# MINISTRY FOR THE ENVIRONMENT, PHYSICAL PLANNING AND PUBLIC WORKS

CLIMATE CHANGE
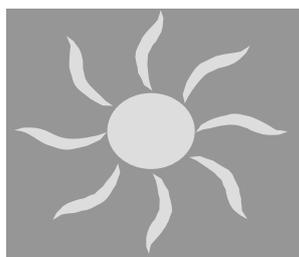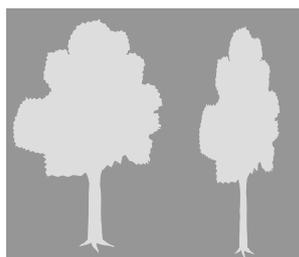
EMISSIONS INVENTORY

ANNUAL INVENTORY SUBMISSION UNDER THE CONVENTION AND THE KYOTO PROTOCOL FOR GREENHOUSE AND OTHER GASES FOR THE YEARS 1990-2007

APRIL   2009

ANNUAL INVENTORY SUBMISSION UNDER THE CONVENTION AND THE KYOTO PROTOCOL FOR GREENHOUSE AND OTHER GASES FOR YEARS 1990-2007

EXECUTIVE SUMMARY

ES.1 Greenhouse gas inventories and climate change

The present report, prepared by Greece (Ministry for the Environment, Physical Planning and Public Works (Climate Team) in co-operation with the National Technical University of Athens, NTUA – School of Chemical Engineering (Inventory Team)), contains estimates of GHG emissions for the period 1990-2007. **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 in-country review of the GHG inventories submitted in 2007 and 2008, held from 8 to 13 of September 2008, 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).

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.

In this context, the third meeting of the Conference of the Parties to the Convention, held in Kyoto (1-11 December 1997), finalised the negotiations related to the establishment of a legal instrument; the Kyoto Protocol on Climate Change (henceforth the Protocol). The Protocol provides a foundation upon which future action can be intensified.

The Protocol introduced legally binding commitments for developed countries to reduce, individually or jointly, emissions of 6 greenhouse gases (CO_2, CH_4, N_2O, HFC, PFC and SF_6) 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 CO_2 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 (after 2012) 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).

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.

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 for the Environment, Physical Planning and Public Works (henceforth Ministry for the Environment, Physical Planning and Public Works, MINENV) 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, as well as the environmental acquis communautaire. Moreover, the Ministry for the Environment, Physical Planning and Public Works is responsible for the co-ordination of all ministries involved, as well as of 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 Ministry for the Environment, Physical Planning and Public Works has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Elpida Politi, National UNFCCC Focal point, Address: Villa Kazouli, Kifisias 241, 14561, Athens, Greece, e-mail: epoliti@ekpaa.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 entities participating in it are:

> The **Ministry for the Environment, Physical Planning and Public Works** designated as *the national entity responsible for the national inventory*, which has the overall responsibility, but also plays an active role in the inventory planning, preparation and management process.

> 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.

> **Other competent Ministries** / agencies through their appointed focal persons, ensure the data provision and contribute to methodological issues,

International 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 National Statistical Service of Greece (NSSG), the government 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, 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 (as of the present submission). This stage also includes the evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the IPCC Guidelines, the IPCC Good Practice Guidance and the LULUCF Good Practice Guidance.

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

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within NTUA) check. The **official approval procedure** follows for one month period of interactions between the Inventory Team (NTUA) and the Climate Team (MINENV), starting on 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 MINENV, who supervises the National GHG inventory system, approves the inventory and then the NIR is submitted, by the Ministry for the Environment, Physical Planning and Public Works, 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. Moreover, the final results (NIR and CRF tables) are available in the MINENV web site (http://www.minenv.gr/4/41/g4107.html).

ES.2 Emissions trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO_2, CH_4, N_2O, HFC, PFC and SF_6) for the period 1990 - 2007 are presented in ***Table ES.1*** (in kt CO_2 eq).

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

Base year GHG emissions for Greece (1990 for CO_2, CH_4, and N_2O - 1995 for F-gases) were estimated at 107.71 Mt CO_2 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 2007, GHG emissions (without *LULUCF*) amounted to 131.85 Mt CO_2 eq showing an increase of 22.42 % compared to base year emissions and of 24.91% compared to 1990 levels. If emissions / removals from *LULUCF* were included then the increase would be 25.24% (from 102.37 Mt CO_2 eq in 1990 to 128.20 Mt CO_2 eq in 2007).

Carbon dioxide emissions accounted for 86.1% of total GHG emissions in 2007 (without *LULUCF*) and increased by approximately 36.6% from 1990. Nitrous oxide emissions accounted for 7.15% of total GHG emissions in 2007 and decreased by 22.82% from 1990, while methane emissions accounted for 6.16 % of the total GHG emissions in 2007 and decreased by 9.73% from 1990. Finally, F-gases emissions that accounted for 0.6% of total GHG emissions in 2007, decreased by 78% from 1995 (base year for F-gases), due to cease of HCFC-22 production.

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2007 are presented in ***Table ES.2***.

The main features of the sectoral evolution of emissions presented in Table ES.2 are:

✤ Emissions from *Energy* in 2007 accounted for 81.99% of total GHG emissions (without LULUCF) and increased by approximately 37.91% compared to 1990 levels.

The living standards improvement, due to the economic development of the period 1990 – 2007, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from *Energy*.

The evolution of GHG emissions from Energy can be distinguished into three 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 0.8% 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 3.8% which is higher that the rate of increased of GDP for the same period (3.4%). Finally, the average annual rate of emissions increase for the period 2000 – 2007 decreased at 1.4% while GDP increased with higher rate (approximately 8%).

The majority of GHG emissions (54.6%) in 2007 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is

estimated at 22%, 9.8% and 12.1% respectively. The rest 1.5% of total GHG emissions from Energy derived from fugitive emissions from fuels.

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 limit the increase of GHG emissions. However, the positive results from the improvement of the vehicles performance are reduced by the high use of passenger cars in transportation activity. The introduction of metro system in Athens is expected to moderate the high use of passenger cars.

✧ Emissions from *Industrial processes* in 2007 accounted for 6.9% of the total emissions (without *LULUCF*) and have almost remained stable to 1990 levels (0.48% of increase). However, in general emissions show an upward trend until 1999 and an abrupt decrease from 2005 to 2006. This intense flunctuation is mainly due to the cease of HCFC-22 production. Emissions in 2007 are slightly lower than emissions of 2006, with a decrease of 0.71%.

✧ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.12% of the total emissions) and has slightly decreased compared to 1990 level of emissions.

✧ Emissions from *Agriculture* that accounted for 8.57% of total emissions in 2007 (without *LULUCF*), decreased by approximately 17% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N_2O 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 sector *Waste* (2.42% of the total emissions, without *LULUCF*), decreased by approximately 28.4% 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.

Table ES.1   Total GHG emissions in Greece (in kt CO$_2$ eq) for the period 1990-2007

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
A. GHG emissions per gas (excluding LULUCF)											
CO$_2$	83,150.00	82,877.20	84,590.05	84,243.20	86,364.84	86,751.70	89,038.68	93,688.97	98,627.35	97,863.17	103,439.41
CH$_4$	9,003.69	9,011.61	8,930.47	8,930.88	9,032.27	9,058.47	9,227.30	9,221.01	9,282.53	9,091.14	8,933.98
N$_2$O	12,212.74	11,894.44	11,732.28	10,885.24	10,721.40	11,033.25	11,288.92	11,080.00	10,984.04	10,923.87	10,781.79
HFC	935.06	1,106.82	908.39	1,606.64	2,143.91	3,254.21	3,749.47	3,969.46	4,381.37	5,062.89	3,818.72
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72	148.38
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	**105,562.18**	**105,150.79**	**106,416.75**	**105,821.91**	**108,359.48**	**110,184.19**	**113,379.79**	**118,128.51**	**123,482.81**	**123,076.66**	**127,126.27**
B. GHG emissions/removals from LULUCF											
CO$_2$	-3,248.20	-3,596.04	-3,074.99	-3,879.75	-3,553.42	-4,406.97	-3,993.22	-3,957.00	-3,590.82	-4,436.43	-2,636.09
CH$_4$	49.87	25.48	75.40	66.35	62.25	34.76	21.75	46.65	125.11	9.71	166.10
N$_2$O	5.06	2.59	7.65	6.73	6.32	3.53	2.21	4.73	12.70	0.99	16.86
Total	**-3,193.27**	**-3,567.97**	**-2,991.93**	**-3,806.66**	**-3,484.86**	**-4,368.69**	**-3,969.27**	**-3,905.62**	**-3,453.02**	**-4,425.74**	**-2,453.13**
C. GHG Emissions from International Transport											
CO$_2$	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
CH$_4$	16.73	15.37	17.67	20.55	21.83	23.39	20.62	20.76	23.14	20.72	23.83
N$_2$O	90.21	81.50	91.52	104.26	113.64	118.06	106.04	105.86	116.41	109.99	118.83
Total	**10,582.24**	**9,575.47**	**10,774.91**	**12,337.14**	**13,387.00**	**14,004.00**	**12,525.96**	**12,469.78**	**13,734.57**	**12,816.03**	**13,999.80**

	2001	2002	2003	2004	2005	2006	2007
A. GHG emissions per gas (excluding LULUCF)							
CO_2	105,636.93	105,275.08	109,503.94	109,749.98	111,046.80	109,624.74	113,565.83
CH_4	8,545.14	8,521.12	8,407.67	8,301.50	8,146.27	8,127.90	8,128.08
N_2O	10,628.48	10,510.61	10,367.13	10,284.89	9,931.72	9,660.20	9,425.77
HFC	3,307.95	3,381.18	2,941.99	2,942.13	2,628.43	596.65	665.57
PFC	91.38	88.33	77.30	71.38	71.31	71.16	58.66
SF_6	4.06	4.25	4.25	4.47	6.45	8.37	9.92
Total	**128,213.94**	**127,780.57**	**131,302.28**	**131,354.35**	**131,830.97**	**128,089.01**	**131,853.83**
B. GHG emissions/removals from LULUCF							
CO_2	-4,983.90	-5,278.04	-5,029.08	-5,140.04	-5,001.42	-5,092.96	-3,807.96
CH_4	22.88	3.20	4.48	11.34	6.94	16.73	142.70
N_2O	2.32	0.33	0.45	6.11	0.74	1.70	14.48
Total	**-4,958.70**	**-5,274.51**	**-5,024.15**	**-5,122.58**	**-4,993.74**	**-5,074.53**	**-3,650.78**
C. GHG emissions from International Transport							
CO_2	13,351.48	12,214.71	13,150.47	13,327.28	11,465.99	12,663.40	12,934.93
CH_4	23.17	20.80	21.34	21.53	19.07	20.59	20.36
N_2O	114.49	105.12	114.16	115.76	92.76	101.43	108.74
Total	**13,489.14**	**12,340.63**	**13,285.97**	**13,464.57**	**11,577.82**	**12,785.42**	**13,064.03**

Table ES.2   *Total GHG emissions (in kt CO₂ eq) by sector for the period 1990-2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	78,388.35	78,175.50	79,829.14	79,514.79	81,725.73	81,701.05	84,110.92	88,702.88	93,490.59	92,774.50	98,175.53
Industrial processes	9,055.99	9,003.06	8,960.63	9,447.75	9,860.08	11,392.90	12,021.83	12,293.99	12,851.26	13,474.04	12,559.74
Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33
Agriculture	13,497.16	13,317.49	13,102.06	12,343.86	12,204.27	12,546.92	12,665.16	12,539.77	12,551.73	12,435.69	12,258.07
Waste	4,450.97	4,478.96	4,352.09	4,345.39	4,406.17	4,388.68	4,429.72	4,438.79	4,436.84	4,232.46	3,975.59
Total [1]	**105,562.18**	**105,150.79**	**106,416.75**	**105,821.91**	**108,359.48**	**110,184.19**	**113,379.79**	**118,128.51**	**123,482.81**	**123,076.66**	**127,126.27**
LULUCF	-2,991.93	-3,806.66	-3,484.86	-4,368.69	-3,969.27	-3,905.62	-3,453.02	-4,425.74	-2,453.13	-4,958.70	-5,274.51
Index per sector											
Energy	100.00	99.73	101.84	101.44	104.26	104.23	107.30	113.16	119.27	118.35	125.24
Industrial processes	100.00	99.42	98.95	104.33	108.88	125.81	132.75	135.76	141.91	148.79	138.69
Solvents	100.00	103.57	101.84	100.24	96.17	91.12	89.66	90.19	89.79	94.25	92.70
Agriculture	100.00	98.67	97.07	91.46	90.42	92.96	93.84	92.91	93.00	92.14	90.82
Waste	100.00	100.63	97.78	97.63	98.99	98.60	99.52	99.73	99.68	95.09	89.32
Total [2]	**100.00**	**99.61**	**100.81**	**100.25**	**102.65**	**104.38**	**107.41**	**111.90**	**116.98**	**116.59**	**120.43**

[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

Year	2001	2002	2003	2004	2005	2006	2007
Energy	100,571.58	100,365.92	104,431.81	104,594.79	105,433.71	104,034.76	108,108.83
Industrial processes	11,754.89	11,690.15	11,326.25	11,331.47	11,422.58	9,165.49	9,099.71
Solvents	154.67	155.12	155.50	155.87	157.70	159.64	160.34
Agriculture	12,207.46	12,137.24	11,989.56	11,984.79	11,632.44	11,476.22	11,297.76
Waste	3,525.34	3,432.14	3,399.16	3,287.43	3,184.55	3,252.90	3,187.19
Total [1)]	**128,213.94**	**127,780.57**	**131,302.28**	**131,354.35**	**131,830.97**	**128,089.01**	**131,853.83**
LULUCF	-5,024.15	-5,122.58	-4,993.74	-5,074.53	-3,650.78	-2,991.93	-3,806.66
Index per sector							
Energy	128.30	128.04	133.22	133.43	134.50	132.72	137.91
Industrial processes	129.80	129.09	125.07	125.13	126.13	101.21	100.48
Solvents	91.14	91.40	91.62	91.84	92.92	94.07	94.48
Agriculture	90.44	89.92	88.83	88.79	86.18	85.03	83.70
Waste	79.20	77.11	76.37	73.86	71.55	73.08	71.61
Total [2)]	**121.46**	**121.05**	**124.38**	**124.43**	**124.88**	**121.34**	**124.91**

[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 (NOx), carbon monoxide (CO), non-methane organic volatile compounds (NMVOC) and sulphur dioxide (SO$_2$) emissions for the period 1990-2007.

The key features of emissions trends for indirect greenhouse gases and SO$_2$ are the following:

✤ NOx emissions increased by 26.35% from 1990 to 2007. Energy sector accounts for the high majority of emissions (99.3%). The decrease in NOx emissions from transport after 1998 is attributed to the substitution of old technology vehicles by new catalytic ones (NOx emissions from this category account for the 39.78% of total NOx emissions in 2007). Emissions from *Industrial processes* decreased by 26.42% 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 45.27% from 1990 to 2007 and as a result total CO emissions in 2007 decreased by 37.88%. Emissions from industrial processes in 2007 increased by 3.61% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2007 emissions from LULUCF accounted for 6.64% of total CO emissions (incl LULUCF), and are by 186% higher than emissions of 1990.

✤ NMVOC emissions decreased by 22.95% from 1990 to 2007. Emissions from transport, which is the main source of NMVOC emissions in Greece (18.75% of total NMVOC emissions in 2007), decreased by 65.38% compared to 1990 levels, while emissions from *Energy* decreased by 31.96% from 1990 to 2007. The significant increase of NMVOC emissions from *Industrial processes* (approximately 39.55% from 1990 to 2007) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 4.84% compared to 1990 levels.

✤ SO$_2$ emissions increased by 14.35% from 1990 to 2007. Emissions from electricity generation, which is the main source of SO$_2$ emissions in Greece (68.1 % of total SO$_2$ emissions for 2007), increased with a mean annual rate of increase of 2.00% for the period 1990 – 2007. The operation of a desulphurisation plant at a large installation for electricity generation since 1998 resulted in the restriction of the increase of SO$_2$ 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 SO$_2$ emissions from manufacturing industry and construction, transport and other sectors by 34.28%, 12.8% and 22.5% respectively for the period 1990 – 2007. Emissions from *Industrial processes* decreased by 19.14% from 1990 due to decrease of sulphuric acid industrial production.

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1.1   Greenhouse gas inventories and climate change

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

Naturally occurring greenhouse gases (GHG) include water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). In the last few years, a new category of greenhouse gases has emerged that includes hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6). 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 (NOx), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2).

1.1.1   International framework and national commitments

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 (CO_2, CH_4, N_2O, HFC, PFC and SF_6) 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 CO_2 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 CO_2 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% ± 3% by 2000 compared to 1990 levels. The measures taken in order to achieve this restriction in the CO_2 emissions were described in the

1st Greek National Action Plan for the abatement of CO_2 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 CO_2, CH_4 and N_2O 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 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.

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.

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.

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 1990-2007, and the mandatory supplementary information required for the 2009 submission under the Kyoto Protocol, the above obligations are addressed.

1.1.3   Structure of the report

The present NIR consists of 9 chapters and 7 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 – 2007 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**. Finally, **Chapter 9** gives an overview of the recalculations made since the 2008 submission and the future improvements planned.

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) and additional information concerning road transport is presented. 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. Supplementary information under Article 7 paragraph 1 of the Kyoto Protocol is provided in **Annex VII.**

1.2   Institutional arrangements for inventory preparation

1.2.1   Overview

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 for the Environment, Physical Planning and Public Works (MINENV) 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 Ministry for the Environment, Physical Planning and Public Works 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 Ministry for the Environment, Physical Planning and Public Works has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission. (Contact person: Elpida Politi, National UNFCCC Focal point, Address: Villa Kazouli, Kifisias 241, 14561, Athens, Greece, e-mail: epoliti@ekpaa.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 Ministry for the Environment, Physical Planning and Public Works designated as the *national entity responsible for the national inventory*, which has the overall responsibility, but also plays an active role in the inventory planning, preparation and management process.

➢ 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.

➢ Other competent Ministries / agencies through their appointed focal persons, ensure the data provision and contribute to methodological issues,

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

The legal framework defining the roles-responsibilities and the co-operation between the MINENV Climate team, the NTUA Inventory team and the designated focal persons of the competent Ministries were formalized by:

- o written communication between MINENV's Deputy Minister Mr Stavros Kaloyannis and his respective ministers of the other ministries involved (February 2008).

- o a circular 918/21-4-08 released by MINENV entitled "Structure and operation of the National Greenhouse Gases Inventory System- Roles and Responsibilities"

The above-mentioned circular includes a description of each entity's responsibilities, concerning the inventory preparation, data providing, approval procedure and 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.
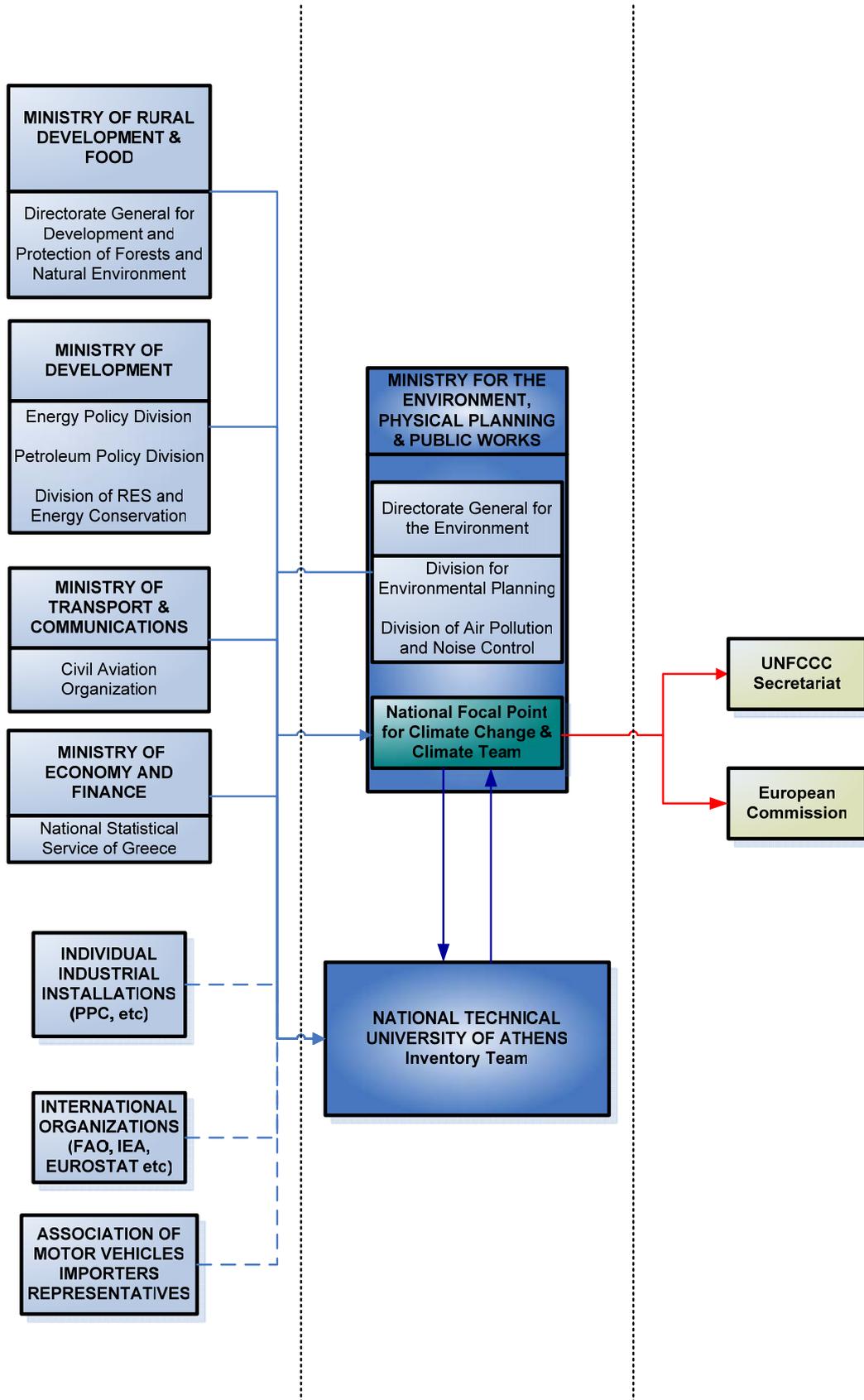
Figure 1.1   *Organizational Structure of the National Inventory System*

1.2.2   Roles and Responsibilities

1.2.2.1 Ministry for the Environment, Physical Planning and Public Works

The Ministry for the Environment, Physical Planning and Public Works, as the national entity, has the overall responsibility 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 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 MINENV.

➢ 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.

➢ The administration of the National Registry. The administration of the registry is assigned to the National Center for the Environment and Sustainable Development, which reports to the Ministry for the Environment 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 Ministry for the Environment, Physical Planning and Public Works 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. MINENV 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.

For the fulfillment of the above-mentioned roles and responsibilities of the ministry, a Climate Team was established within the Ministry for the Environment, Physical Planning and Public Works (MINENV Climate Team), comprising the following experts:

1. Elpida Politi, National UNFCCC focal point, *Co-ordinator*

2. Afroditi Kotidou

3. Efthymiou-Charalampopoulou Nektaria

4. Moraiti Christina, alternate Lazaridis Klimis

5. Ballas Dionisios, alternate Koromila Chryssoula

For each inventory sector, specified in the circular, a member of the MINENV's Climate Team has been assigned as responsible for overseeing the NTUA's inventory work and for communication with other Ministries' / agencies' data providers.

Furthermore, for expanding the overseeing role of MINENV 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 MINENV. 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 for the Environment, Physical Planning and Public Works has assigned, on a contract basis, the National Technical University of Athens (NTUA) / School of Chemical Engineering as the national institution that has the overall 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 fulfill for the GHG inventory preparation:

1. Data collection (activity data and emission factors) for all source / sinks categories that are Energy, Industrial Processes, Solvents and Other Product Use, Agriculture, Land Use, Land Use Change and Forestry, 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. GHG emissions estimates preparation 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 MINENV'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 MINENV.

15. Training the representatives of providing data 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 MINENV's Climate Team to perform greenhouse gas balance projections in terms of sources and sinks as a minimum for the years 2010, 2015 and 2020, 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. Prof. Dimitris Marinos-Kouris
    E-mail: marinos@chemeng.ntua.gr
    Tel: +30 210 772 3148
    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. Ioannis Sempos (Sebos), Chemical Engineer, MBA, NTUA technical staff
    E-mail: isebos@mail.ntua.gr
    Tel: +30 210 772 3240
    FAX: +30 210 772 3155

5. Spyridoula Ntemiri, Chemical Engineer, NTUA
    E-mail: spyrdem@chemeng.ntua.gr
    Tel: +30 210 772 3149
    FAX: +30 210 772 3155

6. Leonidas Kallinikos, Chemical Engineer, NTUA
    E-mail: leokalls@central.ntua.gr
    Tel: +30 210 772 3240
    FAX: +30 210 772 3155

It should be stressed that, when 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.

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

➢ The Ministry for the Environment, Physical Planning and Public Works provides information and data for Large Combustion Plants (fuel consumption, NO_x and SO_2 emissions – Department of industries), solid waste management (Department of Solid Waste Management) and domestic wastewater handling practices (Department of Water Resources). (Contact persons: Dimitris Chadjidakis, Macheras Ioannis, 147, Patission Street, 11251, Athens, Greece , tel.: +30210 8650053, fax: +30210 8646939)

➢ The National Statistical Service of Greece, supervised by the Ministry of Economy and Finance, represents the main source of information for the estimation of emissions / removals from most of the IPCC source / sink categories (contact persons: Ioanna Papanagnou, 46, Pireos str. and Eponiton, 18510 Pireas, Greece, tel: +30210 4852045, fax: +30210 4852453, e-mail: papanag@statistics.gr, and Konstantina Katartzi).

➢ The Ministry of Development is responsible for reporting and maintaining annual statistical 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) as well as for providing those data to international organizations such as the International Energy Agency (IEA), the European Statistical Service EUROSTAT, etc (Contact persons: Constantinos Chatzigianakis, Director of Electricity production division, 119, Mesogeion Avenue, 10192, Athens, Greece, tel: +30210 6969450, fax: +30210 6969416, e-mail ChatzigianakisK@ypan.gr, and Xarikleia Piperopoulou, Director in the General Secretariat of Industry, 119, Mesogeion Avenue, 10192, Athens, Greece, tel: +30210 6965820, fax: +30210 6965829, e-mail: piperopouloux@ypan.gr).

➢ The Ministry of Rural Development and Food provides information and data (through the National Statistical Service of Greece 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.) and LULUCF. As concerns the emissions / removals from activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol, the Ministry of Rural Development and Food is the responsible entity for the identification and measurement of areas of land subject to these activities and estimation of the respective emissions / removals. The above-mentioned 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. (Contact persons: Eirini Nikolaou, and Panagiotis Drougas, General Directorate of Forests, 31, Chalkokondili str., Athens, tel: +30210 2124728, fax: +30210 2125240122, e-mail: xa31u037@minagric.gr, xa31u025@minagric.gr).

