5 LULUCF	5.E.2.3 Grassland converted to Settlements	
Carbon	5 LULUCF	5.F.2.1 Forest Land converted to Other Land	
Carbon	5 LULUCF	5.F.2.2 Cropland converted to Other Land	
Carbon	5 LULUCF	5.F.2.3 Grassland converted to Other Land	
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	
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.
CO ₂	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 emisisions.
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 emisisions.
HFCs	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD for potential emisisions.

Sources and sinks not estimated (NE)			
GHG	Sector	Source/sink category	Explanation
N ₂ O	1 Energy	1.B.2.D Geothermal	Lack of background information and methodological approach
N ₂ O	5 LULUCF	5.D.2 5.D.2 Land converted to Wetlands	
SF ₆	2 Industrial Processes	2.F.8 Electrical Equipment	Lack of AD for potential emissions.
SF ₆	2 Industrial Processes	2.F.P2.1 In bulk	Lack of AD for potential emissions.
SF ₆	2 Industrial Processes	2.F.P2.2 In products	Lack of AD for potential emissions.
SF ₆	2 Industrial Processes	2.F.P3.1 In bulk	Lack of AD for potential emissions.
SF ₆	2 Industrial Processes	2.F.P3.2 In products	Lack of AD for potential emissions.
SF ₆	2 Industrial Processes	2.F.P4 Destroyed amount	Lack of AD for potential emissions.

Sources and sinks reported elsewhere (IE)				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
Carbon	5.B.2.2 Grassland converted to Cropland			
Carbon	5.A.1 Forest Land remaining Forest Land		Included in Gains	
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 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.
CH4	Other non-specified		For confidentiality reasons, military fuel use is not reported separately	

Sources and sinks reported elsewhere (IE)				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
			but included under the relevant categories in the energy sector.	
CH4	Municipal Sludge Disposal on Land	Municipal sludge disposal on land		
CO2	1.B.2.A.4 Refining / Storage		Included in fuel combustion sector.	
CO2	1.B.2.B.5.1 at industrial plants and power stations		Included in category 1.B.2.B.3 & 4	
CO2	1.B.2.B.5.2 in residential and commercial sectors		Included in category 1.B.2.B.3 & 4	
CO2	1.AA.1.B Petroleum Refining	The emissions from H2 production from NG were reallocated to the IP sector.	The emissions from H2 production from NG were reallocated to the IP sector.	The emissions from H2 production from NG were reallocated to the IP sector.
CO2	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).
CO2	SO2 scrubbing	Reallocated to IP 2.A.3 category.	Reallocated to IP 2.A.3 category.	Reallocated to IP 2.A.3 category.
CO2	Other non-specified		For confidentiality reasons, military fuel use is not reported separately but included under the relevant categories in the energy sector.	
CO2	5.A.1 Forest Land remaining Forest Land			
N2O	6.B.1 Industrial Wastewater			Emissions from sludge are reported in Industrial wastewater/wastewater
N2O	6.B.2.1 Domestic and Commercial (w/o human sewage)	IE		N2O emissions are 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	

Sources and sinks reported elsewhere (IE)				
GHG	Source/sink category	Allocation as per IPCC Guidelines	Allocation used by the Party	Explanation
			fuel use is not reported separately but included under the relevant categories in the energy sector.	
SF6	2.F.8 Electrical Equipment		Not enough data to permit the separate reporting of installation emissions in manufacture. See also Planned Improvements of the Category in NIR 2011.	