➢ The Ministry of Transport and Communications provides information and data for the vehicle fleet and its technical characteristics. The Civil Aviation Organization, supervised by the Ministry of Transport and Communications, provides information on Landing and Take-off cycles for both domestic and international aviation (Contact persons: Anastasios Kokkinos, General Director of Civil Aviation Organisation, tel: +30210 8916555, fax: +30210 8983226 and Panagiotis Tselikas, tel: +30210 6508233. fax: +30210 6508200).

Data from the Association of Motor Vehicles Importers Representatives are supplementary to the official data and are only used in cases where official data are temporarily not available. The above-mentioned data are used by NTUA experts for the preparation of GHG emissions. As concerns emissions from road transport the model COPERT III is being used.

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, associations, along with individual public and private industrial companies contribute to data providing and development of methodological issues as appropriate. For example, data from the Association of Motor Vehicles Importers Representatives are supplementary to the official data and are only 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 a data source for the GHG inventory preparation. However, these data are used supplementary to the above mentioned data sources (e.g. for QC).

1.3   GHG emissions inventory preparation process

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 National Statistical Service of Greece (NSSG), the government 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. National Statistical Service of Greece and International Iron & Steel Institute for steel production) as well as time-series assessment in order to identify changes that cannot be explained. In cases where problems and/or inconsistencies are identified, the agency's representative, responsible for data providing, is called to explain the inconsistency and/or help solving the problem.

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

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

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within NTUA) check. The official approval procedure follows for one month period of interactions between the Inventory Team (NTUA) and the Climate Team (MINENV), 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 MINENV, who supervises the National System, approves the inventory and then the Ministry for the Environment, Physical Planning and Public Works submits the NIR to the European Commission and to the UNFCCC Secretariat.
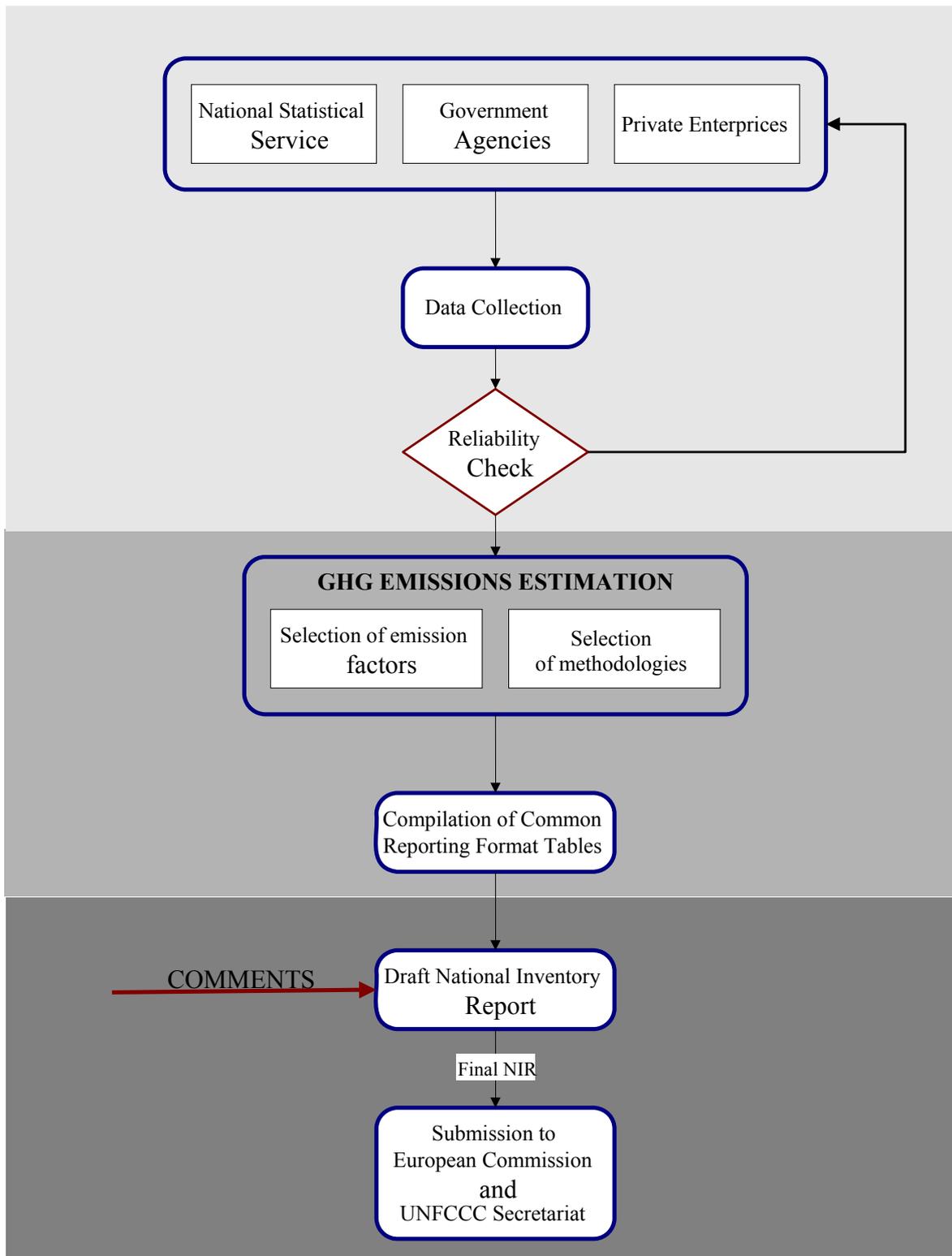
Figure 1.2   *GHG emissions inventory preparation process in Greece*

DELIVERABLES										To: European Commission CRF tables for year X-2 & Information acc to 280/2004/EC (15th January)		To: European Commission National Inventory Report (15th March)	To: UNFCCC Secretariat National Inventory Report (15th April)
					Year X-1						Year X		
		MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
ACTIVITIES	Data collection & check												
	Estimation of emissions and check												
	CRF tables compilation for year X-2												
	National Inventory Report compilation and check												
	Official examination and approval												
	Preparation of Centralised Inventory File and delivery to MINENV climate team.												

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

As shown in the timetable, the government agencies and ministries and the individual private or public industrial companies referred previously should have collected and delivered to the MINENV 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 MINENV web site (http://www.minenv.gr/4/41/g4107.html).

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 MINENV, 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.

1.4   Methodology and data sources

1.4.1   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 methodology[1]. 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) need also 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 are depended on the availability of the data needed for the correct application of the selected methodology.

✎   Availability of resources needs also to be considered as searching for and the collection of the necessary data to apply a detailed methodology for a source category should not affect the completeness and the on-time preparation of an inventory submission.

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[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*

	CO2		CH4		N2O		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	PS	T2	D	T2	D		
3. Transport	CR,M,T1,T2a	D,M,CR	CR,M,T2a	CR,D,M	CR,M,T2a	CR,D,M		
4. Other sectors	T2	D	T2	D	T2	D		
B. Fugitive emissions from fuels								
1. Solid fuels	T1,CS	D, CS	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, NO	NA, NO	NA, NO	NA, NO		
B. Chemical industry	T1a	CS,PS	T1	D	D	D		
C. Metal production	CR, CS, T1	CR, CS, PS	NA	NA	NA	NA	T3	PS
E. Production of halocarbons and SF$_6$							T1	D
F. Consumption of halocarbons and SF$_6$							T2a , CS	D, CS
3. Solvents and other products use	CR	CR			NE	NE		
4. Agriculture								
A. Enteric fermentation			T1,T2	CS,D				
B. Manure management			T1	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,T1a,T1b	D		
F. Field burning of agricultural residues			D	D	D	D		
5. Land Use, Land Use Change and Forestry								
A. Forest land	CS,D,T1,T2	CS,D	T1	D	T1	D		
B. Cropland	T1,T2	CS,D	NA	NA	NA	NA		
C. Grassland	NA	NA	T1	D	T1	D		
D. Wetlands	NA	NA	NA	NA	NA	NA		
E. Settlements	NA	NA	NA	NA	NA	NA		
6. Waste								
A. Solid waste disposal on land	NA	NA	T2	CS,D				
B. Wastewater handling			D	D	D	D		
C. Waste incineration	D	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

1.4.2   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, 2006 & 2007 constituted a significant source of information and an additional quality control check. Data collected, cover the period 2000 – 2007 and in some cases the whole period 1990 – 2007. Data processing resulted in (a) the estimation of country specific emission factors (e.g. cement production) (b) the improvement of completeness in specific sub-source categories (e.g. iron and steel production) and (c) the distribution of fuel consumption into different technologies / activities in Manufacturing industries and Construction.

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

SECTOR		STATISTICAL DATA	DATA SOURCES
1.A1	Electricity generation	Fuel consumption	• Public Power Corporation • Ministry of Development • ETS verified reports
1.A2	Manufacturing industry and construction	Fuel consumption	• Ministry of Development • ETS verified reports
1.A3	Transport	Number of vehicles Aircraft landing and take off cycles	• Ministry of Transport and Communication • National Statistical Service of Greece • Association of Greek Auto Importers • Civil Aviation Organization
1.A4	Residential / Tertiary sector / Agriculture	Fuel consumption	• Ministry of Development
1.B	Fugitive emissions from fuels	Amount of fuels Transmission/distribution pipelines length	• Ministry of Development
2	Industrial processes	Industrial production	• National Statistical Service of Greece. • Industrial units • ETS verified reports • Market surveys • National Association of Refrigerating and Cooling Technicians
3	Solvents and other products use	Amount of solvents/other products use	• Ministry for the Environment, Physical Planning and Public Works
4	Agriculture	Cultivated areas Agricultural production Livestock population Fertilizer use	• National Statistical Service of Greece • 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	Forest area Forest fires	• Ministry of Rural Development and Food General Directorate for the Forests and the Natural Environment
6	Waste	Quantities - composition of solid waste generated Recycling Population Industrial production	• Ministry for the Environment, Physical Planning and Public Works • National Statistical Service of Greece

1.4.3   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 (NOx, 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 CO_2 eq) for the 100-year horizon*

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydrofluorocarbons (HFC)	
HFC-23	11700
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_2F_6	9200
C_4F_{10}	7000
C_6F_{14}	7400
Sulphur hexafluoride (SF_6)	23900

1.5   Key categories analysis

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 for carbon dioxide, methane and nitrous oxide and 1995 for F - gases.

The key categories for the Greek inventory system (without *LULUCF*) are presented in **Table 1.4.** Differences compared to the results of the analysis presented in the previous submissions are

mainly attributed to the inclusion of "new" sources in the inventory and in general to the recalculation of emissions performed.

Seven key sources are found in the energy sector, being responsible for 80.8% of total GHG emissions in 2007 (without *LULUCF*).

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

Source categories	Gas	Criteria
Energy		
Stationary combustion – Solid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Gaseous fuels	CO_2	Level, Trend
Transport – Road transport	CO_2	Level, Trend
Transport – Navigation	CO_2	Level
Transport - Aviation	CO_2	Level, Trend
Coal mining and handling	CH_4	Level
Industrial processes		
Cement production	CO_2	Level, Trend
Ozone depleting substances substitutes	F-gases	Level, Trend
Nitric acid production	N_2O	Trend
Agriculture		
Enteric fermentation	CH_4	Level
Agricultural soils – Direct emissions	N_2O	Level, Trend
Agricultural soils – Animal production	N_2O	Level
Agricultural soils – Indirect emissions	N_2O	Level, Trend
Waste		
Solid waste disposal on land	CH_4	Level, Trend
Wastewater handling	CH_4	Trend

The methodology applied for the determination of the key categories with *LULUCF* is similar to the one presented above. The key categories identified 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 differences in the source categories identified.

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

Source categories	Gas	Criteria
Energy		
Stationary combustion – Solid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Gaseous fuels	CO_2	Level, Trend
Transport – Road transport	CO_2	Level, Trend
Transport – Navigation	CO_2	Level
Transport - Aviation	CO_2	Level, Trend
Coal mining and handling	CH_4	Level
Industrial processes		
Cement production	CO_2	Level, Trend
Nitric acid production	N_2O	Trend
Ammonia production	CO2	Trend
Ozone depleting substances substitutes	F-gases	Trend
Agriculture		
Enteric fermentation	CH_4	Level, Trend
Agricultural soils – Direct emissions	N_2O	Level, Trend
Agricultural soils – Animal production	N_2O	Level, Trend
Agricultural soils – Indirect emissions	N_2O	Level, Trend
Land Use, Land Use Change and Forestry		
Forest Land remaining Forest Land	CO_2	Level
Cropland remaining Cropland	CO_2	Level, Trend
Land converted to Forest Land	CO_2	Trend
Waste		
Solid waste disposal on land	CH_4	Level, Trend
Wastewater handling	CH_4	Trend

1.6   Quality assurance – Quality control system

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, it is expected that the pressure upon national GHG emissions inventories will increase and therefore quality management would be essential 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 for the Environment, Physical Planning and Public Works. 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 1.6** 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.

Energy	Industrial processes	Solvents	Agriculture	LULUCF	Waste
E1. Data collection	IP1. Data collection	S1. Data collection	A1. Data collection	LU1. Data collection	W1. Data collection
E2. Data check	IP2. Data check	S2. Data check	A2. Data check	LU2. Data check	W2. Data check
E3. Emissions estimation	IP3. Emissions estimation	S3. Emissions estimation	A3. Emissions estimation	LU3. Emissions estimation	W3. Emissions estimation
E4. Check of estimates	IP4. Check of estimates	S4. Check of estimates	A4. Check of estimates	LU4. Check of estimates	W4. Check of estimates
E5. Record keeping	IP5. Record keeping	S5. Record keeping	A5. Record keeping	LU5. Record keeping	W5. Record keeping

IN1. CRF Compilation

IN2. CRF Check

E6. Inventory report for energy	IP6. Inventory report for industrial processes	S6. Inventory report for solvents	A6. Inventory report for agriculture	LU6. Inventory report for LULUCF	W6. Inventory report for waste

IN3. Compilation of National Inventory report

IN4. Check of National Inventory Report

IN5. Centralised archiving of inventory information

IN6. Dissemination of results

Figure 1.4   Flow chart activities concerning the GHG emissions inventory

Table 1.6   *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.

All the procedures described there, are followed by both the MINENV and the NTUA staff members. Furthermore, internal audits took place by MINENV/NTUA between September and November of 2008 and an audit by an independent local expert is scheduled in 2009.

Supplies (QM 07)

Expert review of input data and parameters (QA 01)

Data quality control check (QC 03)

Data collection (QC 01)

Estimation of GHG emissions / removals (QC 02)

Input data record keeping (QC 04)

Data collection & check

GHG emissions estimation & check

Record keeping

Uncertainty analysis (EU 01)

System review (QM 01)

System improvement (QM 02)

Training (QM 03)

Quality management (QM 08)

IN1. CRF Compilation

IN2. CRF Check

Compilation of reports (AI 02)

Internal review (QM 05)

Record keeping (QM 04)

IN3. Sectoral reports and compilation of National Inventory Report

IN4a. Internal check of National Inventory Report

Recalculations management (II 01)

Non compliance - Corrective and preventive actions (QM 06)

Expert review of GHG emissions / removals inventory (QA 02)

IN4b. Official examination & approval

Centralised archiving of inventory information (AI 01)

IN5. Centralised archiving of inventory information

Documents control (QM 09)

Public review (QA 03)

IN6. Dissemination / Site update

Internal communication (QM 10)

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

1.7 Uncertainty

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 CO_2, CH_4 and N_2O emissions and with 1995 as base year for 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 classification of source / sink categories does not coincide completely with the one used for the identification of key categories because it was carried out at levels dictated by the availability of existing appropriate information. Emissions from sources not included in the uncertainty analysis represent less than 1% of total emissions in 2007 (without *LULUCF*).

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

Table 1.7 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 2007, were estimated at:

3.6% for CO_2 emissions

55.9% for CH_4 emissions

81.0% for N_2O emissions and

183.9% for the F-gases emissions.

Table 1.7   *Uncertainty estimates per source category and gas (without LULUCF)*

Source categories	Gas	Uncertainty (%)
Stationary combustion – Solid fuels		7.1
Stationary combustion – Liquid fuels		7.1
Stationary combustion – Gaseous fuels		7.1
Mobile combustion – Road transport		7.1
Mobile combustion – Navigation		7.1
Mobile combustion – Aviation		7.1
Pipeline transport	CO_2	7.1
Fugitive – Oil and Natural gas		300.0
Cement production		2.8
Lime production		29.2
Ammonia Production		2.8
Iron & steel production		7.1
Waste incineration		100.1
Total CO_2		**3.6**
Fuel combustion		100.1
Mobile combustion – Road transport		40.2
Mobile combustion – Navigation		100.1
Mobile combustion – Aviation		100.1
Pipeline transport		100.1
Fugitive – Oil and Natural gas		300.0
Fugitive – Coal mining and handling	CH_4	300.0
Enteric fermentation		30.4
Manure management		50.2
Rice cultivation		40.0
Field burning of agricultural residues		28.3
Managed solid waste disposal on land		41.8
Unmanaged solid waste disposal on land		73.0
Wastewater handling		42.4
Total CH_4		**54.9**
Fuel combustion		300.0
Mobile combustion – Road transport		50.2
Mobile combustion – Navigation		300.0
Mobile combustion – Aviation		300.0
Pipeline transport		300.0
Nitric acid production	N_2O	100.1
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
Total N_2O		**80.9**
HFC-23 emissions from production of HCFC-22		70.7
Ozone depleting substances substitutes	**F-gases**	200.1
PFC from Aluminium production		1.4
Total F-gases		**183.9**
Total uncertainty (%)		**7.37**

In general, the uncertainties associated with CO_2 are very low, while the least accurate estimations are those for N_2O 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 CO_2 depends only on the type of fuel, while CH_4 and N_2O factors depend heavily on the technology of the engine used. As a result, the uncertainty in emissions factors for marine transport is 5% for CO_2 and an order of magnitude for CH_4 and N_2O.

Total uncertainty is 7.37% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 8.96%. These results are similar compared to the results of the analysis performed in previous submissions. The results of the uncertainty analysis for the *LULUCF* sector are presented in ***Table 1.8***.

Table 1.8   *Uncertainty analysis for the LULUCF sector*

Source / Sink categories	Gas	Uncertainty (%)
Forest land remaining forest land	CO_2	100.5
Conversion to forest land	CO_2	100.1
Cropland remaining cropland	CO_2	72.8
Forest land remaining forest land	CH_4	71,6
Cropland remaining cropland	CH_4	100.5
Forest land remaining forest land	N_2O	71,6
Cropland remaining cropland	N_2O	100.5

The uncertainty estimates for GHG emissions per gas, with LULUCF, in 2007, were estimated at (the detailed calculations are presented in Annex IV):

↳   4.5% for CO_2 emissions,

↳   54.9% for CH_4 emissions,

↳   80.8% for N_2O emissions and

↳   183.9% for the F-gases emissions.

Total uncertainty is 18.5%, while the uncertainty that carried over into the GHG emissions trend is 13.2%. The inventory uncertainty is higher when the LULUCF sector is included in the analysis due to the significant uncertainty estimates for the LULUCF source / sink categories (Table 1.8).

1.8 Completeness

In the present inventory report, which supersedes all previous ones, estimates of GHG emissions in Greece for the years 1990-2007 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 SO_2.

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

↳ CO_2 emissions from ferroalloys (use of fuels as reducing agents) production are reported under *Energy*.

↳ CH_4 emissions from ammonia, primary aluminium and steel production are not estimated due to the lack of emission factors.

↳ F-gases emissions from foam blowing, fire extinguishers, aerosols (except of MDIs) and solvents are not estimated due to lack of activity data. At present, various actions are being implemented in order to estimate some of the emissions in the next submissions.

↳ *Potential emissions* of F-gases are not estimated, as, for the time being, imports/exports of the relative chemical compounds are not recorded separately. Some steps are being implemented in order to approach activity data.

↳ N_2O emissions from *Solvents and other products use*.

↳ CH_4 emissions from Agricultural soils.

↳ N_2O emissions from wastewater handling.

↳ CH4 and N2O emissions from the sludge component of industrial wastewater.

↳ CH4 and N2O emission from clinical waste incineration.

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 Emissions trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO_2, CH_4, N_2O, HFC, PFC and SF_6) for the period 1990 - 2007 are presented in *Table 2.1* (in kt CO_2 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 CO_2, CH_4, and N_2O - 1995 for F-gases) were estimated at 107.71 Mt CO_2 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 2007, GHG emissions (without *LULUCF*) amounted to 131.85 Mt CO_2 eq showing an increase of 22.42 % compared to base year emissions and of 24.91% compared to 1990 levels. If emissions / removals from *LULUCF* were included then the increase would be 25.24% (from 102.37 Mt CO_2 eq in 1990 to 128.20 Mt CO_2 eq in 2007).

Carbon dioxide emissions accounted for 86.1% of total GHG emissions in 2007 (without *LULUCF*) and increased by approximately 36.6% from 1990. Nitrous oxide emissions accounted for 7.15% of total GHG emissions in 2007 and decreased by 22.82% from 1990, while methane emissions accounted for 6.16 % of the total GHG emissions in 2007 and decreased by 9.73% from 1990. Finally, F-gases emissions that accounted for 0.6% of total GHG emissions in 2007, decreased by 78% from 1995 (base year for F-gases), due to cease of HCFC-22 production.

Table 2.1a   *Total GHG emissions in Greece (in kt CO$_2$ 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$_2$	83,150.00	82,877.20	84,590.05	84,243.20	86,364.84	86,751.70	89,038.68	93,688.97	98,627.35	97,863.17	103,439.41
CH$_4$	9,003.69	9,011.61	8,930.47	8,930.88	9,032.27	9,058.47	9,227.30	9,221.01	9,282.53	9,091.14	8,933.98
N$_2$O	12,212.74	11,894.44	11,732.28	10,885.24	10,721.40	11,033.25	11,288.92	11,080.00	10,984.04	10,923.87	10,781.79
HFC	935.06	1,106.82	908.39	1,606.64	2,143.91	3,254.21	3,749.47	3,969.46	4,381.37	5,062.89	3,818.72
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72	148.38
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	**105,562.18**	**105,150.79**	**106,416.75**	**105,821.91**	**108,359.48**	**110,184.19**	**113,379.79**	**118,128.51**	**123,482.81**	**123,076.66**	**127,126.27**
B. GHG emissions/removals from LULUCF											
CO$_2$	-3,248.20	-3,596.04	-3,074.99	-3,879.75	-3,553.42	-4,406.97	-3,993.22	-3,957.00	-3,590.82	-4,436.43	-2,636.09
CH$_4$	49.87	25.48	75.40	66.35	62.25	34.76	21.75	46.65	125.11	9.71	166.10
N$_2$O	5.06	2.59	7.65	6.73	6.32	3.53	2.21	4.73	12.70	0.99	16.86
Total	**-3,193.27**	**-3,567.97**	**-2,991.93**	**-3,806.66**	**-3,484.86**	**-4,368.69**	**-3,969.27**	**-3,905.62**	**-3,453.02**	**-4,425.74**	**-2,453.13**
C. GHG Emissions from International Transport											
CO$_2$	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
CH$_4$	16.73	15.37	17.67	20.55	21.83	23.39	20.62	20.76	23.14	20.72	23.83
N$_2$O	90.21	81.50	91.52	104.26	113.64	118.06	106.04	105.86	116.41	109.99	118.83
Total	**10,582.24**	**9,575.47**	**10,774.91**	**12,337.14**	**13,387.00**	**14,004.00**	**12,525.96**	**12,469.78**	**13,734.57**	**12,816.03**	**13,999.80**

Table 2.1b   *Total GHG emissions in Greece (in kt CO$_2$ eq) for the period 2001-2007*

	2001	2002	2003	2004	2005	2006	2007
A. GHG emissions per gas (excluding LULUCF)							
CO$_2$	105,636.93	105,275.08	109,503.94	109,749.98	111,046.80	109,624.74	113,565.83
CH$_4$	8,545.14	8,521.12	8,407.67	8,301.50	8,146.27	8,127.90	8,128.08
N$_2$O	10,628.48	10,510.61	10,367.13	10,284.89	9,931.72	9,660.20	9,425.77
HFC	3,307.95	3,381.18	2,941.99	2,942.13	2,628.43	596.65	665.57
PFC	91.38	88.33	77.30	71.38	71.31	71.16	58.66
SF$_6$	4.06	4.25	4.25	4.47	6.45	8.37	9.92
Total	**128,213.94**	**127,780.57**	**131,302.28**	**131,354.35**	**131,830.97**	**128,089.01**	**131,853.83**
B. GHG emissions/removals from LULUCF							
CO$_2$	-4,983.90	-5,278.04	-5,029.08	-5,140.04	-5,001.42	-5,092.96	-3,807.96
CH$_4$	22.88	3.20	4.48	11.34	6.94	16.73	142.70
N$_2$O	2.32	0.33	0.45	6.11	0.74	1.70	14.48
Total	**-4,958.70**	**-5,274.51**	**-5,024.15**	**-5,122.58**	**-4,993.74**	**-5,074.53**	**-3,650.78**
C. GHG emissions from International Transport							
CO$_2$	13,351.48	12,214.71	13,150.47	13,327.28	11,465.99	12,663.40	12,934.93
CH$_4$	23.17	20.80	21.34	21.53	19.07	20.59	20.36
N$_2$O	114.49	105.12	114.16	115.76	92.76	101.43	108.74
Total	**13,489.14**	**12,340.63**	**13,285.97**	**13,464.57**	**11,577.82**	**12,785.42**	**13,064.03**

2.2   Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2007 are presented in *Table 2.2*.

✥ Emissions from *Energy* in 2007 *(Figure 2.1)* accounted for 81.99% of total GHG emissions (without LULUCF) and increased by approximately 37.91% compared to 1990 levels.

The living standards improvement, due to the economic growth of the period 1990 – 2007, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from *Energy*.

The evolution of GHG emissions from Energy can be distinguished into three 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 0.8% 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 3.8% which is higher that the rate of increased of GDP for the same period (3.4%). Finally, the average annual rate of emissions increase for the period 2000 – 2007 decreased at 1.4% while GDP increased with higher rate (approximately 8%).

The majority of GHG emissions (54.6%) in 2007 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 22%, 9.8% and 12.1% respectively. The rest 1.5% of total GHG emissions from Energy derived from fugitive emissions from fuels.

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 limit the increase of GHG emissions. However, the positive results from the improvement of the vehicles performance are reduced by the high use of passenger cars in transportation activity. The introduction of metro system in Athens is expected to moderate the high use o passenger cars.

✥ Emissions from *Industrial processes* in 2007 accounted for 6.9% of the total emissions (without *LULUCF*) and have almost remained stable to 1990 levels (0.48% of increase). However, in general emissions show an upward trend until 1999 and an abrupt decrease from 2005 to 2006. This intense flunctuation is mainly due to the cease of HCFC-22 production. Emissions in 2007 are slightly lower than emissions of 2006, with a decrease of 0.71%.

✥ The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.12% of the total emissions) and has slightly decreased compared to 1990 level of emissions.

✥ Emissions from *Agriculture* that accounted for 8.57% of total emissions in 2007 (without *LULUCF*), decreased by approximately 17% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N_2O 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 sector *Waste* (2.42% of the total emissions, without *LULUCF*), decreased by approximately 28.4% 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.

Figure 2.1   Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2007

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

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	78,388.35	78,175.50	79,829.14	79,514.79	81,725.73	81,701.05	84,110.92	88,702.88	93,490.59	92,774.50	98,175.53
Industrial processes	9,055.99	9,003.06	8,960.63	9,447.75	9,860.08	11,392.90	12,021.83	12,293.99	12,851.26	13,474.04	12,559.74
Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33
Agriculture	13,497.16	13,317.49	13,102.06	12,343.86	12,204.27	12,546.92	12,665.16	12,539.77	12,551.73	12,435.69	12,258.07
Waste	4,450.97	4,478.96	4,352.09	4,345.39	4,406.17	4,388.68	4,429.72	4,438.79	4,436.84	4,232.46	3,975.59
Total [1]	**105,562.18**	**105,150.79**	**106,416.75**	**105,821.91**	**108,359.48**	**110,184.19**	**113,379.79**	**118,128.51**	**123,482.81**	**123,076.66**	**127,126.27**
LULUCF	-2,991.93	-3,806.66	-3,484.86	-4,368.69	-3,969.27	-3,905.62	-3,453.02	-4,425.74	-2,453.13	-4,958.70	-5,274.51
Index per sector											
Energy	100.00	99.73	101.84	101.44	104.26	104.23	107.30	113.16	119.27	118.35	125.24
Industrial processes	100.00	99.42	98.83	104.33	108.88	125.81	132.75	135.76	141.91	148.79	138.69
Solvents	100.00	103.57	101.84	100.24	96.17	91.12	89.66	90.19	89.79	94.25	92.70
Agriculture	100.00	98.67	97.07	91.46	90.42	92.96	93.84	92.91	93.00	92.14	90.82
Waste	100.00	100.63	97.78	97.63	98.99	98.60	99.52	99.73	99.68	95.09	89.32
Total [2]	**100.00**	**99.61**	**100.81**	**100.25**	**102.65**	**104.38**	**107.41**	**111.90**	**116.98**	**116.59**	**120.43**

[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 CO$_2$ eq) by sector for the period 2001-2007*

Year	2001	2002	2003	2004	2005	2006	2007
Energy	100,571.58	100,365.92	104,431.81	104,594.79	105,433.71	104,034.76	108,108.83
Industrial processes	11,754.89	11,690.15	11,326.25	11,331.47	11,422.58	9,165.49	9,099.71
Solvents	154.67	155.12	155.50	155.87	157.70	159.64	160.34
Agriculture	12,207.46	12,137.24	11,989.56	11,984.79	11,632.44	11,476.22	11,297.76
Waste	3,525.34	3,432.14	3,399.16	3,287.43	3,184.55	3,252.90	3,187.19
Total [1]	**128,213.94**	**127,780.57**	**131,302.28**	**131,354.35**	**131,830.97**	**128,089.01**	**131,853.83**
LULUCF	-5,024.15	-5,122.58	-4,993.74	-5,074.53	-3,650.78	-2,991.93	-3,806.66
Index per sector							
Energy	128.30	128.04	133.22	133.43	134.50	132.72	137.91
Industrial processes	129.80	129.09	125.07	125.13	126.13	101.21	100.48
Solvents	91.14	91.40	91.62	91.84	92.92	94.07	94.48
Agriculture	90.44	89.92	88.83	88.79	86.18	85.03	83.70
Waste	79.20	77.11	76.37	73.86	71.55	73.08	71.61
Total [2]	**121.46**	**121.05**	**124.38**	**124.43**	**124.88**	**121.34**	**124.91**

[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   Emissions trends per gas

2.3.1   Carbon dioxide

The trend of carbon dioxide emissions from 1990 to 2007 by source category is presented in **Table 2.3**. Total CO_2 emissions increased from 83.15 Mt in 1990 to 113.56 Mt in 2007 (without LULUCF). This upward trend (increase of 36.57% from 1990 to 2007) is mainly attributed to the increased electricity production as well as to the increased energy consumption in the residential and transport sectors.

CO_2 emissions from *Energy* increase almost continuously, from 76.23 Mt in 1990 to 105.48 Mt in 2007, presenting a total increase of 38.37% from 1990 to 2007. Carbon dioxide emissions from *Industrial processes* in 2007 increased by 17.41% compared to 1990 levels. On the contrary, emissions from *Solvents and other products use* decreased by 5.52% compared to 1990 levels. Finally, emissions from *Waste* in 2007 show a continuous increase from 1990. (**Figure 2.2**).
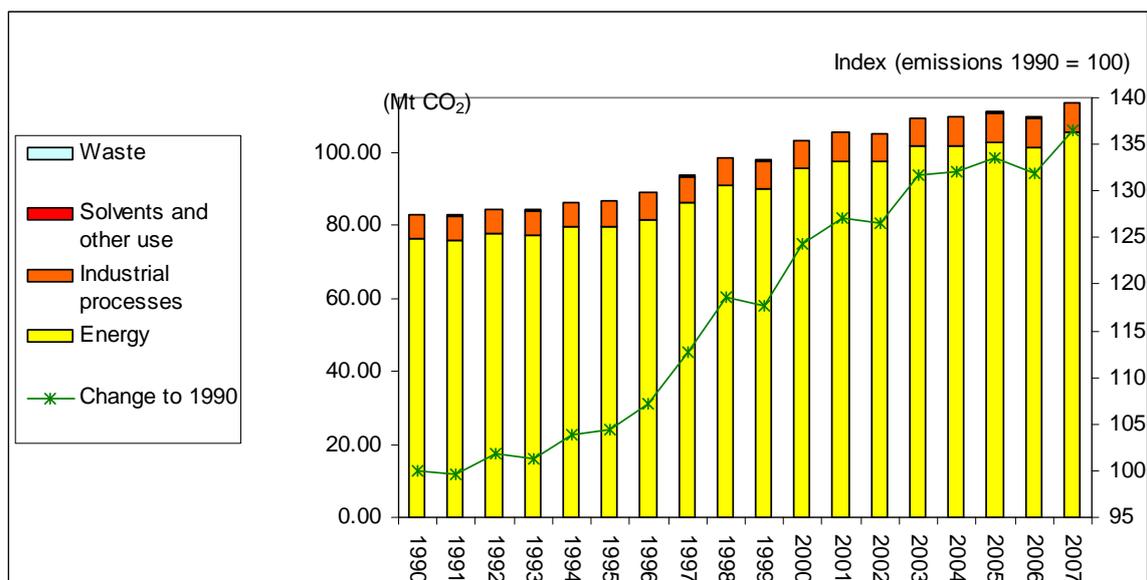
Figure 2.2   CO₂ emissions by sector (in Mt) for the years 1990 – 2007 (without LULUCF)

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)	**79,901.80**	**79,281.16**	**81,515.07**	**80,363.45**	**82,811.42**	**82,344.73**	**85,045.45**	**89,731.97**	**95,036.53**	**93,426.74**	**100,803.32**
Total (without LULUCF)	**83,150.00**	**82,877.20**	**84,590.05**	**84,243.20**	**86,364.84**	**86,751.70**	**89,038.68**	**93,688.97**	**98,627.35**	**97,863.17**	**103,439.41**
1. Energy	**76,229.46**	**75,980.70**	**77,577.10**	**77,296.36**	**79,465.78**	**79,423.87**	**81,693.27**	**86,262.00**	**90,938.09**	**90,180.79**	**95,464.58**
A. Fuel combustion	76,159.23	75,909.80	77,518.90	77,249.03	79,420.56	79,385.14	81,649.67	86,222.85	90,910.91	90,179.34	95,377.03
1. Energy industries	43,149.20	42,014.12	44,286.97	44,199.12	46,178.70	44,948.38	44,145.03	47,590.80	50,117.94	50,410.08	54,887.20
2. Man. Industry and Construction	10,378.38	10,232.00	9,525.25	9,275.65	9,096.12	9,855.78	10,546.98	10,649.91	10,703.59	9,434.92	10,424.59
3. Transport	14,505.74	15,242.53	15,647.18	15,855.55	16,167.57	16,529.50	17,004.68	17,763.95	19,523.59	19,942.60	19,067.82
4. Other sectors	8,125.91	8,421.16	8,059.51	7,918.71	7,978.16	8,051.48	9,952.98	10,218.20	10,565.78	10,391.74	10,997.42
B. Fugitive emissions	70.23	70.90	58.20	47.33	45.22	38.73	43.60	39.15	27.18	1.44	87.56
2. Industrial processes	**6,750.68**	**6,720.57**	**6,839.96**	**6,776.57**	**6,735.69**	**7,173.03**	**7,193.10**	**7,273.75**	**7,536.71**	**7,522.27**	**7,817.35**
A. Mineral products	6,378.66	6,343.37	6,465.98	6,415.96	6,392.42	6,829.33	6,859.36	6,918.78	6,963.14	6,980.86	7,106.36
B. Chemical production									195.28	158.63	294.37
C. Metal production	372.02	377.20	373.98	360.60	343.27	343.70	333.74	354.97	378.29	382.78	416.61
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	**-3,248.20**	**-3,596.04**	**-3,074.99**	**-3,879.75**	**-3,553.42**	**-4,406.97**	**-3,993.22**	**-3,957.00**	**-3,590.82**	**-4,436.43**	**-2,636.09**
6. Waste	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**
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 2001-2007 (in kt)

Year	2001	2002	2003	2004	2005	2006	2007
Total (with LULUCF)	100,653.03	99,997.04	104,474.85	104,609.94	106,045.38	104,531.78	109,757.87
Total (without LULUCF)	105,636.93	105,275.08	109,503.94	109,749.98	111,046.80	109,624.74	113,565.83
1. Energy	97,778.68	97,527.08	101,620.85	101,827.16	102,716.65	101,416.21	105,476.40
A. Fuel combustion	97,672.24	97,443.38	101,521.34	101,708.61	102,600.10	101,305.98	105,362.64
1. Energy industries	55,408.34	54,838.01	56,082.31	57,402.02	57,784.88	55,487.68	58,840.15
2. Man. industry and Construction	10,541.77	10,121.53	9,906.74	9,197.51	8,973.88	9,213.93	10,485.01
3. Transport	19,877.47	20,096.87	21,246.27	21,619.27	21,707.00	22,571.36	23,371.33
4. Other sectors	11,844.66	12,386.97	14,286.02	13,489.81	14,134.35	14,033.00	12,666.15
B. Fugitive emissions	106.44	83.71	99.52	118.55	116.55	110.24	113.75
2. Industrial processes	7,703.42	7,592.47	7,726.80	7,765.96	8,170.59	8,046.62	7,926.03
A. Mineral products	7,128.57	6,906.46	6,945.71	6,941.66	7,342.09	7,199.55	7,055.64
B. Chemical production	137.13	187.90	293.03	311.18	285.24	314.89	321.45
C. Metal production	437.72	498.11	488.07	513.12	543.27	532.18	548.93
3. Solvents	154.67	155.12	155.50	155.87	157.70	159.64	160.34
5. LULUCF	-4,983.90	-5,278.04	-5,029.08	-5,140.04	-5,001.42	-5,092.96	-3,807.96
6. Waste	0.15	0.41	0.79	0.98	1.87	2.26	3.06
International transport [1]	13,351.48	12,214.71	13,150.47	13,327.28	11,465.99	12,663.40	12,934.93
Aviation	2,321.55	2,321.55	3,021.87	3,106.36	2,387.08	2,862.92	2,923.24
Marine	11,029.93	9,893.16	10,128.61	10,220.92	9,078.91	9,800.48	10,011.69

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

2.3.2   Methane

The trend of methane emissions from 1990 to 2007 by source category is presented in *Table 2.4* and in *Figure 2.3*.

Agriculture represents the largest anthropogenic source of methane emissions in Greece since 2001 (with enteric fermentation being the main source category in the sector), accounting for 43.67% of total methane emissions in 2007 (without *LULUCF*). Methane emissions from *Agriculture* in 2007 increased by 2.28% compared to 1990 levels. Methane emissions from *Waste* in 2007 accounted for 34.54% of total methane emissions and decreased by 31.96% from 1990. 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 the remaining 21.79% of the total methane emissions.
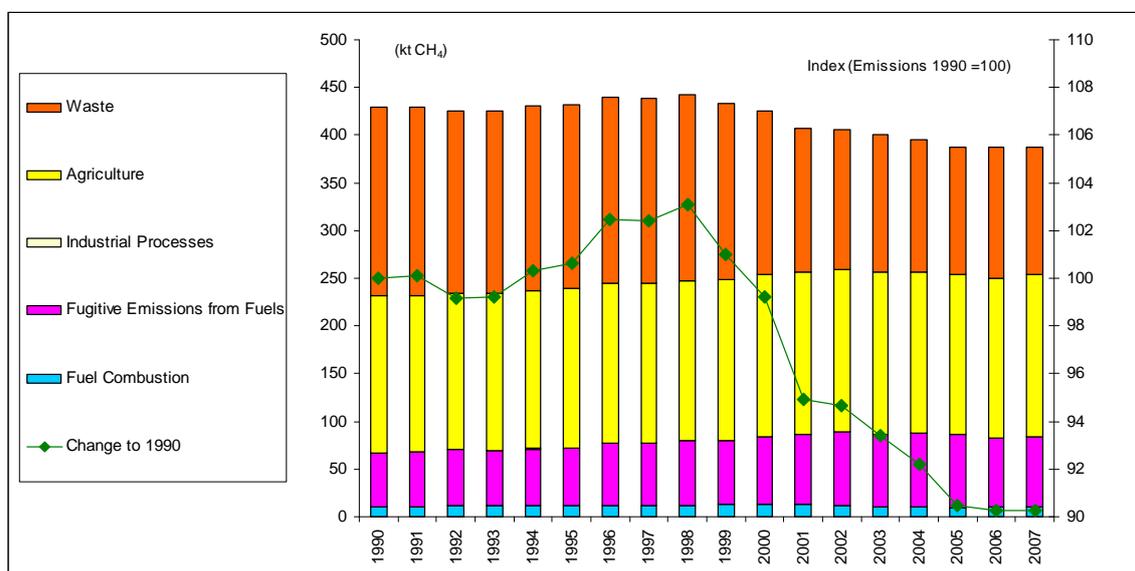
Figure 2.3   *CH$_4$ emissions by sector (in kt) for the period 1990 – 2007 (without LULUCF)*

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)	**431.12**	**430.34**	**428.85**	**428.44**	**433.07**	**433.01**	**440.43**	**441.32**	**447.98**	**433.37**	**433.34**
Total (without LULUCF)	**428.75**	**429.12**	**425.26**	**425.28**	**430.11**	**431.36**	**439.40**	**439.10**	**442.03**	**432.91**	**425.43**
1. Energy	**67.00**	**68.00**	**71.06**	**69.90**	**71.31**	**72.33**	**77.50**	**76.79**	**79.74**	**80.50**	**84.42**
A. Fuel combustion	10.49	10.81	12.00	11.80	11.54	11.74	12.27	12.21	12.41	13.02	13.67
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	0.44	0.43	0.42	0.41	0.42	0.45	0.46	0.45	0.42	0.48
3. Transport	5.45	5.76	6.13	6.36	6.51	6.76	7.16	7.30	7.59	7.65	7.61
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	**0.02**	**0.03**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.01**
4. Agriculture	**165.25**	**163.60**	**163.04**	**164.50**	**165.66**	**166.87**	**167.72**	**168.07**	**168.18**	**168.47**	**169.19**
A. Enteric fermentation	137.02	135.54	135.47	135.94	136.32	137.19	137.59	137.80	138.44	139.22	140.57
B. Manure management	23.66	23.30	23.15	23.11	23.07	23.01	23.00	23.03	23.15	23.27	23.25
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	**2.37**	**1.21**	**3.59**	**3.16**	**2.96**	**1.66**	**1.04**	**2.22**	**5.96**	**0.46**	**7.91**
6. Waste	**196.47**	**197.50**	**191.13**	**190.85**	**193.11**	**192.13**	**194.14**	**194.20**	**194.08**	**183.93**	**171.80**
A. Solid waste disposal on land	86.04	89.47	84.85	88.13	91.56	93.11	96.87	100.59	103.25	98.92	103.50
B. Wastewater handling	110.43	108.03	106.28	102.72	101.55	99.02	97.27	93.60	90.82	85.01	68.30
International Transport [1]	**0.80**	**0.73**	**0.84**	**0.98**	**1.04**	**1.11**	**0.98**	**0.99**	**1.10**	**0.99**	**1.13**
Aviation	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Marine	0.77	0.71	0.81	0.95	1.01	1.08	0.95	0.96	1.07	0.95	1.09

[1] Emissions from International Transport are not included in national totals

Table 2.4b   *CH$_4$ emissions by source category for the period 2001-2007 (in kt)*

Year	2001	2002	2003	2004	2005	2006	2007
Total (with LULUCF)	**408.00**	**405.92**	**400.58**	**395.85**	**388.25**	**387.84**	**393.85**
Total (without LULUCF)	**406.91**	**405.77**	**400.37**	**395.31**	**387.92**	**387.04**	**387.05**
1. Energy	**86.10**	**88.84**	**86.62**	**88.34**	**86.60**	**82.15**	**84.36**
A. Fuel combustion	12.83	11.45	11.12	10.84	9.73	9.94	10.03
1. Energy industries	0.78	0.78	0.80	0.80	0.83	0.84	0.89
2. Manufacturing industry and Construction	0.47	0.48	0.42	0.42	0.44	0.44	0.45
3. Transport	7.20	6.70	6.37	5.65	5.00	4.78	4.89
4. Other sectors	4.37	3.49	3.52	3.97	3.46	3.87	3.79
B. Fugitive emissions from fuels	73.27	77.39	75.51	77.50	76.87	72.21	74.33
1. Solid fuels	66.68	70.82	68.64	70.39	69.74	64.84	66.80
2. Oil and natural gas	6.60	6.57	6.87	7.10	7.12	7.37	7.53
2. Industrial processes							
4. Agriculture	**170.32**	**170.91**	**169.36**	**167.97**	**167.54**	**167.96**	**169.02**
A. Enteric fermentation	141.41	141.89	140.45	138.90	138.39	138.97	139.55
B. Manure management	23.27	23.16	23.12	23.10	23.09	23.21	23.19
C. Rice cultivation	4.22	4.48	4.52	4.55	4.62	4.46	5.00
F. Field burning of agricultural residues	1.42	1.38	1.27	1.42	1.43	1.32	1.28
5. LULUCF	**1.09**	**0.15**	**0.21**	**0.54**	**0.33**	**0.80**	**6.80**
6. Waste	**150.49**	**146.02**	**144.38**	**139.00**	**133.78**	**136.94**	**133.68**
A. Solid waste disposal on land	108.46	109.81	114.35	114.45	113.07	118.08	116.64
B. Wastewater handling	42.03	36.21	30.03	24.55	20.71	18.85	17.04
International Transport [1]	1.10	0.99	1.02	1.03	0.91	0.98	0.97
Aviation	0.04	0.04	0.04	0.04	0.03	0.03	0.00
Marine	1.06	0.95	0.98	0.98	0.88	0.95	0.97

[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 2007 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 (82.2% approximately of the total nitrous oxide emissions in 2007, without *LULUCF*). Emissions from this sector decreased by 22.7 % 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 9.13% of total nitrous oxide emissions in 2007) increased by 14.53% from 1990. However, emissions from the *Energy* sector tend to decrease in recent years (2004-2007), mainly due to the penetration of natural gas in electricity production.

Production of nitric acid is the major source of N_2O emissions from *Industrial processes* and accounts for 4.66% of total N_2O emissions in 2007. Nitrous oxide emissions from this source decreased by 60.37% from 1990, due to the reduction of nitric acid production in Greece.

N_2O emissions from *Waste* in 2007 (4% of total emissions without *LULUCF*) increased by 5.97% compared to 1990 levels.
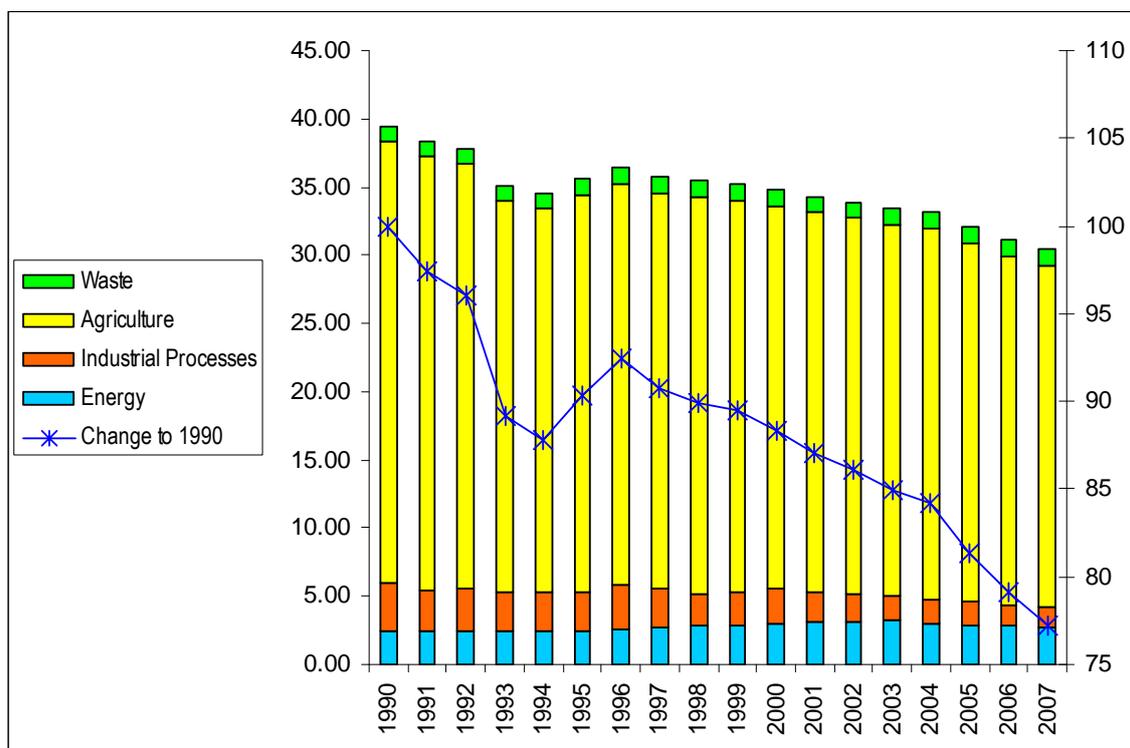
Figure 2.4   ***N_2O emissions by sector (in kt) for the period 1990 – 2007 (without LULUCF)***

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)	39.41	38.38	37.87	35.14	34.61	35.60	36.42	35.76	35.47	35.24	34.83
Total (without LULUCF)	39.40	38.37	37.85	35.11	34.59	35.59	36.42	35.74	35.43	35.24	34.78
1. Energy	2.43	2.47	2.45	2.42	2.46	2.45	2.55	2.67	2.83	2.91	3.03
A. Fuel combustion	2.42	2.47	2.45	2.42	2.46	2.45	2.55	2.67	2.83	2.91	3.03
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	0.15	0.16	0.16	0.16	0.16	0.17	0.18	0.18	0.18	0.17	0.18
3. Transport	0.54	0.56	0.57	0.58	0.60	0.66	0.74	0.83	0.96	1.05	1.09
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
4. Agriculture	32.34	31.88	31.22	28.68	28.15	29.17	29.49	29.07	29.10	28.70	28.08
B. Manure management	0.97	0.95	0.93	0.92	0.91	0.91	0.91	0.91	0.92	0.93	0.94
D. Agricultural soils	31.34	30.89	30.26	27.72	27.19	28.22	28.55	28.12	28.15	27.74	27.11
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	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.04	0.00	0.05
6. Waste	1.05	1.07	1.09	1.09	1.13	1.14	1.14	1.16	1.16	1.19	1.19
International transport [1]	0.29	0.26	0.30	0.34	0.37	0.38	0.34	0.34	0.38	0.35	0.38
Aviation	0.09	0.07	0.08	0.08	0.10	0.09	0.09	0.09	0.09	0.10	0.09
Marine	0.21	0.19	0.22	0.25	0.27	0.29	0.25	0.25	0.28	0.25	0.29

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

Table 2.5b   N₂O emissions by source category for the period 2001-2007 (in kt)

Year	2001	2002	2003	2004	2005	2006	2007
Total (with LULUCF)	**34.29**	**33.91**	**33.44**	**33.20**	**32.04**	**31.17**	**30.45**
Total (without LULUCF)	**34.29**	**33.91**	**33.44**	**33.18**	**32.04**	**31.16**	**30.41**
1. Energy	**3.18**	**3.14**	**3.20**	**2.94**	**2.90**	**2.88**	**2.78**
A. Fuel combustion	3.18	3.14	3.20	2.94	2.90	2.88	2.78
1. Energy industries	0.61	0.60	0.61	0.63	0.63	0.59	0.62
2. Man. industry and Construction	0.18	0.17	0.16	0.15	0.15	0.15	0.16
3. Transport	1.22	1.13	1.07	0.98	0.93	0.90	0.88
4. Other sectors	1.16	1.24	1.35	1.18	1.19	1.24	1.12
B. Fugitive emissions from fuels	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**
4. Agriculture	**27.84**	**27.57**	**27.20**	**27.28**	**26.17**	**25.64**	**24.99**
B. Manure management	0.94	0.95	0.94	0.93	0.93	0.94	0.95
D. Agricultural soils	26.86	26.59	26.23	26.31	25.20	24.66	24.01
F. Field burning of agr. residues	0.04	0.03	0.03	0.04	0.04	0.03	0.03
5. LULUCF	**0.01**	**0.00**	**0.00**	**0.02**	**0.00**	**0.01**	**0.05**
6. Waste	**1.18**	**1.18**	**1.18**	**1.19**	**1.20**	**1.21**	**1.22**
International transport [1]	**0.37**	**0.34**	**0.37**	**0.37**	**0.30**	**0.33**	**0.35**
Aviation	0.09	0.09	0.11	0.11	0.07	0.07	0.09
Marine	0.28	0.25	0.26	0.26	0.23	0.25	0.26

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 SF_6, 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 CF_4 and C_2F_6). 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). HFC-23 production has ceased, since 2006, due to the closure of the plant producing HCFC-22.

↳   Manufacturing, operation and maintenance of refrigeration and air conditioning equipment. HFC emissions increased significantly since 1995 (base year), mainly due to the increase of air conditioning equipment in the residential sector and the new passenger cars with air-conditioning systems.

↳   Use of F-Gases in metered dose inhalers, which is based on data from NSSG and generally is estimated to be increased throughout the inventory years.

↳   The use of SF_6 in the electricity transmissions / distribution system.

Table 2.6   *Actual F-gases emissions for the period 1990-2007 (in kt CO₂ eq)*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HFC	935.06	1,106.82	908.39	1,606.64	2,143.91	3,254.21	3,749.47	3,969.46	4,381.37	5,062.89
HFC-23	935.06	1,106.82	908.39	1,606.64	2,143.91	3,253.07	3,746.34	3,960.22	4,359.89	5,023.04
HFC-32										
HFC-125										
HFC-134a						1.15	3.13	9.24	21.48	39.84
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72
SF₆	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87
Total	1,195.75	1,367.54	1,163.95	1,762.59	2,240.97	3,340.77	3,824.89	4,138.52	4,588.90	5,198.48

	2000	2001	2002	2003	2004	2005	2006	2007
HFC	3,818.72	3,307.95	3,381.18	2,941.99	2,942.13	2,628.43	596.65	665.57
HFC-23	3,735.11	3,181.46	3,194.57	2,661.05	2,550.60	2,157.48		
HFC-32	2.37	4.16	8.46	14.08	19.60	26.08	36.66	41.84
HFC-125	11.05	19.44	39.49	65.74	91.46	121.67	171.07	195.09
HFC-134a	70.19	102.88	138.66	201.12	280.47	323.20	388.92	428.64
PFC	148.38	91.38	88.33	77.30	71.38	71.31	71.16	58.66
SF₆	3.99	4.06	4.25	4.25	4.47	6.45	8.37	9.92
Total	3,971.09	3,403.39	3,473.76	3,023.55	3,017.98	2,706.19	676.17	734.15

2.4   Emissions trends for indirect greenhouse gases and sulphur dioxide

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

These gases are generated through a variety of anthropogenic activities. Emissions trends for indirect greenhouse gases and SO_2 are presented in *Table 2.7*, while more information on the emissions of indirect greenhouse gases and SO_2 is provided in Annex V.

✤ NO_x emissions increased by 26.35% from 1990 to 2007. Energy sector accounts for the high majority of emissions (99.3%). The decrease in NO_x emissions from transport after 1998 is attributed to the substitution of old technology vehicles by new catalytic ones (NOx emissions from this category account for the 39.78% of total NO_x emissions in 2007). Emissions from *Industrial processes* decreased by 26.42% 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 45.27% from 1990 to 2007 and as a result total CO emissions in 2007 decreased by 37.88%. Emissions from industrial processes in 2007 increased by 3.61% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires. In 2007 emissions from LULUCF accounted for 6.64% of total CO emissions (incl LULUCF), and are by 186% higher than emissions of 1990.

✤ NMVOC emissions decreased by 22.95% from 1990 to 2007. Emissions from transport, which is the main source of NMVOC emissions in Greece (18.75% of total NMVOC emissions in 2007), decreased by 65.38% compared to 1990 levels, while emissions from *Energy* decreased by 31.96% from 1990 to 2007. The significant increase of NMVOC emissions from *Industrial processes* (approximately 39.55% from 1990 to 2007) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 4.84% compared to 1990 levels.

✤ SO_2 emissions increased by 14.35% from 1990 to 2007. Emissions from electricity generation, which is the main source of SO_2 emissions in Greece (68.1 % of total SO_2 emissions for 2007, increased with a mean annual rate of increase of 2.00% for the period 1990 – 2007. The operation of a desulphurisation plant at a large installation for electricity generation since 1998 resulted in the restriction of the increase of SO_2 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 SO$_2$ emissions from manufacturing industry and construction, transport and other sectors by 34.28%. 12.8% and 22.5% respectively for the period 1990 – 2007. Emissions from *Industrial processes* decreased by 19.14% 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
NOx	**299.15**	**316.07**	**325.61**	**322.72**	**330.51**	**317.46**	**322.41**	**332.01**	**355.36**	**346.46**	**339.25**
1. Energy	296.10	312.85	322.61	319.85	327.62	314.64	319.52	329.20	352.78	343.86	336.53
Transport	148.9	158.3	162.3	163	165.4	163.1	161.3	165.3	184.8	180	157.5
Other energy sectors	147.20	154.55	160.31	156.85	162.22	151.54	158.22	163.90	167.98	163.86	179.03
2. Industrial processes	1.88	1.64	1.68	1.60	1.53	1.54	1.62	1.52	1.38	1.42	1.47
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	0.59	0.30	0.89	0.79	0.74	0.41	0.26	0.55	1.48	0.11	1.97
CO	**1,345.17**	**1,368.18**	**1,390.72**	**1,387.89**	**1,384.65**	**1,377.23**	**1,402.93**	**1,403.76**	**1,434.42**	**1,361.71**	**1,408.73**
1. Energy	1,295.20	1,307.46	1,337.67	1,337.75	1,333.68	1,328.37	1,354.54	1,354.90	1,384.63	1,310.64	1,356.39
Transport	913.16	921.61	941.31	948.35	943.36	953.89	984.81	970.14	964.53	938.63	912.22
Other energy sectors	382.04	385.85	396.36	389.40	390.32	374.48	369.74	384.77	420.10	372.01	444.17
2. Industrial processes	22.91	22.78	22.19	20.60	18.75	18.61	18.74	18.89	21.67	23.45	23.13
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	20.78	10.62	31.42	27.65	25.94	14.48	9.06	19.44	52.13	4.05	69.21
NMVOC	**384.07**	**398.81**	**407.67**	**412.51**	**420.41**	**425.38**	**430.86**	**433.31**	**446.47**	**448.36**	**454.19**
1. Energy	300.45	311.78	320.59	325.67	334.51	336.00	341.60	343.13	351.39	350.01	351.22
Transport	160.30	168.13	176.47	182.90	191.14	187.54	192.23	191.85	194.53	190.80	184.25
Other energy sectors	140.15	143.65	144.12	142.77	143.37	148.46	149.37	151.28	156.86	159.20	166.97
2. Industrial processes	26.97	28.77	29.62	30.68	31.60	37.74	38.21	38.75	43.72	44.60	49.76
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	**481.18**	**521.89**	**537.16**	**532.51**	**524.35**	**547.98**	**537.77**	**531.41**	**539.05**	**557.71**	**507.94**
1. Energy	471.60	512.79	528.87	524.64	516.30	539.19	529.14	522.49	529.97	548.37	499.47
Transport	33.21	33.43	34.85	31.09	36.21	30.47	29.06	30.64	45.28	48.68	23.93
Other energy sectors	438.39	479.36	494.02	493.55	480.10	508.73	500.08	491.85	484.70	499.69	475.54
2. Industrial processes	9.57	9.10	8.29	7.87	8.05	8.78	8.63	8.92	9.08	9.35	8.48

Table 2.7b   *Emissions trends for indirect greenhouse gases and SO₂ (in kt) for the period 2001-2007*

Year	2001	2002	2003	2004	2005	2006	2007
NOx	**353.38**	**353.11**	**363.77**	**362.13**	**388.61**	**363.64**	**377.99**
1. Energy	350.73	350.41	361.21	359.43	385.82	361.06	375.41
Transport	162.4	155.6	156	153.7	165.6	149.8	150.4
Other energy sectors	188.33	194.81	205.21	205.73	220.22	211.26	225.01
2. Industrial processes	1.36	1.45	1.37	1.39	1.45	1.35	1.38
4. Agriculture	1.29	1.25	1.19	1.31	1.33	1.23	1.21
5. LULUCF	0.27	0.04	0.05	0.13	0.09	0.20	1.69
CO	**1,318.25**	**1,282.01**	**1,242.96**	**1,208.67**	**983.32**	**892.43**	**835.68**
1. Energy	1,265.90	1,230.21	1,192.61	1,155.09	929.75	841.23	784.99
Transport	881.54	854.76	838.34	797.58	712.07	616.88	499.77
Other energy sectors	384.35	375.44	354.27	357.51	217.68	224.35	285.22
2. Industrial processes	22.44	22.89	23.66	23.78	23.47	23.56	23.74
4. Agriculture	29.91	28.91	26.69	29.80	30.09	27.64	26.94
5. LULUCF	9.53	1.33	1.87	4.73	3.03	6.97	59.46
NMVOC	**448.33**	**446.85**	**431.75**	**431.06**	**361.94**	**308.72**	**295.94**
1. Energy	346.21	342.52	334.35	327.94	274.45	210.92	204.40
Transport	180.40	173.47	172.36	162.33	131.80	56.90	55.49
Other energy sectors	165.81	169.05	161.99	165.61	142.65	154.02	148.91
2. Industrial processes	49.78	51.84	44.79	50.39	34.44	44.12	37.63
3. Solvents	52.35	52.49	52.61	52.73	53.05	53.68	53.90
SO₂	**512.84**	**524.28**	**562.68**	**557.07**	**559.25**	**541.24**	**550.83**
1. Energy	504.49	515.74	554.08	548.34	549.20	533.57	543.09
Transport	28.32	24.66	26.30	31.20	29.18	31.86	28.96
Other energy sectors	476.17	491.08	527.79	517.14	520.01	501.72	514.13
2. Industrial processes	8.35	8.54	8.60	8.72	10.06	7.67	7.74

3.   Energy (CRF sector 1)

3.1   Overview

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.

The remainder of this chapter is organized as follows. Paragraph 3.1 continues with the presentation of emissions trends from energy, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the status of completeness of the GHG inventory for the energy sector. Next (Paragraphs 3.2 – 3.6), 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 as well as on related methodological issues is provided.

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

✤   Stationary combustion[2], 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 2007 amounted to approximately 1320 PJ. The consumption of solid fuels and oil products accounts for 85% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar and wind energy) are 1.6% and 1.8% respectively. Finally, the share of natural gas in gross inland consumption is more than 10% while the rest 1.2% of gross inland consumption is covered by electricity (net imports – exports). In 2007, gross inland consumption increased by approximately 48% compared to 1990, presenting a 2.3% 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.

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[2] Emissions from off-road machinery should be reported under Stationary combustion according to the IPCC Guidelines
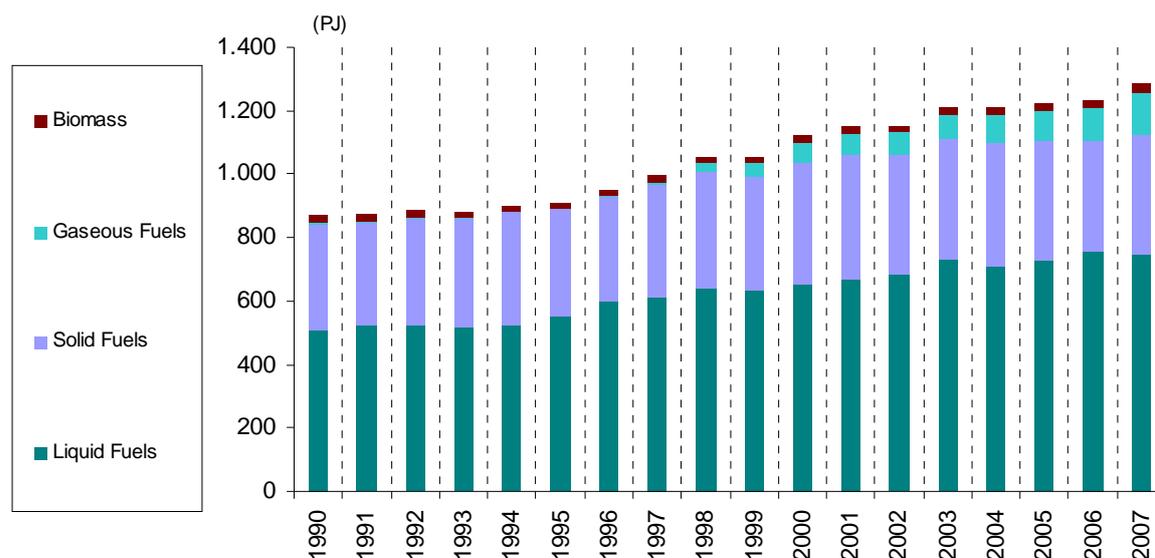
Figure 3.1   Gross inland consumption (in PJ) by energy type for the period 1990 - 2007

GHG emissions from *Energy* in 2007 increased by 38% compared to 1990 (***Figure 3.2***), while the average annual rate of increase for the period 1990 – 2007 was 1.9%. The highest increase on an annual basis (compared to the previous year) was recorded in 2000 (emissions increased by 5.8%), due to the significant increase in electricity demand as a result of particular weather conditions (very high summer temperatures).
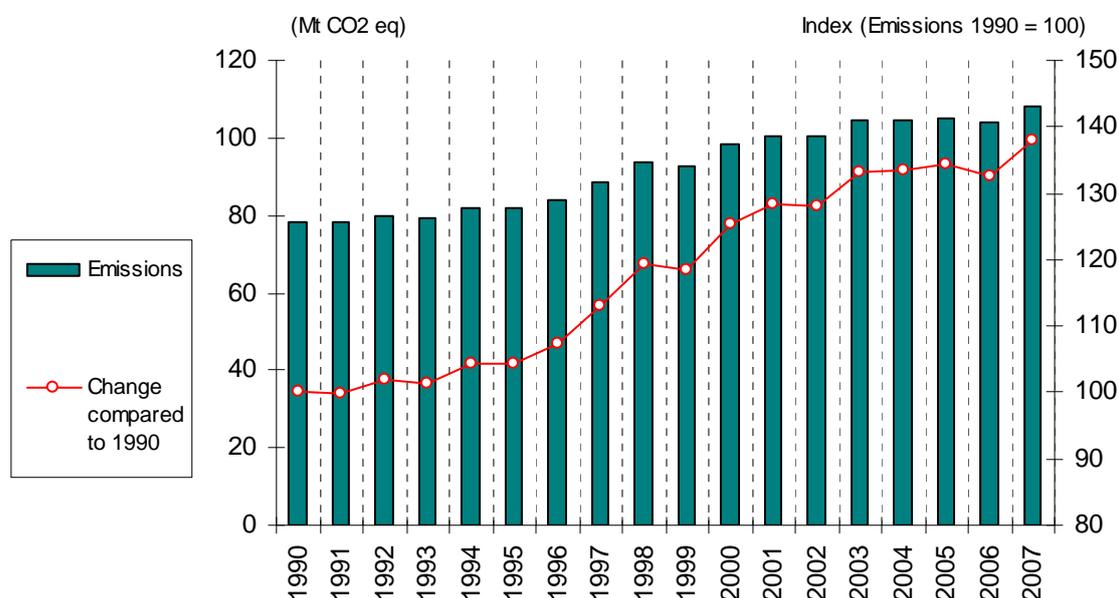
Figure 3.2   Total GHG emissions from Energy (in Mt CO2 eq) for the period 1990 – 2007

The evolution of GHG emissions from *Energy* can be distinguished into three 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 0.8% 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 3.8% which is higher that the rate of increased of GDP for the same period (3.4%). Finally, the average annual rate of emissions increase for the period 2000 – 2007 decreased at 1.4% while GDP increased with higher rate (approximately 8%).

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 (54.6%) in 2007 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 22%, 9.8% and 12.1% 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 2.9%, followed by Other sectors (i.e. residential, tertiary and agriculture sectors) with a 2.8% average annual rate of increase. Emissions from energy industries increased with an average annual rate of 1.9%, while emissions from manufacturing industries and construction emissions increased with a mean annual rate of 0.3%. Finally, fugitive emissions from fuels increased with an average annual rate of 1.8% for the period 1990 – 2007.

Table 3.1   *GHG emissions from Energy by source category and gas for the period 1990 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO2 emissions (in Mt)																		
A. Fuel Combustion																		
1. Energy Industries	43,15	42,01	44,29	44,20	46,18	44,95	44,15	47,59	50,12	50,41	54,89	55,41	54,84	56,08	57,40	57,78	55,49	58,84
2. Industry	10,38	10,23	9,53	9,28	9,10	9,86	10,55	10,65	10,70	9,43	10,42	10,54	10,12	9,91	9,20	8,83	9,10	10,49
3. Transport	14,51	15,24	15,65	15,86	16,17	16,53	17,00	17,76	19,52	19,94	19,07	19,88	20,10	21,25	21,62	21,71	22,57	23,37
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	14,29	13,49	14,13	14,03	12,67
B. Fugitive Emissions from Fuels																		
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0,06	0,09	0,07	0,09	0,11	0,11	0,10	0,11
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
CH4 emissions (in kt)																		
A. Fuel Combustion																		
1. Energy Industries	0,60	0,61	0,62	0,63	0,64	0,65	0,65	0,67	0,70	0,71	0,79	0,78	0,78	0,80	0,80	0,83	0,84	0,89
2. Industry	0,31	0,31	0,31	0,30	0,29	0,30	0,42	0,43	0,42	0,40	0,46	0,45	0,46	0,41	0,41	0,44	0,44	0,45
3. Transport	5,45	5,76	6,13	6,36	6,51	6,76	7,16	7,30	7,59	7,65	7,61	7,20	6,70	6,37	5,65	5,00	4,78	4,90
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	3,49	3,52	3,97	3,55	3,97	3,89
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
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	7,10	7,12	7,37	7,53
N2O emissions																		
A. Fuel Combustion (in kt)																		
1. Energy Industries	0,50	0,48	0,51	0,51	0,53	0,51	0,50	0,54	0,57	0,56	0,60	0,61	0,60	0,61	0,63	0,63	0,59	0,62
2. Industry	0,21	0,21	0,21	0,21	0,21	0,23	0,19	0,19	0,20	0,18	0,19	0,19	0,18	0,17	0,16	0,15	0,15	0,16
3. Transport	0,54	0,56	0,57	0,58	0,60	0,66	0,74	0,83	0,96	1,05	1,09	1,22	1,13	1,07	0,98	0,93	0,90	0,88
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
B. Fugitive Emissions from Fuels (int)																		
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
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

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 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 Method	CO_2 Emission factor	CH_4 Method	CH_4 Emission factor	N_2O Method	N_2O 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	PS	T2	D	T2	D
1A3	**Transport**						
1A3a	Aviation	T2α	D. CR	T2α	D. CR	T2α	D. CR
1A3b	Road transport	T1	D	M	M	M	M
1A3c	Railways	T1	D	CR	CR	CR	CR
1A3d	Navigation	T1	D	CR	CR	CR	CR
1A3e	(Pipeline transport	CR	D	CR	CR	CR	CR
1A4	**Other sectors**						
1A4a	Commercial / Institutional	T2	D	T2	D	T2	D
1A4b	Residential	T2	D	T2	D	T2	D
1A4c	Agriculture / Forestry / Fisheries	T2	D	T2	D	T2	D
1B	**Fugitive emissions from fuels**						
1B1	Solid fuels	T1,CS	D,CS	T1	D	NA	NA
1B2	Oil and Natural gas	T1	D	T1	D	T1	D
International transport [1)]							
	Aviation	T2a	D	T2a	T2a	T2a	T2a
	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 compiled by the Ministry of Development and the reports of installations under the EU ETS. The

Ministry of Transport and the National Statistical Service 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 81% of total national GHG emissions in 2007 (without *LULUCF*).

Table 3.3   Key categories from Energy

IPCC source categories	Gas	Criteria
Stationary combustion – Solid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Gas	CO_2	Level, Trend
Mobile combustion – Road vehicles	CO_2	Level, Trend
Mobile combustion - Navigation	CO_2	Level
Mobile combustion – Aviation	CO_2	Level, Trend
Coal mining and handling	CH_4	Level

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 1.7*). In *Table IV.1* 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			
	CO₂	CH₄	N₂O	HFC	PFC	SF₆	NOx	CO	NMVOC	SO₂
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	☒	☒	NA				NA	NA	NA	
Oil	☒	☒	☒				☒	☒	☒	☒
Natural gas	☒	☒	☒						NE	NE
International transport [1]										
Aviation	☒	☒	☒				☒	☒	☒	☒
Marine	☒	☒	☒				☒	☒	☒	☒

[1] Emissions from international transport are not included in national totals

NE: Not Estimated

NA: Not Applicable

3.2 Stationary combustion

3.2.1 Overview

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 72% - 76% of total fossil fuel consumption in Greece for the period 1990 – 2007 (***Figure 3.3***).
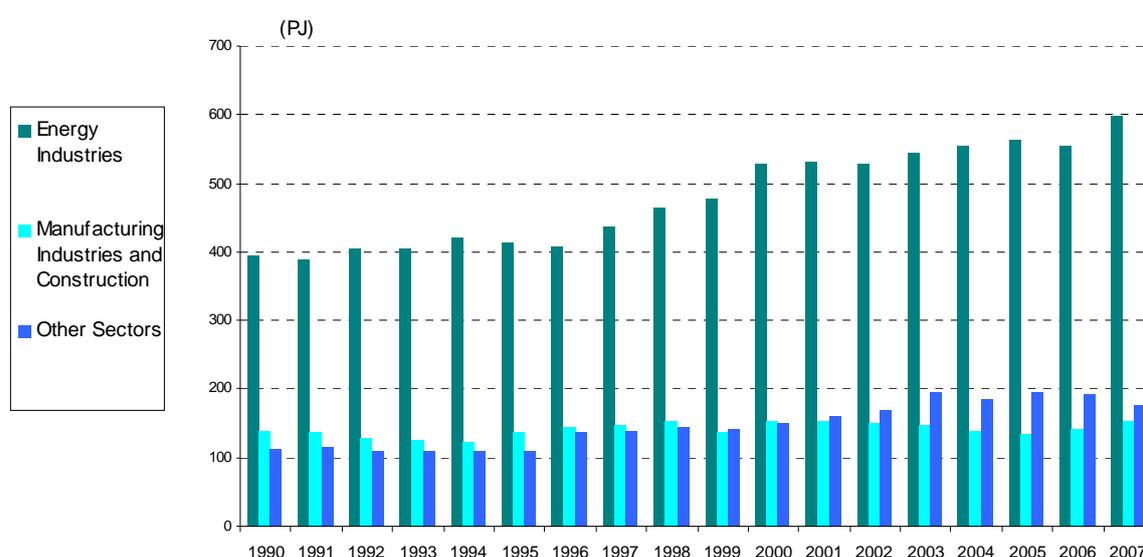
Figure 3.3   *Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2007*

The consumption of fossil fuels in 2007 increased by approximately 44% compared to 1990, with an average annual rate of increase of 2.2% for the period 1990 – 2007.

✋ Fuel consumption in energy industries accounts for 63% (average value for the period 1990 – 2007) of fuel consumption in stationary combustion. The average annual rate of increase for the period 1990 – 2007 is estimated at 2.5%, resulting in an increase of 52% in 2007 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.

✋ 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 2007 increased by 10% compared to 1990 levels.

✤ Fossil fuels consumption in Other sectors increased by 58% from 1990 to 2007, as, according to the national energy balance, consumption of fossil fuels in 1996 increased by approximately 24% compared to 1995 and remained high since then.

GHG emissions from stationary combustion follow the trend of fossil fuels consumption, presenting however a lower annual rate of increase. Therefore, GHG emissions in 2007 (82.7 Mt CO_2 eq) increased by 32.6% compared to 1990 (62.4 Mt CO_2 eq), with an average annual rate of increase estimated at 1.7% for the period 1990 – 2007 (***Figure 3.4***). It is noted that emissions from stationary combustion account for around 60% of total national emissions (without *LULUCF*) for the period 1990 – 2007 (63% for 2007), while **three** key categories are included in this sector (**CO_2 emissions from solid, liquid and gaseous fuels combustion**).
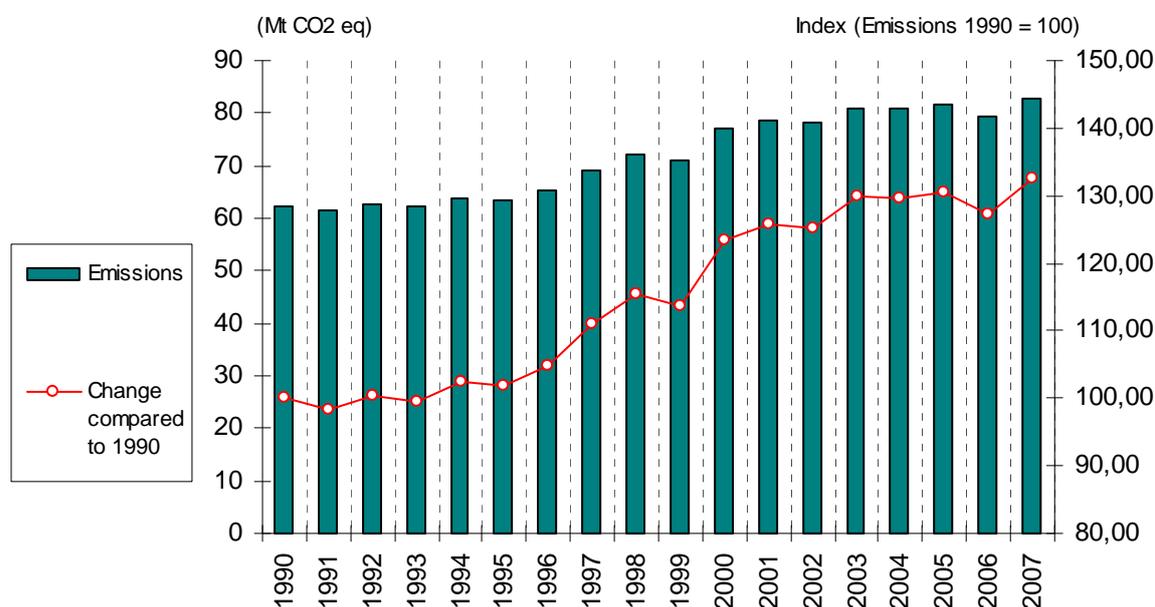
Figure 3.4   ***GHG emissions (in Mt CO_2 eq) from stationary combustion for the period 1990 – 2007***

Emissions from stationary combustion per gas and source category are presented in ***Table 3.5***.

Carbon dioxide represents the major GHG from stationary combustion with a share in total emissions from stationary combustion being above 99% in 2007. Overall. CO_2 emissions in 2007 increased by 33% compared to 1990 levels with an average annual rate of increase estimated at 1.7%. N_2O emissions in 2007 account for 0.7% of emissions from stationary combustion. decreasing with an average annual rate of 0.06% during the period 1990 – 2007. CH_4 emissions account for the rest 0.13% of total emissions of the sector. and increased by 6.5% from 1990 to 2007.

Table 3.5   ***GHG emissions per gas and source category from stationary combustion for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GHG emissions per gas																		
CO_2 (in Mt)	61.65	60.67	61.87	61.39	63.25	62.86	64.64	68.46	71.39	70.24	76.31	77.79	77.35	80.28	80.09	80.75	78.62	81.99
CH_4 (in kt)	4.92	4.93	5.74	5.31	4.91	4.85	5.08	4.88	4.79	5.34	6.03	5.60	4.73	4.73	5.18	4.83	5.26	5.24
N_2O (in kt)	1.93	1.97	1.93	1.90	1.92	1.84	1.82	1.86	1.89	1.88	1.95	1.96	2.02	2.13	1.97	1.97	1.99	1.90
GHG emissions per source category (in Mt CO_2 eq)																		
Energy industries	43.32	42.18	44.46	44.37	46.36	45.12	44.31	47.77	50.31	50.60	55.09	55.61	55.04	56.29	57.61	58.00	55.69	59.05
Industry	10.45	10.30	9.60	9.35	9.17	9.93	10.61	10.72	10.77	9.50	10.49	10.61	10.19	9.97	9.26	8.89	9.16	10.54
Other sectors	8.59	8.90	8.54	8.37	8.42	8.47	10.39	10.65	10.99	10.83	11.46	12.30	12.84	14.78	13.94	14.58	14.50	13.09
TOTAL (Mt CO_2 eq)	**62.36**	**61.38**	**62.59**	**62.09**	**63.95**	**63.53**	**65.32**	**69.14**	**72.07**	**70.93**	**77.04**	**78.52**	**78.07**	**81.04**	**80.81**	**81.46**	**79.35**	**82.69**

Energy industries constitute the major contributor (71% in 2007) in the overall GHG emissions from stationary combustion, followed by manufacturing industry and construction from 1990 to 1996 and by other sectors since 1997 (emissions from other sectors increase with a mean annual rate of 2.8% for the period 1990 – 2007).

3.2.2 Methodology

The calculation of GHG emissions from stationary combustion was based on the Revised 1996 IPCC Guidelines and the IPCC Good Practice Guidance. CH_4 and N_2O emission factors are differentiated by technology and fuel, while CO_2 emission factors are differentiated only by fuel. The determination of emission factors was based on data derived from verified ETS reports, as described in this paragraph.

CO_2 emissions from stationary combustion are estimated on the basis of fuel consumption per source and the 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_{CO2} is CO_2 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 is the main source of information regarding fuel consumption by sector and activity (see Annex II). The basic characteristics of fuels used in the Greek energy system and the estimated CO_2 emission factors are presented in ***Table 3.6***.

Concerning the data presented in the table above, the following should be mentioned

✤ The IPCC Guidelines constitute the main source of information regarding carbon content and fraction of carbon oxidised by fuel type (IPCC 1997, Tables 1-1 and 1-6), except for lignite used for electricity generation and domestic natural gas.

✤ Information on the net calorific value (NCV) per fuel is mainly provided by the national energy balance, compiled by the Ministry for Development (Energy Policy Division). This information is also submitted by the Ministry annually to both the IEA and the EUROSTAT. For the fuels Refinary gas, Petcoke and BKB/Patent fuel NCV values were obtained from the verified emission reports from installations under the EU ETS. 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 CO_2 emission factor is higher.

✤ 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).

Table 3.6   *Carbon dioxide emission factors (in t CO_2 / TJ). net calorific value (in TJ / kt)*
                    and other parameters by fuel type

Fuel type	Net calorific value (TJ/kt)	Carbon content. CC (tC/TJ)	Oxidation factor. OF (%)	EF (tCO₂/TJ) (CC*OF*44/12)	EF (tCO₂/TJ) (source: ETS reports)
Liquid fuels					
Refinery gas	47.65[3]	18.2	99.0	66.07	57.54
LPG	47.31	17.2	99.0	62.44	61.85[4]
Gasoline	44.80	18.9	99.0	68.61	
Jet fuels	44.60	19.5	99.0	70.79	
Kerosene	44.75	19.6	99.0	71.15	
Diesel oil	43.00	20.2	99.0	73.33	73.33
Heavy fuel oil	40.19	21.1	99.0	76.59	76.59
Naphtha	45.01	20.0	99.0	72.60	18.33[5]
Petroleum coke	32.25[6]. 31.93[7]	27.5	99.0	99.83	93.54[7]
Other oil products	40.19	20.0	99.0	72.60	
Solid fuels					
Steam coal	27.21	25.8	98.0	92.71	93.68[8]
Lignite					
Electricity generation		34.0	98.0	122.00	122.0
Other sectors		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		16.18. 16.37[9]	99.5	59.10	58.59[10]
Natural gas – Imports		15.3	99.5	55.82	54.90[11]
Gas works gas		15.3	99.5	55.82	

✤   Plant specific emission factors were used for the estimation of emissions, that were obtained
    from the verified emission reports from installations under the EU ETS (sixth coloumn of
    Table 3.6). For the cases not covered by the emissions factors derived from ETS data,
    emissions factors were calculated from carbon content and oxidation factor (fifth coloumn of
    Table 3.6).

---

[3] Mean value. It depends on refineries' feedstock characteristics and processes applied.

[4] Only for petroleum refining category. It comprises LPG used for hydrogen production.

[5] Used for estimating emissions for non energy use of naptha.

[6] Petcoke consumed in refineries.

[7] Petcoke consumed in manufacturing industries (e.g. cement plants).

[8] Coal consumed in manufacturing industries (e.g. cement plants).

[9] Depends on the reservoir that the gas is extracted.

[10] 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.

[11] Mean value for electricity production.

- Domestic natural gas is produced from two reservoirs:

  1. the South Kavala reservoir, which has a NCV of 11408 kcal/Nm^3, a carbon content of 16.18 tC/TJ and an emission factor of 59.03 tCO$_2$/TJ,

  2. the Prinos reservoir, which has a NCV of 12312 kcal/Nm^3, a carbon content of 16.37 tC/TJ and an emission factor of 59.72 tCO$_2$/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 3.7***.

Table 3.7   ***Net calorific value of lignite by sector (in TJ / kt) for the period 1990 - 2007***

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

- The carbon content in lignite used for electricity production is based on studies of the Public Power Corporation (PPC 1993). The value of 33.95 t C / TJ 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 3.7).
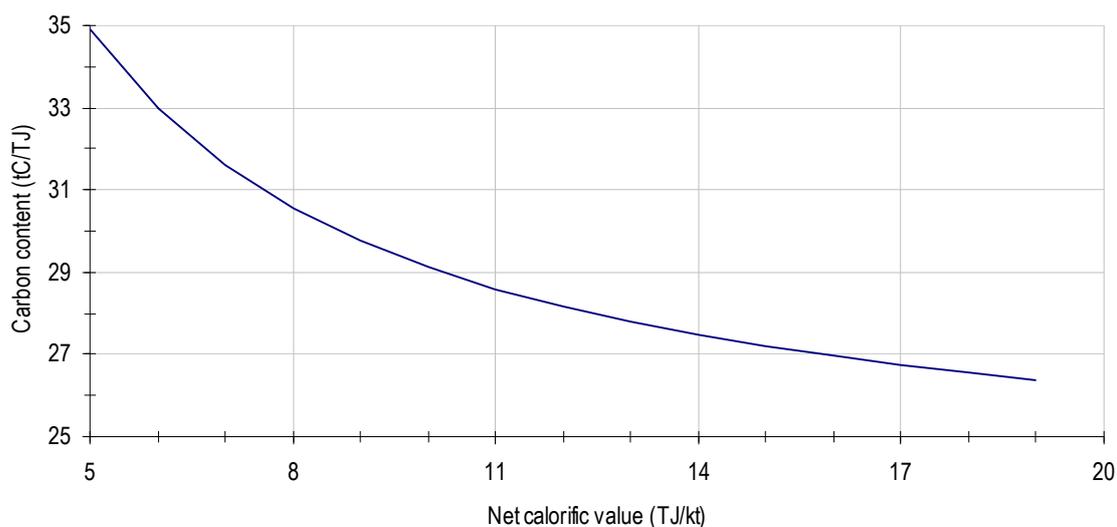
Figure 3.5   ***The relationship between the net calorific value and the carbon content of lignite***

For the estimation of CH_4 and N_2O 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. CH_4 and N_2O 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 2005-2007 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.

Public electricity and heat production

Electricity production in Greece increases continuously at average annual rate of 3.6% for the period 1990 - 2007. Gross electricity production in 2007 (63.5 TWh) was approximately 81% higher compared to 1990 levels (*Figure 3.6*).

Electricity generation relies mostly on the use of fossil fuels (approximately 92% of electricity production in 2007). Specifically, 63% of electricity is produced by solid fuels (lignite using steam coal and / or BKB as additives), while the share of liquid fuels and natural gas is 14% and 22% respectively. The rest of electricity production derives from hydropower and wind energy.

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.
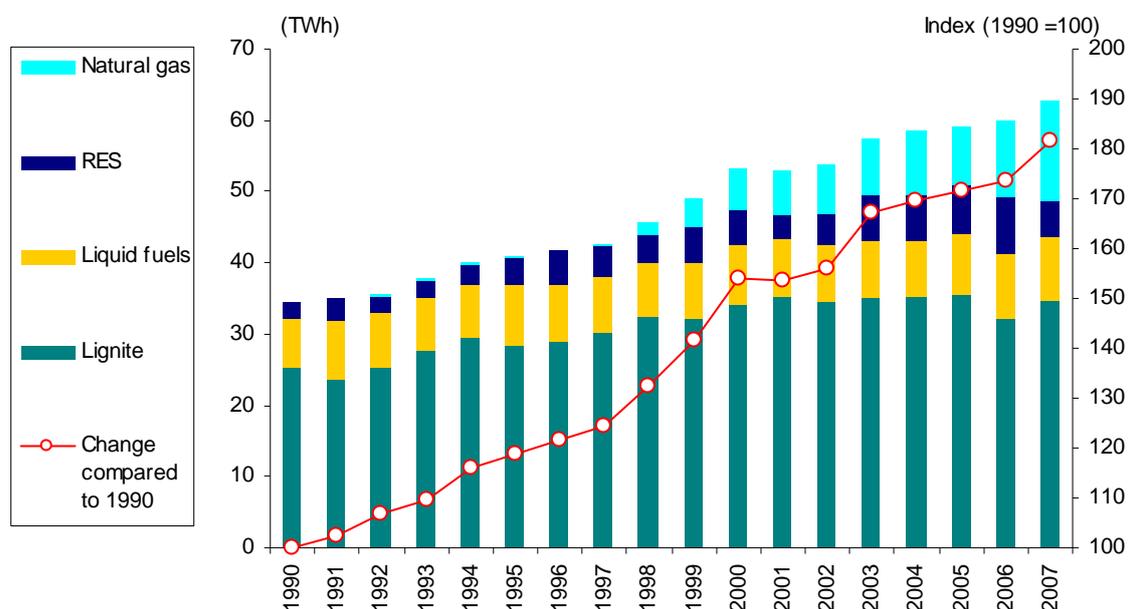
Figure 3.6   Electricity production (in TWh) by energy type for the period 1990 – 2007

GHG emissions from electricity and heat production for the period 1990 – 2007 are presented in *Table 3.8*.

Differences that resulted from recalculations / improvements between the emissions estimates presented in the current submission and the estimates presented in the previous submission are attributed mainly to:

1. As a consequence of adjustments applied by the ERT that performed the audit of the initial report of Greece during 23-28 April 2007, conservativeness factors have been applied for the estimation of N2O emissions of 1990 from liquid and solid fuels combustion and CO2 emissions of 1990 from solid fuel combustion. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, the above mentioned emissions were recalculated so that the base year to be consistent with other years of the inventory time series (conservativeness factor was removed).

2. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, the following emissions were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years):

    a. CH4 emissions for the years 1990-2004 from liquid and solid fuels combustion

    b. CH4 and N2O emissions for the years 1997-2004 from gaseous fuel combustion.

3. In previous submission and for the year 2005, the emissions were calculated by apllying the Implied EFs per solid, liquid and gaseous fuel resulted from the calculations of year 2004. In this year submission the emissions of year 2005 were recalculated based on Tier 2 methodology with CS/PS EF for CO2 and IPCC default EF per technology for N2O and CH4.

4. Emissions of CO2, CH4 and N2O from lignite combustion were recalculated for years 2005 and 2006, because of updated more accurate data of net calorific value of lignite. These data were obtained through collaboration with Ministry of Development and respective departments of Public Power Company.

5. Emissions from biomass combustion (landfill and sewage/sludge biogas) were recalculated or estimated for the first time for the years 1999-2006, since updated data were obtained from the Ministry of Development.

GHG emissions from electricity generation in 2007 increased by 35% compared to 1990 levels at an average annual rate of 2% for the period 1990 – 2007. 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 (1.4%) because of the penetration of natural gas and the high availability of hydroelectric plants

(the highest of the period 1990 – 2003). 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.

CO_2 emissions in 2007 accounted for 99.64% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 78% of total emissions in 2007. However, due to the penetration of natural gas, total emissions per electricity produced by fossil fuels has a decreasing trend.

Petroleum refining

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.

GHG emissions from refineries (***Table 3.9***) are calculated on the basis of fuel consumption (liquid fuels only) which is obtained from the national energy balance and the estimated emission factors described previously. It is noted that only CO_2 and N_2O emissions from catalytic cracking are included in this sub-source category, while CH_4 emissions are supposed to be included in Fugitive emissions from fuels.

The total increase of GHG emissions from refineries in 2007, compared to 1990 levels, is estimated at 62%, with an average annual rate of increase estimated at 3.1% for the period 1990 – 2007. 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.

Differences resulted from recalculations / improvements between the emissions estimates presented in the current submission and the estimates presented in the previous submission are attributed mainly to:

1. As a consequence of adjustments applied by the ERT that performed the audit of the initial report of Greece during 23-28 April 2007, conservativeness factors have been applied for the estimation of N2O emissions of 1990 from liquid fuels combustion. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, the above mentioned emissions were recalculated so that the base year to be consistent with other years of the inventory time series (conservativeness factor was removed).

2. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, CH4 emissions for the years 1990-2004 from liquid fuels combustion were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also applied for the rest years).

3. In previous submission and for the year 2005, the emissions were calculated by apllying the Implied EFs of liquid fuels resulted from the calculations of year 2004. In this year submission the emissions of year 2005 were recalculated based on Tier 2 methodology with PS EF for CO2 and IPCC default EF per technology for N2O and CH4.

4. Emissions of CO2, CH4 and N2O from petcoke and refinery gases were recalculated for years 2005 and 2006, because the NCV of these fuels derived from ETS reports was used as more accurate.

Table 3.8   ***GHG emissions from public electricity and heat production per gas and fuel type and total emissions for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2 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
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
Gaseous fuels	NO	NO	NO	NO	NO	NO	NO	0.11	0.80	1.99	2.92	2.88	3.07	3.42	3.71	3.59	4.25	5.62
CH_4 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
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
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	0.07	0.08	0.10
N_2O 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
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
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
TOTAL (Mt CO_2 eq)	40.74	39.54	41.92	41.84	43.64	42.38	41.31	44.71	47.19	47.85	51.70	52.17	51.48	52.88	54.04	54.47	51.58	54.96

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

Table 3.9   ***GHG emissions from petroleum refineries for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2 (kt)	2464.85	2514.08	2438.53	2430.72	2605.28	2637.51	2890.67	2948.00	3020.22	2734.25	3279.15	3338.03	3448.62	3305.04	3452.06	3445.21	4005.47	3989.15
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
N_2O (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
TOTAL (kt CO_2 eq)	2473.20	2522.60	2446.73	2438.98	2614.10	2646.47	2900.50	2958.03	3030.47	2743.56	3290.30	3349.42	3460.37	3316.34	3463.84	3457.68	4020.06	4003.71

Other energy industries

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 - 2007) were used in this inventory. GHG emissions (***Table 3.10***) are calculated on the basis of the consumption of natural gas as it is presented in Annex II, the allocation of the consumption into gas turbines and boilers as described in ETS reports 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 ETS data.

GHG emissions from the other energy industries in 2007 decreased by approximately 15% compared to 1990. The annual variation of emissions is related to the changes of the primary production of crude oil and natural gas.

Differences resulted from recalculations / improvements between the emissions estimates presented in the current submission and the estimates presented in the previous submission are attributed mainly to:

1. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, CH_4 and N_2O emissions for the years 1990-2004 from gaseous fuels combustion were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

2. The CO_2 emissions for years 2005 and 2006 were recalculated by applying an EF derived from ETS reports which includes CO_2 emissions from sour gas cleaning process among with the emissions from combustion.

Table 3.10   *Allocation of natural gas consumption and GHG emissions (in kt CO$_2$ eq) from other energy industries for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	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	70.86	90.14	86.98
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
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	0.04	0.05	0.05
TOTAL	119.58	127.14	110.35	104.89	120.88	115.55	121.75	129.37	98.02	7.25	121.93	115.86	122.24	105.82	127.70	83.06	105.62	101.91

Manufacturing industries and construction

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 - 2007 provided significant information regarding the structure of energy demand in industry per activity / technology. On the basis of those data (a) energy consumption per activity (e.g. steel production) as well as unit consumption indices were estimated, (b) the fuels used per activity were identified and (c) disaggregation of energy demand into different activities is performed (e.g. energy consumption in Iron & Steel as reported in the national energy balance is allocated between steel production and grey iron foundries). 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) and the results of the questionnaires analysis providing that the estimated total energy consumption is in accordance with the official figures provided by the energy balance.

The assumptions made for the estimation of GHG emissions for the period 1990 – 2007 (**Table 3.11**) 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 - 2007. 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 - 2007 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 - 2007. 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 - 2007 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.

✤ 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 CH_4 and N_2O 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 - 2007.

- For years 1990-2004, it is assumed that steam coal and petroleum coke consumption refers only to cement production. For 2005 - 2007 data from verified ETS reports were used.

- Energy consumption in the rest activities is estimated on the basis of the calculated specific consumption (according to data collected during the formulation of the NAP for the period 2005 – 2007), production data, fuels used in each activity and information from the national energy balance. For 2005 - 2007 data from verified ETS reports were used.

✤ Non-energy fuels use and the relevant emissions (see Table 3.11) are reported under the corresponding source categories. The non-energy fuels use per energy balance sector is presented in Annex II.

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.

Non-ferrous metals and other industries (cement plants mainly) constitutes the only sub-source category in which emissions increased for the period 1990 – 2007. Overall, GHG emissions from industry in 2007 increased by 1% compared to 1990, with an average annual rate of 0.3% for the period 1990 – 2007.

Differences resulted from recalculations / improvements between the emissions estimates presented in the current submission and the estimates presented in the previous submission are attributed mainly to:

1.A.2a Iron and Steel

1. As a consequence of adjustments applied by the ERT that performed the audit of the initial report of Greece during 23-28 April 2007, conservativeness factors have been applied for the estimation of N_2O emissions of 1990 from liquid fuels combustion. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, the above mentioned emissions were recalculated so that the base year to be consistent with other years of the inventory time series (conservativeness factor was removed).

2. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, CH_4 emissions from liquid for the years 1990-2004 and CH_4 and N_2O emissions from gaseous fuels combustion for the years 1997-2004 were recalculated for

time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

3. In previous submission and for the year 2005, the emissions were calculated by applying the Implied EFs of liquid and gaseous fuels resulted from the calculations of year 2004. In this year submission the emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N_2O and CH_4.

4. Correction of error of EF of CO_2 for diesel, heavy fuel oil and natural gas for year 2006.

1.A.2b Non Ferrous Metals

5. Conservativeness factor was removed for base year N_2O emissions from liquid and solid fuels.

6. CH_4 emissions from liquid and solid fuels for the years 1990-2004 and CH_4 and N_2O emissions from gaseous fuels combustion for the years 1998-2004 were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

7. Emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N_2O and CH_4.

8. Correction of error of NCVs of coal, lignite and BKB used for year 2006.

1.A.2c Chemicals

9. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, the emissions from the production of NH_3 from natural gas were reallocated to industrial processes sector (2B1) for the period 1998-2006.

10. Conservativeness factor was repoved for base year N_2O emissions for liquid and CO2 and N_2O from solid fuels.

11. CH_4 and N_2O emissions from liquid and solid fuels combustion for the years 1990-2004 and 1990-1998, respectively, were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

12. Emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO2 and IPCC default EF per technology for N_2O and CH_4.

13. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, emissions of CO_2 for year 1991 from lignite consumption were recalculated by using updated activity data.

1.A.2d Pupl, paper and Print

14. Conservativeness factor was removed for base year N_2O emissions from liquid fuels.

15. CH_4 and N_2O emissions from liquid and gaseous fuels combustion for the years 1990-2004 and 1997-2004, respectively, were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

16. Emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N_2O and CH_4.

1.A.2e Food Processing, Beverages and Tobacco

17. Conservativeness factor was removed for base year N_2O emissions from liquid and solid fuels.

18. CH_4 and N_2O emissions from liquid, solid and gaseous fuels combustion for the years 1990-2004, 1990-1997 and 1996-2004, respectively, were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

19. Emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N_2O and CH_4.

20. Error correction of NCV of heavy fuel oil for year 2006.

1.A.2f Other

21. Conservativeness factor was removed for base year N_2O emissions from liquid and solid fuels.

22. CH_4 and N_2O emissions from liquid, solid and gaseous fuels combustion for the years 1990-2004 were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

23. Emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N2O and CH4.

24. Updated data used of heavy fuel and coal consumption (correction of errors) for year 2006.

Table 3.11   *GHG emissions (in kt CO₂ eq) from manufacturing industries and construction for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Iron and Steel																		
CO_2	475.14	428.33	425.83	376.75	366.44	352.45	259.78	283.68	271.28	318.26	286.46	310.89	324.56	305.08	230.72	187.10	175.38	201.36
CH_4	0.40	0.36	0.36	0.32	0.31	0.30	0.22	0.24	0.20	0.22	0.19	0.20	0.21	0.20	0.13	0.08	0.07	0.08
N_2O	1.19	1.06	1.06	0.94	0.92	0.89	0.66	0.70	0.57	0.60	0.49	0.51	0.53	0.52	0.29	0.13	0.13	0.15
Non ferrous metals																		
CO_2	1260.78	1306.08	1244.60	1333.75	1302.42	1308.76	1465.97	1299.03	1362.98	1303.70	1624.35	1558.07	1654.53	1770.03	1668.05	1351.36	1383.64	1537.91
CH_4	0.58	0.64	0.63	0.64	0.62	0.63	0.68	0.64	0.70	0.73	0.81	0.80	0.84	0.87	0.83	0.70	0.72	0.72
N_2O	5.29	5.43	5.11	5.53	5.45	5.46	6.23	5.44	5.67	5.35	6.91	6.65	7.10	7.66	7.20	6.69	6.44	6.64
Chemicals																		
CO_2	1312.27	996.89	563.42	528.76	442.07	456.79	686.08	803.12	999.14	535.34	635.51	632.96	634.12	774.14	874.45	955.65	972.79	926.25
CH_4	0.31	0.18	0.17	0.14	0.14	0.15	0.34	0.40	0.49	0.27	0.28	0.27	0.26	0.25	0.35	0.36	0.40	0.38
N_2O	2.42	2.39	2.40	2.90	3.06	3.02	3.06	3.59	3.82	3.61	3.53	3.51	3.29	3.52	3.75	4.07	3.91	3.65
Paper. pulp and print																		
CO_2	301.47	288.51	281.40	265.90	250.81	211.00	289.37	340.36	306.18	314.84	374.28	344.68	354.92	365.32	253.16	230.12	269.84	256.59
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
N_2O	0.44	0.42	0.40	0.38	0.37	0.32	1.02	1.24	1.47	2.23	1.94	1.91	1.84	1.85	1.18	1.10	1.38	1.28
Food processing – Beverages – Tobacco																		
CO_2	902.31	925.19	939.89	960.05	920.05	936.47	1005.97	974.52	1061.65	966.04	1090.22	994.80	1040.29	1092.91	877.74	761.16	828.39	698.04
CH_4	0.64	0.66	0.67	0.68	0.64	0.62	4.90	4.89	4.94	4.90	5.91	5.73	6.15	5.27	5.37	6.06	5.51	5.53
N_2O	1.41	1.39	1.41	1.44	1.40	1.37	10.71	11.19	11.60	12.13	14.34	13.99	14.71	13.21	13.18	14.83	13.69	13.15
Other industries																		
CO_2	6126.41	6287.00	6070.10	5810.45	5814.33	6590.29	6839.81	6949.21	6702.36	5996.75	6413.77	6700.37	6113.11	5599.25	5293.38	5346.31	5472.80	6864.86
CH_4	4.41	4.52	4.50	4.32	4.19	4.43	2.54	2.54	2.27	2.02	2.21	2.30	2.09	1.75	1.79	1.98	2.45	2.66
N_2O	52.87	55.15	55.19	55.21	55.24	58.91	36.98	37.75	37.63	31.58	32.62	33.27	29.39	25.77	24.29	18.80	19.90	25.00
TOTAL	**10448.58**	**10304.42**	**9597.35**	**9348.34**	**9168.63**	**9932.04**	**10614.53**	**10718.76**	**10773.13**	**9498.81**	**10494.09**	**10611.12**	**10188.14**	**9967.82**	**9256.02**	**8886.62**	**9157.60**	**10544.41**

Residential – Tertiary sector

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) and 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 3.12* for the residential sector and *Table 3.13* for the commercial/ institutional sector) are calculated on the basis of fuel consumption as it is presented in Annex II, the emission factors of CO_2 presented in Table 3.6 and default IPCC EF for CH_4 and N_2O as in the previous categories of stationary combustion.

GHG emissions from the residential and the commercial/institutional sector in 2007 increased substantially compared to 1990 levels (82% and 185% 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.

Recalculations performed are discussed in Agriculture section.

Agriculture

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 – 2007.

GHG emissions (*Table 3.14*) are estimated on the basis of fuel consumption as it is presented in Annex II, CO_2 emission factors presented in Table 3.6 and default IPCC EF for CH_4 and N_2O as in the previous categories of stationary combustion.

The majority of GHG emissions from agriculture are attributed to agricultural machinery (approximately 95% for the period 1990 – 2007). Overall, in 2007 emissions from agriculture decreased by approximately 12% compared to 1990 emissions.

Differences resulted from recalculations / improvements between the emissions estimates presented in the current submission and the estimates presented in the previous submission for Residential, Tertiary and Agriculture sector are attributed mainly to:

1. As a consequence of adjustments applied by the ERT that performed the audit of the initial report of Greece during 23-28 April 2007, conservativeness factors have been applied to activity data of biomass consumed in residential sector for the estimation of N_2O and CH_4 emissions of 1990. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, the above mentioned emissions were recalculated so that the base year to be consistent with other years of the inventory time series (conservativeness factor was removed).

2. Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, CH_4 and N_2O emissions from liquid, solid and gaseous fuels for the years 1990-2004 were recalculated for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

3. In previous submission and for the year 2005, the emissions were calculated by apllying the Implied EFs of liquid, solid and gaseous fuels resulted from calculations of year 2004. In this year submission the emissions of year 2005 were recalculated based on Tier 2 methodology with EF from Table 3.6 for CO_2 and IPCC default EF per technology for N_2O and CH_4.

4. Updated data used for diesel in Agriculture sector and lignite in Agriculture and Residential sector for year 2006.

Table 3.12   *GHG emissions (in kt CO_2 eq) from the residential sector for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2 emissions																		
Solid fuels	81.71	114.96	107.86	107.77	110.14	99.81	108.96	120.44	102.11	62.68	69.86	65.70	23.46	14.17	23.45	11.35	5.53	6.87
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
Gaseous fuels	4.92	5.68	8.29	7.64	4.52	6.28	6.28	6.53	10.68	9.09	11.35	12.21	19.99	43.71	80.98	168.70	320.95	412.76
CH_4 emissions																		
Solid fuels	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	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	8.08	8.50	8.08	8.24	7.84	6.96
Gaseous fuels	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.12	0.16
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
N_2O emissions																		
Solid fuels	0.40	0.56	0.53	0.52	0.54	0.49	0.53	0.59	0.50	0.31	0.35	0.32	0.12	0.07	0.12	0.06	0.03	0.03
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
Gaseous fuels	0.04	0.05	0.07	0.06	0.04	0.05	0.05	0.05	0.42	0.01	0.01	0.01	0.01	0.02	0.04	0.09	0.18	0.23
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

Table 3.13 **GHG emissions (in kt CO_2 eq) from the commercial / institutional sector for the period 1990 – 2007**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2 emissions																		
Solid fuels	9.92	8.50	2.83	1.42	1.42	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	7.57	NO	NO
Liquid fuels	505.09	649.71	610.00	581.80	599.67	646.72	786.18	759.26	767.34	743.71	757.34	982.41	987.27	1066.03	1119.55	1357.69	1392.15	1255.75
Gaseous fuels	12.06	12.81	12.96	12.61	13.11	12.66	12.66	13.26	20.36	17.33	20.10	28.48	42.45	64.66	101.68	171.57	206.44	245.31
CH_4 emissions																		
Solid fuels	0.00	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	NO	NO
Liquid fuels	0.43	0.52	0.49	0.47	0.48	0.51	0.61	0.60	0.60	0.59	0.61	0.80	0.82	0.88	0.88	1.10	1.13	1.01
Gaseous fuels	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.06	0.08	0.09
N_2O emissions																		
Solid fuels	0.05	0.04	0.01	0.01	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.04	NO	NO
Liquid fuels	1.27	1.52	1.42	1.35	1.39	1.46	1.76	1.72	1.72	1.71	1.77	2.33	2.39	2.57	2.54	3.18	3.27	2.93
Gaseous fuels	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.06	0.10	0.11	0.14

NO: Not Occurring

Table 3.14 **GHG emissions (in kt CO_2 eq) from agriculture for the period 1990 - 2007**

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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	8.19	8.17	8.32
N_2O	337.65	349.96	323.96	316.06	318.40	295.55	299.92	299.50	299.50	299.59	299.82	303.55	334.93	366.85	310.87	316.51	331.68	295.20

3.2.3   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 pararagraphs. Summarizing the recalculations performed were as follows:

✥ Reallocation of emissions to industrial processes sector: Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, the emissions from the production of NH_3 from natural gas were reallocated to industrial processes sector (2B1) for the period 1998-2006.

✥ Removal of conservativeness factor of base year emissions: As a consequence of adjustments applied by the ERT that performed the audit of the initial report of Greece during 23-28 April 2007, conservativeness factors have been applied for base year estimations of N_2O emissions from liquid and solid fuels combustion, CO_2 emissions from solid fuel combustion of 1.A.1a category and biomass consumed in residential sector for energy purposes. Following the recommendation of ERT which performed the in-country review from 8-13 September 2008, the above mentioned emissions were recalculated so that the base year to be consistent with other years of the inventory time series (conservativeness factor was removed).

✥ Time-series consistency: Following the recommendation of ERT which performed an in-country review from 8-13 September 2008, emissions were recalculated (mainly CH_4 from solid and liquid fuels for the period 1990-2004 and CH_4 and N_2O from gaseous fuels for the period 1997-2004) for time-series consistency purposes (the T2 with IPCC default EFs methodology applied for the years 2005-2007 was also apllied for the rest years).

✥ Recalculation of 2005 emissions: In previous submission and for the year 2005, the emissions were calculated by apllying the Implied EFs per solid, liquid and gaseous fuel resulted from calculations of year 2004. In this year submission the emissions of year 2005 were recalculated based on Tier 2 methodology with EF for CO_2 from Table 3.6 and IPCC default EF per technology for N_2O and CH_4.

✥ Application of improved emission factors resulted from ETS data.

✥ Updated data mainly from revised energy balance information (e.g. landfill gas for power production).

✥ Correction of errors.

The results of the recalculation of GHG emissions from stationary combustion, namely the difference (%) per gas, and the impact of them on total emissions excuding LULUCF, between present and previous emissions estimates, are presented in *Table 3.15*.

3.2.4   Planned improvements

In year 2009 an internal inventory review by an independent national expert will take place. Based on the finding of this review improving actions will be planned and executed. Moreover, the further reallocation of non-energy fuels used as feedstock to the industrial processes sector is under process, following the case of natural gas for ammonia production.

Table 3.15　　　　*Recalculation of GHG emissions from stationary combustion*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Recalculations of CO_2 (%)																	
Energy Industries	1.66															0.23	1.36
Manufacturing Ind & Construction	0.08	0.70							-1.20	-2.12	-1.79	-0.86	-1.28	-1.94	-2.22	6.70	-4.68
Other Sectors									0.10							0.12	0.09
Recalculations of CH_4 (%)																	
Energy Industries	76.33	81.80	78.62	80.38	79.03	81.47	73.67	77.85	78.54	78.04	79.97	79.00	79.10	82.54	76.11	0.10	0.09
Manufacturing Ind & Construction	-65.19	-66.16	-64.71	-65.51	-65.91	-65.85	-51.58	-50.70	-51.87	-47.81	-45.05	-46.74	-37.47	-37.07	-32.77	-17.25	-11.79
Other Sectors	7.36	-10.89	-8.80	-9.57	-10.80	-10.02	-10.17	-11.12	-10.19	-6.83	-6.37	-6.35	-2.40	-0.59	-1.83	0.31	12.65
Recalculations of N_2O (%)																	
Energy Industries	44.41	-0.54	-0.44	-0.42	-0.46	-0.46	-0.49	-0.97	-3.72	-8.20	-11.18	-10.87	-11.66	-12.55	-13.21	0.84	0.82
Manufacturing Ind & Construction	16.22	-46.23	-45.29	-43.99	-43.60	-47.86	-59.70	-60.05	-58.87	-61.68	-63.22	-63.65	-65.80	-66.53	-67.46	-63.41	-63.30
Other Sectors	-33.67	-33.99	-34.53	-34.47	-34.45	-36.63	-43.04	-44.05	-45.20	-44.38	-45.76	-48.00	-47.22	-49.04	-51.82	74.17	76.68
Impact of Recalculations on Total Emissions excl LULUCF of CO_2 (%)																	
Energy Industries	0.67															0.10	0.58
Manufacturing Ind & Construction	0.01	0.07							-0.11	-0.17	-0.15	-0.07	-0.10	-0.15	-0.16	0.42	-0.35
Other Sectors									0.01							0.01	0.01
Impact of Recalculations on Total Emissions excl LULUCF of CH_4 (%)																	
Energy Industries	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Manufacturing Ind & Construction	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
Other Sectors	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.01
Impact of Recalculations on Total Emissions excl LULUCF of N_2O (%)																	
Energy Industries	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	0.00	0.00
Manufacturing Ind & Construction	0.01	-0.05	-0.05	-0.05	-0.05	-0.06	-0.08	-0.08	-0.07	-0.07	-0.08	-0.08	-0.09	-0.08	-0.08	-0.06	-0.06
Other Sectors	-0.18	-0.19	-0.19	-0.18	-0.18	-0.18	-0.23	-0.23	-0.23	-0.23	-0.24	-0.26	-0.27	-0.31	-0.30	0.12	0.13

3.3   Transport

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 item.

In total, GHG emissions from transport (**Table 3.16**) in 2007 increased by approximately 60% compared to 1990 emissions (from 14.79 Mt CO_2 eq in 1990 to 23.75 Mt CO_2 eq in 2007). The average annual rate of emissions increase from transport for the period 1990 – 2007 was 3.4% and is higher than the corresponding rate calculated for stationary combustion (2.2% for the same period). On an annual base, the highest increase of emissions (compared to the previous year) was observed in 1998 (approximately 10%) and the highest reduction in 2000 (4.2%). These changes are due to the fluctuation of energy consumption in navigation (+54% for 1998 and –42% for 2000) according to the information provided by the national energy balance account (Table 3.16).

In 2007, the majority of GHG emissions derived from road transport, the contribution of which increased from 81% in 1990 to 91% of total emissions of the sector, since the number of vehicles in the country has considerably increased between 1990 and 2007.

The share of internal navigation in the emissions of the transport sector decreased from 12% in 1990 to 8.5% in 2007. Additionally, the contribution of internal aviation increased from 5% in 1990 to 5.7% in 2007, while the contribution of railways decreased from 1.4% in 1990 to 0.5% in 2007. The contribution of other transport (pipeline transportation) is negligible.

During the period 1990 – 2007 GHG emissions from road transport present an average annual rate of increase of approximately 4%, while emissions from internal navigation increased with an average annual rate of less than 1%. Emissions from internal aviation increased by an average annual rate of 4.9% whereas emissions from railways presented a declining trend with an average annual rate of 2.3%.

Finally, emissions from international navigation and international aviation increased slightly with an average annual rate of the order of 1% for the period 1990 – 2007.

Transport is also a major contributor of indirect greenhouse gases emissions (carbon monoxide, oxides of nitrogen and non-methane volatile organic compounds).

Table 3.16   ***GHG emissions in the transportation sector per category. for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
									Emissions (kt)									
Aviation CO_2	717	621	679	745	771	818	877	997	1014	1212	1331	1227	1052	1185	1227	1213	1280	1348
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05
Road transport CO_2	11761	12612	12917	13217	13398	13829	14488	14819	15567	15841	16029	16375	16974	18006	18108	18309	18895	19785
CH_4	5.15	5.48	5.85	6.10	6.23	6.51	6.92	7.03	7.22	7.30	7.37	6.91	6.42	6.09	5.36	4.87	4.65	4.75
N_2O	0.40	0.43	0.44	0.45	0.46	0.54	0.62	0.69	0.79	0.89	0.95	1.08	0.99	0.93	0.84	0.79	0.74	0.73
Railways CO_2	203	158	152	155	168	139	145	136	149	129	129	129	129	129	129	127	131	118
CH_4	0.11	0.09	0.08	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
N_2O	0.08	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Navigation CO_2	1825	1851	1899	1738	1831	1744	1493	1812	2793	2761	1580	2145	1937	1923	2153	2054	2260	2113
CH_4	0.17	0.18	0.18	0.17	0.17	0.17	0.14	0.17	0.27	0.26	0.15	0.20	0.18	0.18	0.20	0.03	0.04	0.03
N_2O	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.07	0.07	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.05
Other CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.060	5.426	3.617	2.210	3.814	4.912	7.435
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
kt CO_2eq Total	14789	15538	15954	16169	16490	16878	17385	18173	19980	20429	19565	20408	20587	21713	22042	22101	22949	23746

Memo items 1) – International bunkers																		
Emissions (kt CO_2 eq)																		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
International aviation	2474	2134	2227	2370	2812	2637	2526	2444	2565	2880	2527	2349	2349	3056	3142	2408	2887	2952
International marine	8108	7441	8548	9967	10575	11367	10000	10026	11170	9936	11473	11140	9992	10230	10323	9170	9899	10112

[1] Emissions from international transport are not included in national emissions

Table 3.17　　　　　　*Energy consumption (in TJ) in the transportation sector per category. for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
								Energy consumption (in TJ)										
Aviation	10152	8792	9623	10554	10926	11583	12428	14120	14362	17173	18846	17373	14901	16781	17394	17185	18143	19084
Road transport	167182	179052	183365	187638	190257	196369	205851	210651	221208	225134	227903	232929	241641	256195	257910	260893	271255	285763
Railways	2757	2150	2064	2107	2280	1890	1977	1847	2037	1773	1773	1773	1773	1773	1773	1758	1801	1630
Navigation	24848	24913	25568	23445	24652	23482	20091	24333	37397	36918	21363	28895	26155	26024	28980	27674	30610	28405
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	37	97	65	40	68	88	133
Total	**204939**	**214908**	**220620**	**223744**	**228115**	**233324**	**240346**	**250950**	**275003**	**280998**	**269885**	**281007**	**284567**	**300838**	**306097**	**307579**	**321898**	**335015**
								Energy consumption (in TJ)										
International aviation	34646	29875	31168	33175	39373	36921	35360	34201	35895	40309	35360	32863	32863	42776	43972	33762	40497	41389
International marine	106578	97909	112585	131104	138960	149526	131447	131752	146341	130423	150495	145963	131216	134067	135395	119726	129215	132085

3.3.1   Methodology

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 CO_2, 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 N_2O/NH_3 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 CO_2, N_2O, NH_3 and CH_4 calculations
➢ Effect of biodiesel blends on emissions from diesel cars and HDVs
➢ Split of NOx emissions to NO and NO_2
➢ 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.

The different vehicle categories and the total annual kilometres driven by each category as well as other traffic characteristics are presented in *Table 3.18*. As had already been discussed in the last year's NIR, the traffic characteristics applied for each vehicle type and category needed to be further investigated. This is what was done for 2007 traffic data. All the updated data used, namely fleet composition and mileage, were based on up to date statistics and measurements from the Ministry of Transport and the Ministry for the Environment, Physical Planning and Public Works.

It is obvious that an updated vehicles fleet population and composition along with different traffic characteristics and the use of COPERT IV lead, in several cases, to an important differentiation of emissions values. In such cases an effort was made, where possible, to recalculate values for the previous years too. Recalculations carried out will be discussed later.

Table 3.18   Vehicle categories. mileage. average speed and mileage contribution by road vehicle category.

Vehicle categories		Annual Mileage				Average speed		
		Total (10^6 km)	Urban (%)	Rural (%)	Highway (%)	Urban (km/h)	Rural (km/h)	Highway (km/h)
Passenger cars	Conventional	10108	44	42	14	19	60	90
	Euro I	5233	44	42	14	19	60	90
	Euro II	9066	44	42	14	19	60	90
	Euro III	14354	44	42	14	19	60	90
	Euro IV	6068	44	42	14	19	60	90
Light duty vehicles	Conventional	2391	44[1]/35[2]	42/35	14/30	19	60	90
	Euro I	1533	44/35	42/35	14/30	19	60	90
	Euro II	1590	44/35	42/35	14/30	19	60	90
	Euro III	1800	44/35	42/35	14/30	19	60	90
	Euro IV	280	44/35	42/35	14/30	19	60	90
Heavy duty vehicles	Conventional	3099	35	35	30	19	50	70
	Euro I	559	35	35	30	19	50	70
	Euro II	1289	35	35	30	19	50	70
	Euro III	1815	35	35	30	19	50	70
	Euro IV	456	35	35	30	19	50	70
Buses & Coaches	Urban buses	253	100			19		
	Coaches	842	5	45	50	19	60	90
Mopeds & motorcycles	Mopeds	606	90	10		20	40	
	Motorcycles	9123	65	20	15	30	60	90

[1] Gasoline vehicles [2] Diesel vehicles

In 2007 the vehicle fleet has doubled compared to 1990 levels, while a remarkable increase of the share of medium and larger size passenger vehicles is observed (from 15% in 1990, to 35% in 2007).

Road transport is a key category of CO_2. CO_2 emissions in 2007 increased by approximately 68% compared to 1990 emissions, CH_4 emissions decreased slightly (about 8%), while N_2O emissions increased by 85% (***Table 3.19***). During this period, energy consumption augmented by 71%.

The significant increase of GHG emissions is attributed to the increase of passenger cars. This trend is expected to remain unchanged for the near future, since 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 crculating vehicles, as there is a remarkable increase of less polluting vehicles, CO, NOx and NMVOC emissions decrease. Finally, after the considerable reduction of SO_2 emissions attributed to the improvement of the fuels characteristics (i.e. the reduction of their sulphur content), due to the increase in fuel consumption an increase of SO_2 emissions was found too.

Table 3.19   ***GHG emissions (in kt CO₂ eq) and energy consumption (in TJ) from road transportation for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
							Emissions (in Mt CO2 eq)											
CO_2 (kt)	11,761	12,612	12,917	13,217	13,398	13,829	14,488	14,819	15,567	15,841	16,029	16,375	16,974	18,006	18,108	18,309	18,895	19,785
CH_4 (kt)	5.15	5.48	5.85	6.10	6.23	6.51	6.92	7.03	7.22	7.30	7.37	6.91	6.42	6.09	5.36	4.87	4.65	4.75
N_2O (kt)	0.40	0.43	0.44	0.45	0.46	0.54	0.62	0.69	0.79	0.89	0.95	1.08	0.99	0.93	0.84	0.79	0.74	0.73
TOTAL	**11,992**	**12,862**	**13,177**	**13,486**	**13,671**	**14,133**	**14,825**	**15,181**	**15,965**	**16,269**	**16,479**	**16,854**	**17,416**	**18,424**	**18,480**	**18,655**	**19,223**	**20,111**
							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	144,704	149,453	156,486	163,520	167,100	170,920	172,813	180,593
Diesel	59,015	67,118	67,465	68,808	69,371	71,928	74,138	75,048	80,204	81,807	81,894	82,110	83,410	90,993	89,173	88,272	94,459	99,187
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	709.65	756.96	709.65	567.72	520.41	520.41	520.41	567.72
Natural Gas													404.00	446.00	444.00	489.80	516.42	600.30
Other liquids	436.84	467.86	479.13	490.30	497.14	513.11	537.88	550.43	578.01	588.27	595.51	608.64	630.35	668.27	672.77	690.97	712.36	734.46
TOTAL	**167,182**	**179,052**	**183,365**	**187,638**	**190,257**	**196,369**	**205,851**	**210,651**	**221,208**	**225,134**	**227,903**	**232,929**	**241,641**	**256,195**	**257,910**	**260,893**	**269,021**	**281,682**

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. For the other GHG emissions, CORINAIR emission factors were applied (SNAP 0804 – EEA 2001). 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 (CO_2 emissions) is a key category. GHG emissions from navigation in 2007 were 16% higher than the emissions in 1990, on the basis of fuel consumption data from this sector (***Table 3.20***).

Table 3.20   *GHG emissions (in kt CO_2 eq) and energy consumption (in TJ) from internal navigation for the period 1990 – 2007*

	Emissions (in kt CO_2)			ktCO2eq	Energy consumption (in TJ)			
	CO_2	CH_4	N_2O	Total	Diesel	Fuel Oil	Lubricants	Total
1990	1,825	0.17	0.05	**1,843**	14,559	9,525	764	**24,848**
1991	1,851	0.18	0.05	**1,869**	15,469	9,284	161	**24,913**
1992	1,899	0.18	0.05	**1,918**	15,079	10,248	241	**25,568**
1993	1,738	0.17	0.04	**1,755**	15,166	8,078	201	**23,445**
1994	1,831	0.17	0.05	**1,849**	14,082	10,289	281	**24,652**
1995	1,744	0.17	0.04	**1,761**	12,349	10,771	362	**23,482**
1996	1,493	0.14	0.04	**1,508**	9,923	9,847	322	**20,091**
1997	1,812	0.17	0.05	**1,830**	10,226	13,665	442	**24,333**
1998	2,793	0.27	0.07	**2,821**	15,252	21,622	522	**37,397**
1999	2,761	0.26	0.07	**2,788**	12,522	23,752	643	**36,918**
2000	1,580	0.15	0.04	**1,595**	11,396	9,485	482	**21,363**
2001	2,145	0.20	0.05	**2,166**	14,949	13,464	482	**28,895**
2002	1,937	0.18	0.05	**1,956**	14,299	11,374	482	**26,155**
2003	1,923	0.18	0.05	**1,942**	13,042	12,298	683	**26,024**
2004	2,153	0.20	0.05	**2,175**	13,346	15,071	563	**28,980**
2005	2,054	0.03	0.05	**2,071**	14,090	13,102	482	**27,674**
2006	2,260	0.04	0.06	**2,279**	15,378	14,428	804	**30,610**
2007	2,113	0.03	0.05	**2,130**	13,746	14,067	592	**28,405**

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 3.21*).

GHG emissions from internal aviation increased by 88% since 1990 with an average annual increase rate of 5.3% (*Table 3.21*).

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).

GHG emissions from railways (*Table 3.22*) decreased by 58% from 1990 to 2007.

International transport

GHG emissions from international aviation and marine bunkers are calculated with the same methodologies mentioned above 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 3.23*).

GHG emissions from international bunkers (*Table 3.16*) increased by 23% since 1990.

Table 3.21   ***GHG emissions (in kt CO₂ eq). energy consumption (in TJ) and air movement (in thousands LTOs) for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
								Emissions (in kt CO2)										
CO_2	717	621	679	745	771	818	877	997	1.014	1.212	1.331	1.227	1.052	1.185	1.227	1.213	1.280	1.348
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05
TOTAL (in kt CO2eq)	**725**	**628**	**687**	**753**	**780**	**827**	**887**	**1.008**	**1.025**	**1.226**	**1.345**	**1.240**	**1.064**	**1.198**	**1.241**	**1.226**	**1.294**	**1.363**
Energy Consumption (TJ)	10.152	8.792	9.623	10.554	10.926	11.583	12.428	14.120	14.362	17.173	18.846	17.373	14.901	16.781	17.394	17.185	18.143	19.084
LTOs (1000s)	118.55	102.66	112.37	123.24	127.58	135.26	145.12	164.88	167.70	200.53	220.07	202.87	174.00	195.95	203.11	200.67	211.85	222.85

Table 3.22   ***GHG emissions from railways for the period 1990 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2 (kt)	202.69	158.21	151.85	155.03	167.74	139.14	145.50	135.97	149.33	128.55	128.55	128.55	128.55	128.55	128.55	127.45	130.60	118.00
CH_4 (kt)	0.11	0.09	0.08	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
N_2O (kt)	0.08	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total (in kt CO₂ eq)	**229.29**	**178.89**	**171.70**	**175.29**	**189.69**	**157.30**	**164.50**	**153.70**	**169.17**	**145.44**	**145.44**	**145.44**	**145.44**	**145.44**	**145.44**	**144.34**	**147.91**	**133.62**

Table 3.23   *Allocation of LTOs to domestic and international aviation for the period 1990-2007*

	Domestic	International
1990	121070	55311
1991	105306	48322
1992	115898	58729
1993	127499	62218
1994	127565	62946
1995	135252	64958
1996	145115	63154
1997	164879	81558
1998	167701	72783
1999	200527	81147
2000	222962	89210
2001	199529	90120
2002	171441	91247
2003	195948	91232
2004	212216	103872
2005	200672	98251
2006	211854	104132
2007	222848	113508

3.3.2   Recalculations

Road Transportation

As mentioned above, the updated vehicles fleet population and composition along with different traffic characteristics and the use of COPERT IV lead, in several cases, to an important differentiation of emissions values. In such cases an effort was made, where possible, to recalculate values for the previous years too.

Recalculations of CO_2 emissions were carried out for the years 2005 and 2006 as CO_2 emissions calculations are now based on fuel consumption and carbon content. Especially as concerns CO_2 emissions from LPG, recalculations were performed also for 2004.

Methane and N2O recalculations were also conducted. More specifically, methane emissions from gasoline were recalculated for the years 2001-2006, whereas emissions from diesel and LPG were recalculated for years 2005-2006 and 2006 respectively. As for N2O, recalculations from gasoline and diesel were performed for the years 2002-2006 whereas emissions from LPG were recalculated

for the years 2005 and 2006. Finally, SO2 emissions were recalculated for the years 2005 and 2006.

Civil aviation

CO_2 emissions from civil aviation are estimated according the IPCC tier 2a method based on aircraft movements and fuel used, following the Revised 1996 IPCC Guidelines. Consumption of fuels is from the national energy balance, while LTO data are provided by the CAO. In Greece, the number of LTOs from domestic aviation increased by 71.3 per cent over the period 1990.2004; however, over the same period fuel consumption decreased by 15.6 per cent. This issue was identified in previous in-country reviews and acknowledged by Greece as an area for improvement in the NIR. As a consequence, a recalculation of civil aviation emissions of the whole time period was implemented based on the adjustment made to the fuel consumption data. This recalculation was already performed in the last years estimations. This year a recalculation for base year 1990 was carried out without taking into account the conservativeness factor. This recalculation was suggested during last year's in-country review. Finally, for years 2005-2006 a recalculation was conducted taking into account updated emission factors (CORINAIR 2006).

Navigation

Recalculations were carried out for years 2005-2006 taking into account updated emission factors (CORINAIR 2006).

3.3.3   Planned improvements

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

Road Transport
  - Detailed and updated fleet population and composition data (already in process).
  - The problem with emissions calculation cross-check using statistical data for energy consumption due to fuel smuggling and other illegal uses, is expected to be reconsidered in the following years, as since last year legal measures have been applied.
  - Effort will be put to verify the data concerning the consumption of lubricants in road transportation as well as to revise EFs, AD and assumptions made as appropriate.

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 and the Ministry of Development.

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.

3.4   Fugitive emissions from fuels

3.4.1   Coal mining and handling

The geological process of coal formation also produces methane (CH_4), 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 (CH_4 emissions) are a key category. CH_4 emissions (**Table 3.24**) from the mining of lignite in 2007 account for 1.3% of total GHG emissions from *Energy* and 1.06% of total national emissions (without *LULUCF*). Moreover, lignite mining is the third more important source of CH_4 emissions (following enteric fermentation and solid waste disposal on land) and is responsible for 17% of total methane emissions in 2007 (without LULUCF). The average annual rate of emissions increase for the period 1990 – 2007, is estimated at 1.5% (a total increase of 28% in 2007 compared to 1990 levels).

Table 3.24   *CH$_4$ emissions from lignite mining (in kt) and primary production of lignite (in kt) for the period 1990 – 2007*

Year	Production (kt)	CH$_4$ emissions (kt)
1990	51896	52.16
1991	52695	52.96
1992	55051	55.33
1993	54817	55.09
1994	56672	56.96
1995	57662	57.95
1996	59781	60.08
1997	58844	59.14
1998	60884	61.19
1999	62051	62.36
2000	63887	64.21
2001	66344	66.68
2002	70468	70.82
2003	68299	68.64
2004	70041	70.39
2005	69398	69.74
2006	64521	64.84
2007	66464	66.80

Methodology

CH_4 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 3.24) used for the calculation of emissions.

✤ The typical emission factor (1.5 m^3 / 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 / m^3.

Recalculations

No recalculation of emissions was performed.

Planned improvements

Taking into consideration that lignite mining is a key source category, the availability of measurements will be investigated on the basis of which a national emission factor will be calculated.

3.4.2 SO_2 scrubbing

When SO_2 scrubbing technology is used in conjunction with combustion of coal, the process, which removes sulphur dioxide from the flue gas, also releases CO_2 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 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. Those data cover the period 2000 – 2003 and concern limestone consumption in two power plants. Limestone consumption for 2004 was estimated assuming that the specific limestone consumption per electricity produced in those two power plants is kept constant at 2003 levels. For year 2005-2007 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.

3.4.3 Oil and natural gas

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 amounts to 19 Mt of crude oil for year 2007.

✥ 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 450 km, (b) the terminal of the liquefied natural gas which includes two storage tanks with a total capacity of 130,000 m^3 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 3.25*) from oil and natural gas in 2007 accounted for 0.15% of total GHG emissions *Energy* and for 0.13% of total national emissions (without *LULUCF*). Overall, emissions in 2007 increased by 2% compared to 1990 levels.

Table 3.25   *GHG emissions (in kt CO$_2$ eq) from oil and natural gas fro the period 1990 – 2007*

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	91.78	49.16	0.01	**160.69**
2005	18.83	94.94	45.29	0.01	**159.07**
2006	18.88	99.51	45.47	0.01	**163.86**
2007	18.17	104.35	42.66	0.01	**165.19**

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 3.26a*** and ***table 3.26b*** respectively) present a continuous decreasing trend and as a result emissions from venting and flaring are decreasing. Since venting and flaring constitute a significant sub-source within oil and natural gas GHG emissions trends are clearly affected.

Methodology

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 3.26a) used for the calculation of emissions.

✻ Emissions are estimated for the following activities:

- Primary production of crude oil (CO_2 and CH_4),

- Crude oil transport by tankers (CO_2 and CH_4),

- Refining and storage of oil products (CH_4, NOx, CO, NMVOC and SO_2),

- Distribution of oil products (NMVOC) and

- LPG transport (CO_2 and N_2O).

✻ Emissions from crude oil transport are reported under Venting, while emissions from LPG transport are reported under Other (1.B.2d - Other).

✻ The CH_4 emission factor used for refining and storage derives from IPCC Guidelines (Table 1.58 – Western Europe, IPCC 1997). The CO_2 and CH_4 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 3.26a   *Key activity data for the estimation of GHG emissions from oil systems for the period 1990 - 2007*

| Year | Primary production | | Imports | LPG |
	Crude oil (kt)	Natural gas liquids (kt)	Crude oil (kt)	supply (kt)
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	10.5	18699	520
2006	94	11.5	19836	520
2007	74	7	20330	568

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

✍ Activity data for the estimation of emissions (Table 3.26b) derive from the national energy balance, the Public Gas Corporation (length of transmission pipeline) and international institutes and databases (e.g. European Union of the Natural Gas Industry for the length of the distribution pipelines).

✍ Emissions are estimated for the following activities
  - Production and processing of natural gas (CO_2 and CH_4) and
  - Transmission and distribution of natural gas (CH_4).

✍ 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 CO_2 and CH_4 emissions for the period 1996 – 2007 derive from the IPCC Good Practice Guidance (Table 2.16, IPCC 2000).

Table 3.26b   *Key activity data for the estimation of GHG emissions from natural gas systems for the period 1990 - 2007*

Year	Primary production		Distribution Pipeline (km)	Transmission Pipeline (km)
	Natural gas (10⁶ m³)	Sour gas (%)		
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%	3081	960
2005	16	25%	3411	960
2006	23	17%	3756	960
2007	21	14%	4136	960

In relation to emissions from venting and flaring (CO_2, CH_4 and N_2O) it should be mentioned that in most cases more that one variable is used as activity data (see *Table 3.27* 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.

Recalculations

Recalculations were performed at a small extent due to the use of updated data and the correction of errors. The impact of these recalculation was minor.

Table 3.27   ***GHG emissions (in t) from venting and flaring for the period 1990 – 2007***

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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
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
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
N.G. – Production																		
CO_2	2556.00	3053.00	2556.00	1917.00	2130.00	1775.00	1846.00	1349.00	1420.00	71.00	1207.00	1136.0	1917.00	150.16	363.16	292.16	292.16	221.16
CH_4																		
N.G. – Transmission																		
CO_2							8.18	8.93	13.39	13.39	13.79	15.36	15.36	15.36	15.36	15.36	15.36	15.36
CH_4							511	558	837	837	862	960	960	960	960	960	960	960
Flaring																		
Oil – Production																		
CO_2	66944.6	67103.5	54999.4	44904.4	42657.8	36566.9	41323.1	37413.5	25418.1	1287.4	22622.9	15620.17	15588.	11286.8	10910.4	9006.85	8640.70	6578.01
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
N_2O	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
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
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
N_2O	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	124.2	9.20	23.00	18.40	18.40	13.80
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
N_2O	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

3.5 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 production) should be reported under the sector of industrial processes (as it was implemented in this submission for the first time), 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 3.28***) and the fraction of the carbon stored by fuel type (***Table 3.29***), 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, the availability of more detailed data regarding non-energy consumption of fuels and industrial activity in Greece should be examined, as current data do not provide adequate information.

✤ The non-energy use of natural gas for ammonia production is reallocated in industrial processes sector as from this submission, by using data from ETS reports and plant specific information. Non-energy use of lignite is accounted in 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.

Ꙫ No data regarding non-energy use in the iron and steel industry are reported in the national energy balance and, as a result, CO_2 emissions from the use of fuels as reduction agents, are only reported under the industrial processes sector.

Ꙫ 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, the available information does not allow for the allocation of the total figure to individual industrial sub-sectors and, as a result, CO_2 emissions from ferroalloys production are reported under the energy sector instead of the industrial processes sector.

Ꙫ The non-energy use of petroleum coke (see Table 3.28) 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 CO_2 emissions from the non-energy use of fuels is minor.

Table 3.28   *Non-energy fuel use (in PJ) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Naphtha	2.66	3.15	2.34	2.34	1.49	3.20	3.92	2.21	0.63	1.04	2.12	1.71	0.90	2.66	4.55	3.69	6.03	6.63
Lubricants	5.31	3.46	3.50	3.42	3.46	2.97	2.69	3.22	2.09	2.57	2.25	3.18	2.17	2.57	2.81	3.22	1.52	1.07
Bitumen	8.20	8.96	9.44	10.01	10.17	12.02	12.18	12.34	13.87	14.23	16.32	16.64	17.32	14.79	16.64	11.09	14.55	12.18
Natural gas	4.05	3.87	3.68	2.37	0.24	0.16	0.15	1.68	4.95	0.78	0.00	0.03	0.00	0.00	0.00	0.20	0.00	0.01
Lignite	4.86	3.15																
Petroleum coke	1.77	2.14	2.17	1.67	1.61	1.46	1.52	1.52	1.52	1.77	1.80	1.89	1.89	1.92	1.92	1.89	1.86	2.24
Paraffin waxes	0.12	0.12	0.16	0.16	0.12	0.08	0.08	0.04	0.04	0.04	0.04	0.04						
Other oil products	2.37	0.40	1.17	0.52	1.17	0.96	0.84	0.88	1.21	0.36	2.89	3.70	4.74	7.52	5.83	6.83	5.51	4.62

Table 3.29   *Carbon stored (%) by fuel*

	Naphtha	Lubricants	Bitumen	Natural gas	Lignite	Petroleum coke	Paraffin waxes	Other oil products
Carbon stored	75%	50%	100%	33%	0%	NA	50%	50%

NA: Not Applicable

Carbon dioxide emissions from non-energy fuel use, as well as the amount of carbon stored in the final products are presented in **Table 3.30**. Carbon dioxide emissions in 2007 decreased by 63.3% compared to 1990 levels, as the consumption of bitumen (100% carbon stored) increased and the consumption of fuels used in chemical industry decreased due to the reduction of the relative production. It should be noted that the emissions presented in the following table are included (in the CRF tables) under the relevant source-categories.

Table 3.30   *CO$_2$ emissions (in kt) from non-energy use and total amount of carbon stored (in kt) for the period 1990 - 2007*

Year	Carbon stored (kt)	CO$_2$ emissions (kt)
1990	303.28	972.75
1991	286.84	665.81
1992	291.76	362.24
1993	288.84	284.55
1994	274.32	208.39
1995	329.30	210.13
1996	339.26	208.29
1997	329.73	253.17
1998	362.69	447.81
1999	361.40	360.71
2000	435.53	416.30
2001	440.07	374.67
2002	444.38	380.67
2003	459.23	370.98
2004	487.11	344.35
2005	346.56	325.81
2006	437.31	367.65
2007	392.49	357.08

3.6   Comparison of sectoral approach with 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 CO_2 emissions, while the sectoral approach is based on a detailed disaggregation of energy consumption by sector, fuel and technology for the calculation of CO_2 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 ±2%) or else explanations should be provided.

The estimation of carbon dioxide emissions according to the two methodologies is presented in *Table 3.31*.

Table 3.31   *CO₂ emissions (in kt) according to the reference and the sectoral approach for the period 1990 – 2007*

Year	Reference approach	Sectoral approach	Deviation
1990	76791.94	77137.11	-0.45%
1991	77032.84	76725.90	0.40%
1992	79281.46	78048.39	1.58%
1993	78740.54	78127.98	0.78%
1994	81564.50	80082.05	1.85%
1995	81061.10	79755.65	1.64%
1996	82036.97	81957.98	0.10%
1997	86069.86	86432.20	-0.42%
1998	90482.26	91193.66	-0.78%
1999	89770.35	90300.19	-0.59%
2000	94604.90	95846.94	-1.30%
2001	97568.06	97949.32	-0.39%
2002	97673.20	97793.35	-0.12%
2003	99451.77	101727.44	-2.24%
2004	100842.38	102000.18	-1.14%
2005	103367.54	102332.82	1.01%
2006	102343.97	101664.99	0.67%
2007	103964.16	105362.67	-1.33%

As shown in the table above, the estimated deviation (which ranges from –2.24% to 1.85%) is within the threshold defined by the IPCC Guidelines, with the exception of the deviation estimated for 2003. 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 3.32***) 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, CO_2 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 (Table 3.32).

Finally, the significant deviation in the consumption of gaseous fuels (for the period 1991 – 1997) is attributed to the consumption of city gas, which is taken into account only in the sectoral approach since it is a secondary fuel.

Table 3.32   *Deviations during the calculation of energy consumption (apparent and actual) for the period 1990 – 2007*

Year	Liquid fuels	Solid fuels	Gaseous fuels
1990	-1.26%	-0.34%	-9.70%
1991	0.25%	-0.11%	-9.75%
1992	1.45%	1.11%	-10.59%
1993	-0.37%	1.02%	-13.70%
1994	2.00%	1.10%	-21.94%
1995	-0.80%	3.70%	-24.71%
1996	-0.85%	1.01%	-22.61%
1997	-1.89%	0.71%	-3.65%
1998	-2.55%	0.61%	0.12%
1999	-1.74%	0.38%	-0.05%
2000	-2.14%	-1.14%	0.75%
2001	-0.96%	-0.39%	1.37%
2002	-0.01%	-0.19%	0.03%
2003	-3.41%	-1.33%	0.09%
2004	-0.91%	-1.72%	-0.18%
2005	-1.70%	-0.39%	-5.46%
2006	-2.68%	-0.62%	-4.66%
2007	-3.68%	0.02%	0.72%

4.   Industrial processes (CRF sector 2)

4.1   Overview

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 SF_6
- ✍ Consumption of halocarbons and SF_6

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 (Paragraphs 4.2 – 4.7) 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 presented.

4.1.1   Emissions trends

In 2007, GHG emissions from *Industrial processes* decreased by 18.76% compared to base year emissions and increased by 0.48% compared to the emissions of 1990 (***Figure 4.1***), while the average annual rate of increase is estimated at 0.29% for the period 1990 – 2007.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2007, reaching a minimum value of 8.96 Mt CO2 eq in 1992 and a maximum value of 13.47 Mt CO_2 eq in 1999, that are mainly attributed to changes in industrial production and especially in HCFC-22 production.
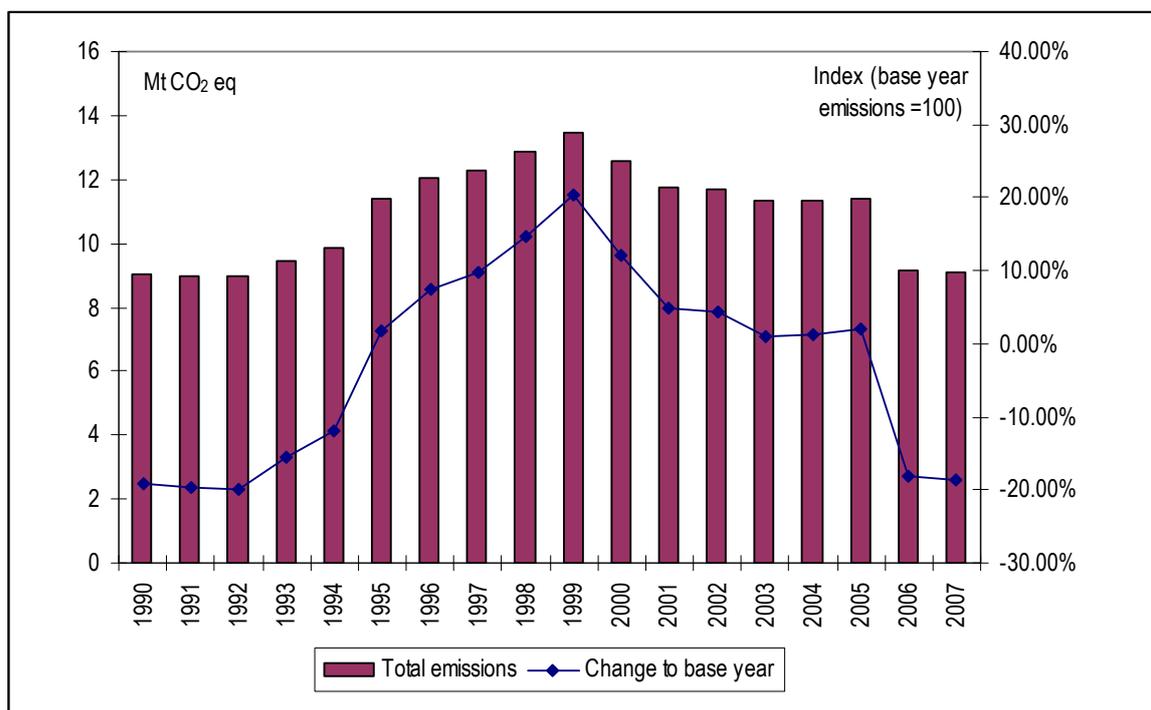
Figure 4.1   *Total GHG emissions (in Mt CO$_2$ eq) from Industrial Processes for the period 1990 - 2007*

The sector of industrial processes is responsible for emissions of carbon dioxide, nitrous oxide 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 55.8% to 87.1%. Overall, CO$_2$ emissions in 2007 increased by 17.4% from 1990, with an average annual rate of increase estimated at 0.98%. CO$_2$ emissions derive mainly from mineral products and metal production.

The contribution of F-gases to total emissions from Industrial processes is also significant, increasing from 13.2% in 1990 to 23.7% in 2005 and then decreasing to 8% in 2007. 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 23.7% in 2005).

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2007, with an average annual rate of change of -4.9%. The reduction of N$_2$O emissions in 2007 compared to 1990 levels is -60%.

The contribution of CH$_4$ emissions (from chemical 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.

Table 4.1   ***GHG emissions (in kt CO₂ eq) per gas from industrial processes for the period 1990 – 2007***

Year	CO₂	CH₄	N₂O	HFC	PFC	SF₆	TOTAL
1990	6750.68	0.52	1109.04	935.06	257.62	3.07	**9055.99**
1991	6720.57	0.55	914.40	1106.82	257.56	3.16	**9003.06**
1992	6839.96	0.52	956.20	908.39	252.30	3.26	**8960.63**
1993	6776.57	0.55	908.04	1606.64	152.59	3.35	**9447.75**
1994	6735.69	0.57	882.84	2143.91	93.62	3.45	**9860.08**
1995	7173.03	0.60	878.50	3254.21	82.97	3.59	**11392.90**
1996	7193.10	0.63	1003.21	3749.47	71.74	3.68	**12021.83**
1997	7273.75	0.62	881.10	3969.46	165.34	3.73	**12293.99**
1998	7536.71	0.59	725.06	4381.37	203.75	3.78	**12851.26**
1999	7522.27	0.33	752.96	5062.89	131.72	3.87	**13474.04**
2000	7817.35	0.24	771.07	3818.72	148.38	3.99	**12559.74**
2001	7703.42		648.08	3303.95	91.38	4.06	**11754.89**
2002	7592.47		623.93	3381.18	88.33	4.25	**11690.15**
2003	7726.80		575.90	2941.99	77.30	4.25	**11326.25**
2004	7765.96		547.53	2942.13	71.38	4.47	**11331.47**
2005	8170.59		545.80	2628.43	71.31	6.45	**11422.58**
2006	8046.62		442.70	596.65	71.16	8.37	**9165.49**
2007	7926.03		439.53	665.57	58.66	9.92	**9099.71**

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. As a result the contribution of GHG emissions from the first two sources to the total sector emissions decreases from 80.76% in 1990 to 77.54% in 2007. The contribution of halocarbons consumption to total emissions from the sector increased considerably (7.42% in 2007 against 0.04% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons. The average annual rate of increase is 52.48% for the period 1995 – 2007. Finally, the contribution of the chemical decreases from 12.25% in 1990 to 8.36% in 2007, whereas metal industry in general remains stable (6.95% in 1990 versus 6.68% in 2007).
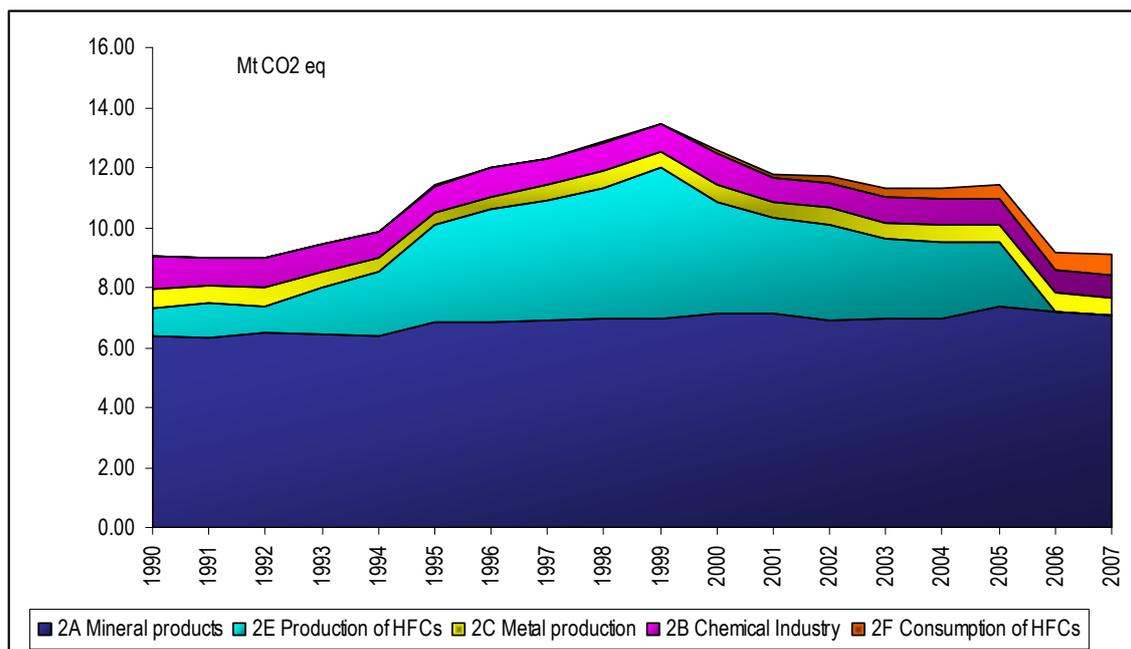
Figure 4.2   *GHG emissions (in Mt CO$_2$ eq) from Industrial processes. per main source category. for the period 1990 – 2007*

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 and the 2000 IPCC Good Practice Guidance. Also, depending on data availability, country specific methodologies are implemented, mostly in cases of time series recalculation due to access of updated data.

✍ CO$_2$ 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. For the *Consumption of Halocarbons and SF$_6$* subcategory, emission factors have been estimated 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 the National Statistical Service of Greece (NSSG). More specifically, the current inventory is substantially improved by the raise of confidentiality issues, after close cooperation with the NSSG, which has been achieved through various meetings between the inventory team and the Production Statistics Section of the NSSG. Additionally, plant specific information has been collected through questionnaires for the formulation of the NAP (years 1990-2003) and

verified reports under the EU ETS. It should be noted that in some cases (glass 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 and, therefore, are not presented in the current report or in the CRF tables.

↳ For the *Consumption of Halocarbons and SF₆* data have been provided by market surveys and NSSG (Division of Trade and Services Sector Statistics and Division of Secondary Sector Division). As proved by sectoral quality control checks, data show intense variations throughout the years. In order to use the more realistic values, several meetings have taken place between the inventory team, members of the NSSG, experts on the consumption of f-gases in the Refrigeration and A/C Equipment and experts on the implementation of the F-gases regulation in Greece. The estimation of SF₆ consumed in electrical equipment is depending on data provided by the Public Power Corporation.

↳ Finally, in many cases data have been recalculated to ensure consistency of the time series and in order to improve accuracy and completeness. The methodologies used to implement the recalculations are consistent to the IPCC Guidelines and the UNFCCC reporting guidelines and are described in each corresponding paragraph. The recalculation methodology includes the use of overlap, surrogate method and interpolation. The use of extrapolation has not been needed, as, the inventory system has been improved to a notable level in the recent years, leading to the timely acquisition of activity 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 – 4.7).

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

	CO_2		CH_4		N_2O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
Mineral products	T1, CS	CS, D, PS, OTH						
Chemical industry	T1a	CS, PS	T1	D	D	D		
Metal production	CR, CS,T1	CR, CS, PS					T3	PS
Production of F-gases							T1	D
Consumption F-gases							T2a, 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 (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).

Table 4.3   *Key categories from industrial processes*

Source category	Gas	Level assessment	Trend assessment
Cement production	CO_2	☒	☒
Nitric acid production	N_2O		☒
Ammonia production	CO_2		☒
Consumption of halocarbons and SF_6 (ODS Substitutes)	HFC	☒	☒

Uncertainty

The results of the uncertainty analysis are presented in Paragraph 1.7, while the detail calculations are presented in Annex IV.

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

- CO_2 emissions from *ammonia production* have been estimated for the first time in the 2009 inventory, using data of the NSSG and the one plant producing ammonia in Greece.

- Emissions from *soda ash production* are reported as not occurring, according to data received by the NSSG.

- Emissions from *soda ash use* are included in the Glass Production category (2.A.7.1.).

- The use of *SF_6 in aluminium and magnesium foundries* has been examined. According to the information collected, there are no magnesium foundries in Greece, while the one aluminium foundry does not make any use of SF_6. This information has been also confirmed by the Aluminium Association of Greece.

- According to members of the Hellenic Semiconductors Industry Association., there is no *semiconductor manufacture* in Greece, resulting in characterizing the relevant emissions as Not Occuring.

The main reasons for the non estimation of GHG emissions refer to the lack of emission factors in the IPCC Guidelines (e.g. CH_4 emissions from *ammonia*, *aluminium*, *iron and steel production* – CO_2 emissions from the non-energy use of *bitumen* and *organic chemicals production*) and the scarcity of activity data. In the latter case, actions have been undertaken or are planned under the new inventory system. The steps to improve completeness include the following:

- CO_2 emissions from *ferroalloys production* are included in the energy sector as available information regarding non-energy use of fuels (Section 3.5) does not allow for its allocation in those sources. However, data on the use of fuels has been requested by the corresponding plant and this issue is expected to be resolved in the following years.

- *Foam Blowing* is being performed by four companies in Greece. After contacted experts of the area, questionnaires have been distributed to all of them. Since some of the companies have not been able to complete the questionnaires until the end of February, this category is expected to be introduced as new in the next inventory (inventory of 2010).

- According to experts the use of f-gases in *Fire Extinguishers* is very limited. The inventory team is trying to contact importers and producers of fire extinguishers.

- Data on *aerosols* and *solvents* is very scarce in Greece, since neither association between members of the aerosol industry seems to exist, nor is there any data availability in the national production statistics.

- As concerns to the *Potential Emissions from the Consumption of Halocarbons and Sf₆*, imports and exports data of the relative compounds (in bulk) have been provided by the NSSG. However, these compounds are not reported separately and the estimation of potential emissions is rather difficult. To resolve this issue, the following steps are being implemented:

  1. The raise of confidentiality regarding the importers/exporters of f-gases has been requested by the NSSG. This is a time-consuming procedure as the request will have to be examined by the relative Committee of the NSSG.

  2. Using the data received by the NSSG, a questionnaire will be prepared and distributed to the importers/exporters in order to collect data concerning the consumption of the above mentioned compounds.

Table 4.4   *Industrial processes – Completeness*

	CO_2	CH_4	N_2O	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/IE					
5. Asphalt roofing	NE					
6. Road paving with asphalt	NE					
7. Other						
Glass production	☒					
B. Chemical industry						
1. Ammonia production	☒	NE				
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			
C. Metal production						
1. Iron and steel production	☒	NE				
2. Ferroalloys production	IE / ☒	NE				
3. Aluminium production	☒	NE			☒	
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	NA
2. Foam blowing				NE	NE	NE
3. Fire extinguishers				NE	NE	NE
4. Aerosols/metered dose inhalers				☒	NE	NE
5. Solvents				NE	NE	NE
6. Semiconductor manufacture				NO	NO	NO
7. Electrical equipment				NE	NE	☒

NE: Not Estimated

IE: Included Elsewhere

NO: Not Occurring

NA: Not Applicable

4.2   Mineral product

4.2.1   Cement production

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

Cement production (CO_2 emissions) is a key category. CO_2 emissions from cement production in 2007 (***Table 4.5***) accounted for 68.93% of total GHG emissions from industrial processes and for 4.75% of total national emissions (without LULUCF). The average annual rate of increase of CO2 emissions from cement production during the period 1990 – 2007 was 0.67% (emissions increased by 11.19% from 1990 to 2007). 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.

Table 4.5   ***CO₂ emissions from cement production (in kt) and clinker production (in kt) for the period 1990 - 2007***

Year	Clinker production (kt)	CO₂ 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

Methodology

During the inventory preparation the calculation of CO_2 emissions from cement production is very important, as this is a key category by both trend and level assessment.

For the years 2005-2007 detailed data have been accessed via the verified EU ETS reports of the plants. These data refer to the quantities of carbonate raw material ($CaCO_3$, $MgCO_3$) used for the production of clinker. The general equation used for each of the eight operating cement plants is described in the following equation:

$$CO_2 \text{Emissions} = \sum_i \left(EF_i \cdot M_i \cdot F_i \right) - M_d \cdot C_d \cdot \left(1 - F_d \right) \cdot EF_d$$

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 2007 the average content of the raw materials in $CaCO_3$ and $MgCO_3$ has been estimated at 76.01% and 2.53%, whereas the fraction calcination was 44% and 52.2%, respectively. Also, the raw material used throughout 2007 was 18.398 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. What is more, the CO_2 emissions from non-carbonate carbon have been ignored, as no such data were available.

In the previous years the calculation for the time series 1990-2006 was based on clinker production, according to the Tier 2 methodology. Following the reporting guidelines, in order to recalculate the time series, the overlap method has been chosen. In order to perform the recalculation the following steps have been followed:

1. For the years 2005-2007 the clinker production and the CaO and MgO content of clinker has been additionally requested and provided by the cement plants.

2. For the same years, emissions have been estimated by both methods (Tier 2[12] and the Carbonates Method).

3. The emissions associated with the new method are estimated according to the following equation (IPCC GPG):

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[12] The Tier 2 method is described by the following equation (IPCC 2000):

$$E = \left(0,785 \cdot CaO + 1,092 \cdot MgO \right) \cdot P_{CL} \cdot CKD$$

where, E is carbon dioxide emissions, CaO is the CaO content (weight fraction) in clinker, MgO is the MgO content (weight fraction) in clinker, P_{CL} is the total clinker production and CKD is a correction factor used to account for the CO2 contained in the non-recycled calcined cement kiln dust.

$$y_0 = x_0 \cdot \left(\sum_{i=m}^{n} y_i \middle/ \sum_{i=m}^{n} x_i \right),$$

where:

y_0 is the recalculated emission estimated computed using the overlap method

x_0 is the estimate developed using the previously used method

sum of y_i and x_i are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years m through n.

For reasons of consistency between both the previous years and the other countries, the activity data of the more recent years (2005-2007) are still expressed in kt of clinker produced.

The average CaO and MgO content of clinker for the years 2005-2007, as provided by the plants, is presented in table 4.6.

Table 4.6   *CaO and MgO content of clinker (2005-2007)*

Year	CaO content of clinker (%)	MgO content of clinker (%)
2005	64.68	2.93
2006	64.65	3.03
2007	64.47	3.26

The implied emission factors for the whole time-series are presented in *Table 4.7*.

In order to perform quality assurance activities, the total clinker produced reported by the plants has been also checked with the value provided by the NSSG. In general the two sources agree, although in certain years (i.e. in 2003 NSSG gives 15.016,56 kt of clinker instead of 11,754.73). In such cases additional information has been requested by the data providers, taking into account the time series (i.e. in the previous example, the value of the NSSG did not fit in with the previous years, nor with the years to follow. Indeed, as it turned out on that year a cement industry of three plants double-reported clinker production by mistake). Also, the national IEF corresponds to the plant-level ones, and is quite close to the default IPCC one.

Table 4.7   *Country specific CO₂ emission factor (in t / t) for clinker (cement) production*
                     for the period 1990 - 2007

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

Recalculations

CO$_2$ emissions for the period 1990-2004 have been recalculated, following the UNFCCC reporting guidelines. The difference (%) between present and previous emissions estimates was -2.38 % for all years.

The impact on total emissions is presented in the following table.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Impact on total emissions (excl LULUCF)	-0.13%	-0.13%	-0.13%	-0.13%	-0.13%	-0.14%	-0.14%	-0.13%	-0.12%	-0.12%	-0.12%

Year	2001	2002	2003	2004
Impact on total emissions (excl LULUCF)	-0.12%	-0.12%	-0.12%	-0.12%

It should be also noted that the clinker production of 2005-2007 has been corrected according to the values given by the plants. However, this did not lead to a recalculation, because the method used was based on the carbonate raw materials, as described previously.

Planned improvements

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

4.2.2   Lime production

Lime production leads to carbon dioxide emissions because of the calcination of limestone ($CaCO_3$) or dolomite ($CaCO_3.MgCO_3$) to produce lime or dolomitic lime. Lime production in Greece is mainly based on limestone.

Lime production (CO_2 emissions) is not a key category. CO_2 emissions from lime production in 2007 (*Table 4.8*) account for 5.15% of total GHG emissions from Industrial processes and for 0.36% of total national emissions (incl LULUCF) and are characterized by fluctuations, mainly because of the difference between plant-specific data and NSSG data. The average annual rate of increase of CO_2 emissions from lime production, for the period 1990 – 2007, is estimated at 0.76%.

Table 4.8   *CO₂ emissions (in kt) from lime production and production of lime (in kt) for the period 1990 - 2007*

Year	CO₂ 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	388.40	0.890	436.16
2005	372.30	0.874	425.98
2006	408.85	0.830	492.48
2007	468.98	0.854	549.45

Methodology

For years 2005 – 2007, 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:

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

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 $CaCO_3$, $MgCO_3$ whereas one of the industries reported also a small content in Ka_2CO_3 and Na_2CO_3. The activity data resulted in 1231.42 kt of $CaCO_3$ eq for the production of lime. The carbonates fraction calcination for $CaCO_3$ was 0.44, for $MgCO_3$ 0.522, for K_2CO_3 0.22 and for Na_2CO_3 0.27.

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 NSSG for the years 1993-2007, whereas for the years 1990-1993 the missing data have been calculated using the trend extrapolation method as described in the IPCC GPG.

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 30%.

Recalculations

In the previous years, for the period 1990-2004, the calculation of carbon dioxide emissions from lime production was based on the national lime production according to the equation 3.4 of the IPCC GPG (Tier 2 method):

$$E = EF \cdot production$$

For consistency reasons, the time-series of 1990-2004 have been recalculated using the overlap method, making use of emissions estimated by both methods for the years 2005-2007.

It should be noted that in the current inventory the hydraulic lime is introduced in the calculations for the first time, as in the previous years such data where not published by the NSSG (they are

considered confidential, and were made available under the new inventory system). For the Tier 2 estimation the emission factors used where the default (0.75 for high-calcium lime and 0.59 for hydraulic lime).

The IEF is generally unstable and greater than the default one. This possibly is attributed to the fact that the CaO content in the lime produced is more than 95%, which is the default value.

The trend of the CO_2 emissions from lime production is depicted in the **Figure 4.3**. Emissions and production seem to reach a maximum in 1999 and a minimum in 2005. According to the data received by the NSSG, this may be explained by the fact that about three plants have been closed since 1999, whereas in the last years all the plants reporting in the national system report also under the EU ETS. According to data received by the EU ETS, it seems that the main lime industries have significantly increased limestone consumption in 2007, which explains the increasing trend between 2005-2007.

CO₂ emissions and lime production
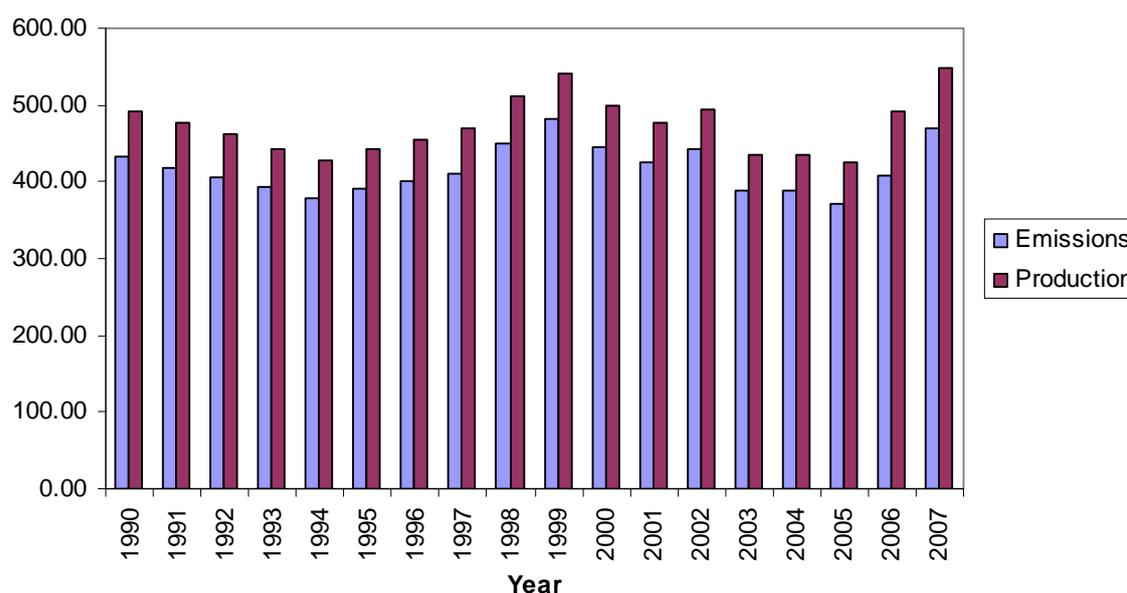
Figure 4.3   *CO₂ emissions (in kt) from lime production and lime production. for the period 1990 – 2007*

The difference between the previous and the current estimates and the impact on total emissions is presented in **Table 4.9**.

Table 4.9   *Recalculations of CO₂ emissions from lime production [1990-2004]*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	17.62%	21.72%	42.58%	-7.22%	-7.44%	-6.53%	-6.05%	-31.24%	12.02%	-7.18%	-9.28%
Impact on total emissions (excl LULUCF)	0.06%	0.07%	0.11%	-0.03%	-0.03%	-0.02%	-0.02%	-0.16%	0.04%	-0.03%	-0.04%

Year	2001	2002	2003	2004
Difference	-14.49%	-8.57%	-20.66%	-20.66%
Impact on total emissions (excl LULUCF)	-0.06%	-0.03%	-0.08%	-0.08%

Planned improvements

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

4.2.3   Limestone and dolomite use

Limestone ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$) 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 are not a key category, according to the results of the analysis carried out in the present inventory. Emissions in 2007 (***Table 4.10***) accounted for 3.26% of total GHG emissions from *Industrial processes* and for 0.22% of total national emissions (without *LULUCF*).

Table 4.10   *Limestone use (in kt) and CO₂ emissions (in kt) for the period 1990 – 2007*

Year	Limestone (kt)	CO₂ emissions (kt)
1990	649.10	285.60
1991	704.32	309.90
1992	698.52	307.35
1993	583.07	256.55
1994	463.94	204.13
1995	446.91	196.64
1996	452.83	199.24
1997	489.26	215.27
1998	552.01	242.89
1999	553.16	243.39
2000	541.81	238.40
2001	564.77	248.50
2002	587.19	258.36
2003	683.27	300.64
2004	686.61	302.11
2005	688.39	302.89
2006	723.05	315.19
2007	668.55	297.97

Methodology

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

CO₂ emissions are estimated according to the following general equation:

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

where, CO₂ 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 CO₂ emissions from limestone and dolomite use, the following are noted:

✤ **Steel production**: Data are generally plant specific, deriving from the EU ETS verified reporting of the plants (for the years 2005-2007) and the reporting performed for the NAP formulation in the previous years. For 2007, the total CaCO₃ equivalent amounts to 40.51 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 $CaCO_3$. Plant specific data on limestone consumption cover the years 1990 and 1998 – 2007. The specific limestone consumption is estimated on the basis of the available information (for the years 1990 and 1998 – 2007) and is used for filling in missing data.

- ✤ **Ceramics production**: Carbonates consumption data (in the context of the ETS reports) have been used for 2006 and 2007 emissions estimation. Activity data refer to $CaCO_3$ and $MgCO_3$ consumption (emission factors 0.44 and 0.522 respectively). The total $CaCO_3$ equivalent amounts to 503.58 kt. Limestone consumption data were available also for the period 2000-2003. Missing data for the period 1990 – 1999 were filled in on the basis of the ceramics production trend reported by the NSSG for the same period.

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

Recalculations

In the previous years the EF used was the default (IPCC 1996). In the more recent years (2005-2007) the EF is plant specific and takes into consideration the calcination of other impurities of the limestone, as reported by the plants. In any case, the EF is quite stable, therefore there is no matter of time-series consistency and no recalculation has been performed.

Planned improvements

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

4.2.4   Asphalt roofing and Road paving with asphalt

These categories are comprised of the non-combustion emissions from the production of asphalt in asphalt manufacturing plants (other than refineries) and its application (such as paving and roofing operations as well as subsequent releases from the surfaces). Asphalt blowing for roofing is also included.

Both activities are sources of NMVOC and CO emissions. Direct CO_2 and CH_4 emissions associated with the use of asphalt are minimal since the majority of the light hydrocarbon compounds were extracted during the refining process to produce commercial fuels. The oxidation of NMVOC and CO in the atmosphere results in CO_2 emissions.

In the present inventory, only NMVOC emissions estimates are included. More specifically, NMVOC emissions from asphalt roofing include only asphalt blowing assuming that 15% of bitumen consumption is used for asphalt roofing and using the emission factor suggested by CORINAIR (27.2 kg / t asphalt – SNAP 060310).

NMVOC emissions from road paving with asphalt derive mainly from the production and use of cutback asphalt.

✣ Activity data are estimated assuming that (a) 85% of bitumen consumption is used for the production of hot mix asphalt, (b) the fraction of bitumen in hot mix asphalt is 8% and (c) the fraction of cutback asphalt to total asphalt production is 5%.

✣ The emission factor is estimated considering a typical fraction of diluents of 35% (v), an evaporation of 70% of the diluents and an average density of 0.8 kg/lt.

4.2.5   Glass production

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

CO_2 emissions from glass production are not a key source. CO_2 emissions from glass production in 2007 decreased by 13.98% compared to 1990 levels (***Table 4.11***) and represent 0.19% of total GHG emissions from *Industrial processes*.

Table 4.11   ***Glass production (in kt) and CO_2 emissions (in kt) for the period 1990 - 2007***

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

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:

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

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 2007 is 0.15 t/t.

↳ Since February 2006 there is only one plant operating in Greece, whereas since 2005 this plant used to have two factories. Production data have been given for both factories for years 2005-2007.

↳ Activity data (glass production) for the period 1990 – 1992 are provided by the NSSG, 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.

↳ As it can be observed in the Table 4.11 above, emissions of the period 2002-2006 show a continuous decrease. This slope is justified by the fact that one of the glass industries in Greece is about to close and has reduced significantly the annual glass production. Moreover, the other glass industry has invested in plants of neighbour countries, making easier the import of glass to Greece.

↳ Emissions in 2007 increased by 19.83% with regards to 2006. According to information provided by the plant, this increase was due to the increase in production (by 15%). Also, the plant has increased the ration of raw materials to glass production, mostly due to the decreased use of cullet. The decreased use is due to general deficiency, but also to the quality demand (increasing consumption of raw materials to cullet improves the quality of the product).

Recalculations

The detailed data of 2005-2007 by the verified EU ETS reports have led to the need for recalculation of the time-series in order to ensure consistency. The overlap method has been performed for the period 1990-2004, by making use of the sets of estimated emissions by both methods for the years 2005-2007.

In the years 1993-1999, the activity data have been re-estimated as errors have been identified in the previous implementation of the linear interpolation method.

The difference between the previous and the current estimates and the impact on total emissions is presented in *Table 4.12*.

Table 4.12   Recalculations of CO$_2$ emissions from glass production [1990-2004]

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	-12.46%	-12.46%	-12.46%	-12.46%	-7.04%	-1.99%	2.75%	7.21%	11.38%	15.29%	18.93%
Impact on total emissions (excl LULUCF)	-0.003%	-0.003%	-0.002%	-0.002%	-0.001%	0.000%	0.000%	0.001%	0.002%	0.002%	0.003%

Year	2001	2002	2003	2004
Difference	-12.46%	-14.31%	-11.22%	-14.46%
Impact on total emissions (excl LULUCF)	-0.003%	-0.003%	-0.002%	-0.002%

Planned improvements

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

4.3 Chemical industry

4.3.1 Ammonia production

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

Up to 1999 there were two ammonia plants in Greece. Since 1998 (and up to today) the one plant still operating is using natural gas. The other plant closed in 2000. According to expert information, it used lignite as feedstock until 1991, and liquid fuels until its closure. In absence of gas consumption data, for the years 1998-1999 only CO_2 emissions from the first plant have been estimated CO_2 emissions in IP refer to emissions from natural gas (years 1998-2007), whereas emissions from the other fuels used (years 1990-1999) are included in the energy sector.

CO_2 emissions from ammonia production are a key category by trend assessment. This is probably because emissions of 1990 are estimated in the energy sector, and therefore, they are misleadingly accounted for non-existing in the base year. CO_2 emissions have increased by 64.6% since 1998 and represent 3.53% of total GHG emissions from *Industrial processes*.

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

$$E = TFR \cdot CCF \cdot 44/12 \,,$$

where E stands for CO_2 emissions, TRF is the total fuel requirement (GJ of natural gas), CCF is the carbon oxidation factor (15.3 kg/kJ for natural gas) and 44/12 is the stoichiometric ratio of carbon dioxide to carbon.

Activity data concerning fuel consumption for the years 1998-2007 have been provided by the plant using natural gas. Ammonia production for the whole time-series has been made available by the NSSG, and for the years 1998-2007 by the one plant still operating in Greece. In that way, data for the years 2000-2007 have been quality checked. Also, for 2006 data from the Ministry of Development have been gathered. All the activity data are presented in *Table 4.13*.

Table 4.13   ***Ammonia production and natural gas consumption (in kt) for the period 1990 - 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Ammonia production (kt)	313.03	255.61	167.94	69.78	0.00	96.98	133.91	122.16	244.76	233.33	147.48
Natural gas consumption (TJ)									3480.94	2827.66	5247.31

Year	2001	2002	2003	2004	2005	2006	2007
Ammonia production (kt)	68.70	94.14	150.18	159.92	143.90	160.90	165.77
Natural gas consumption (TJ)	2444.34	3349.36	5223.31	5546.84	5084.43	5613.09	5729.97

The estimated emissions and IEF are presented in ***Table 4.14***. It should be mentioned that the difference of the IEF between years 1999 and 2000 is due to the fact that for years 1998-1999 part of the CO_2 emissions have been included in the energy sector (emissions regarding the use of lignite as a fuel).

Table 4.14   ***CO_2 emissions (in kt) from ammonia production and IEF(for the period 1998- 2007***

Year	CO_2 emissions (kt)	IEF
1998	195.28	0.798
1999	158.63	0.680
2000	294.37	1.996
2001	137.13	1.996
2002	187.90	1.996
2003	293.03	1.951
2004	311.18	1.946
2005	285.24	1.982
2006	314.89	1.957
2007	321.45	1.939

Recalculations

CO_2 emissions are estimated for the first time in the current inventory. The impact on total emissions is presented in table 4.15.

Table 4.15   *Recalculations of CO₂ emissions from ammonia production [1998-2006]*

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Impact on total emissions	0.15%	0.12%	0.22%	0.10%	0.14%	0.22%	0.24%	0.22%	0.24%

Planned improvements

The possibility of collecting all available data on liquid fuels consumption will be investigated. However, it should be noted that this might be quite difficult, since the one plant closed 9 years ago. Gaps in activity data time series will be filled in as soon as new data become available.

4.3.2   Nitric acid production

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

Nitric acid production (N_2O emissions) is a key category. Nitrous oxide emissions from nitric acid production in 2007 (*Table 4.16*), account for 4.83% of total GHG emissions from *Industrial processes* and for 0.33% of total national emissions (without *LULUCF*). Emissions have decreased by 60.37% from 1990 to 2007.

Table 4.16   *Nitric acid production (in kt) and N_2O emissions (in kt) for the period 1990 – 2007*

Year	HNO₃ production (kt)	N₂O 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

Methodology

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

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

where, E is N_2O emissions, P is nitric acid production, EF is the emission factor, D is the N_2O 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 N_2O / t HNO_3).

✎ Nitric acid production data derive from NSSG and the individual industrial units for 1990-2007. Actually in the recent years there is only one unit producing nitric acid in Greece therefore, data are sent directly by the unit. In order to perform a quality control check these data are being cross-checked with data from NSSG and the Ministry of Development.

✎ The abatement system used by the Greek installations for reduction of NO_x emissions is the absorption tower. This technology does not affect the N_2O emissions (IPCC 2000), and for this reason D and U parameters in the above mentioned equation are not considered.

Recalculations

In 2008 the inventory team has come into communication with the plant, and received some information on the conditions of operation. The plant informed the inventory team that it operates under medium pressure. In the past it was considered that the plant was working under atmospheric pressure.

This difference has led to a change in the emission factor used for the whole period of the inventory. The difference between the previous and the current estimates and the impact on total emissions is presented in *Table 4.17*.

Table 4.17   *Recalculations of CO$_2$ emissions from nitric acid production [1990-2006]*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	55.56%	55.56%	55.56%	55.56%	55.56%	44.25%	55.56%	55.56%	55.40%	55.56%	55.56%
Impact on total emissions (excl LULUCF)	0.30%	0.25%	0.26%	0.25%	0.24%	0.20%	0.27%	0.24%	0.20%	0.20%	0.21%
Year	2001	2002	2003	2004	2005	2006					
Difference	55.56%	55.55%	55.00%	-13.87%	-30.14%	55.56%					
Impact on total emissions (excl LULUCF)	0.18%	0.17%	0.16%	0.15%	-0.07%	-0.14%					

Planned improvements

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

4.3.3   Production of organic chemicals

CH_4 and NMVOC emissions from the production of ethylene and 1,2 dichloro-ethane as well as NMVOC emissions from the production of polyvinylchloride and polystyrene are included in this category.

The contribution of this category to total GHG emissions from Industrial processes is negligible (less than 0.01% for the period 1990 – 2007).

Methodology

CH_4 emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

$$(Emissions) = (Production) * (Emission\ factor)$$

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 NSSG. The available data cover the period 1990 – 2007, whereas the ethylene and and 1,2 dichloro-ethane production has ceased in 1998 and 2000 respectively.

✤ Production of PVC and polystyrene is also confidential and is provided by NSSG. Data cover the period 1990-2006. Due to lack of activity data 2007 has been estimated as the average of years 2004-2006.

Recalculations

Due to the closer cooperation between the inventory team and NSSG new confidential activity data have been made available, leading to recalculations for the years 1994-2006. Production of ethylene and and 1,2 dichloro-ethane has been ceased since 2000, so CH_4 emissions are reported as Not Occurring since.

The difference between the previous and the current estimates and the impact on total emissions is presented in ***Table 4.18***.

Table 4.18   *Recalculations of emissions from organic chemicals production [1994-2000]*

Year	1994	1995	1996	1997	1998	1999	2000
Difference	-5.10	-1.25	3.14	-2.50	-9.73	-50.21	-64.73
Impact on total emissions (excl LULUCF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Planned improvements

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

4.4   Metal production

4.4.1   Iron and steel production

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.

Carbon dioxide emissions from steel production in 2007 (**Table 4.19**) accounted for 2.52% of total GHG emissions from *Industrial production* and for 0.17% of total national emissions (without *LULUCF*). The CO_2 emissions from steel production follow a increasing trend, reaching a a maximum value of 229.71 kt in 2007. Emissions have increased by more than 100% from 1990 to 2007, following the increasing trend of the production.

Table 4.19   *Steel production (in kt) and CO_2 emissions (in kt) for the period 1990 – 2007*

Year	Steel production (kt)	CO₂ Emissions (kt)
1990	999.10	92.70
1991	980.00	90.93
1992	924.00	85.73
1993	980.00	90.93
1994	848.00	78.68
1995	939.00	87.12
1996	809.82	75.14
1997	1,015.67	94.24
1998	1,108.29	102.83
1999	951.53	88.29
2000	1,104.78	102.50
2001	1,281.51	118.90
2002	1,839.80	170.70
2003	1,700.90	157.81
2004	1,966.24	182.43
2005	2,296.40	221.66
2006	2,415.80	222.02
2007	2,554.52	229.71

Methodology

The methodology used for the estimation of 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 2005-2007 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 NSSG for the years 2004-2007 (in the previous years the relevant Prodcom code did not exist).

✤ According to information received by the NSSG, all the iron and steel plants of the country are included in the EU ETS.

✤ In 2007 the average carbon content of the scrap and steel produced has been estimated at 0.83% and 0.2% respectively.

✤ Electrodes consumption is estimated at 0.8 kg/t steel produced.

On the basis of the completed and detailed data of 2005-2007 a country specific CO_2 emission factor is estimated (0.093 t/t).

Recalculations

The aggregated country-specific EF was found to be quite different between the period 2005-2007 and the previous years. According to 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 could 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 NSSG for the years 2004-2006.

The difference between the previous and the current estimates and the impact on total emissions is presented in *Table 4.20*.

Table 4.20   Recalculations of CO$_2$ emissions from iron and steel production [1990-2006]

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	-54.30	-54.58	-54.44	-55.56	-57.77	-58.85	-56.72	-57.06	-59.20	-59.49	-59.47
Impact on total emissions (excl LULUCF)	-0.10	-0.10	-0.10	-0.11	-0.10	-0.11	-0.09	-0.11	-0.12	-0.11	-0.12

Year	2001	2002	2003	2004
Difference	-63.15	-61.43	-60.49	-61.71
Impact on total emissions (excl LULUCF)	-0.16	-0.21	-0.18	-0.22

Planned improvements

Planned improvements also include carrying out calculations for CH$_4$ emissions estimations from the iron and steel production, as soon as an emission factor can be made available.

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

4.4.2   Ferroalloys production

Ferroalloy production involves a metallurgical reduction process that results in CO$_2$ emissions. The carbon in the electrodes captures the oxygen from the metal oxide to form CO$_2$. In addition, the calcination of carbonates fluxes such as limestone or dolomite contribute to these emissions.

The CO$_2$ emissions in 2007 account for the 0.67% of total emissions from Industrial processes, and for the 0.05% 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.

 It should be noted that CO$_2$ emissions from the use of fuels as reducing agents are included in the energy sector (1.A.2b), as there is not enough available information in order to identify the non energy use of fuels in this activity.

Methodology

The estimation of CO$_2$ emissions from ferroalloys production is based on the laterite consumption and the carbon content of it, assuming that all the carbon oxidises to CO$_2$.

✧ Activity data are considered as confidential since there is only one industry operating in Greece.

✧ Activity data for 2005-2007 derive of the verified report of the industry under the EU ETS.

✦   Activity data for the period 200-2003 derive of the reports of the plant during the formulation of the NAP.

✦   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 1990-2004. For the same period of estimation, the carbon content of laterite used is less than 1%, according to plant specific information.

Recalculations

No recalculation was performed.

Planned improvements

Information on the non-energy use of fuels as reducing agents has been requested by the inventory team to the plant. All available data will be used to estimate emissions in the industrial sector, removing the respective emissions from the energy sector.

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

4.4.3   Aluminium production

Primary aluminium production is responsible for emissions of CO_2 and PFC. Carbon dioxide is produced when, during electrolysis, the carbon of the anode reacts with alumina (Al_2O_3). Two PFC (CF_4 and C_2F_6) are formed during the phenomenon known as the anode effect, when the aluminium oxide concentration in the reduction cell electrolyte is low.

Emissions of CO_2 and PFC from aluminium production in 2007 (***Table 4.21***) accounted for 2.82% and 0.65%, respectively, of total GHG emissions from *Industrial processes*. The average annual rate of increase of CO_2 emissions during the period 1990 – 2007 was 0.69 %. The average annual rate of decrease of PFC emissions is estimated at -3.17%, while emissions have decreased by -29.29%, compared to base year emissions (1995).

Emissions of CO_2 depend directly on aluminium production, while PFC emissions are influenced as well from actions on the restriction of the anode effect.

Table 4.21 *CO_2 emissions (in kt) and PFC emissions (in kt CO_2 eq) from primary aluminium production. for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2	231.96	236.17	237.37	228.92	213.93	202.87	202.86	205.60	226.40	247.89
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72

Year	2000	2001	2002	2003	2004	2005	2006	2007
CO_2	251.99	251.16	254.05	257.84	258.29	256.26	255.70	257.32
PFC	148.38	91.38	88.33	77.30	71.38	71.31	71.16	58.66

The trend of the emissions is depicted in the *Figure 4.5*. 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. Information has been provided by the plant, concerning the above mentioned trend. This information includes the following:

✤ During the period 1993-1996, one aluminium series did not operate leading to the decrease of PFCs emissions.

✤ During 1997-1998, 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.
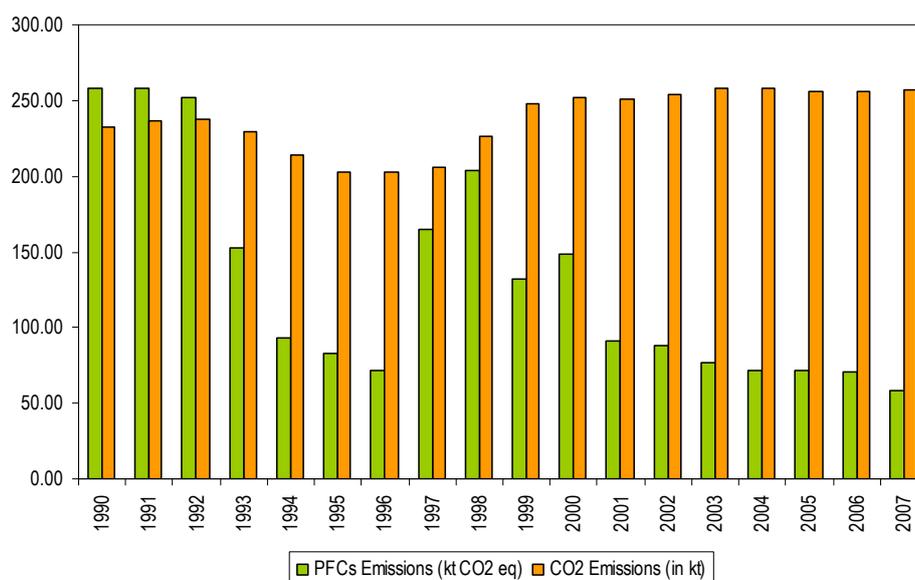
Figure 4.4   *CO_2 and PFCs emissions (in kt) from aluminium production. for the period 1990 – 2007*

Methodology

Carbon dioxide emissions from primary aluminium production are calculated on the basis of aluminium production and a reference emission factor. It should be noticed that data on aluminium production are confidential and therefore are not presented in the current report.

PFC emissions estimates are based on measurements data made by the aluminium industry according to the PESHINEY methodology (Tier 3b methodology, IPCC 2000).

Recalculations

Recalculation of CO_2 and PFCs emissions has been performed for the years 2005-2006 and 2004-2006, respectively, as new data have been made available by the plant. The difference between the previous and the current estimates and the impact on total emissions is presented in ***Table 4.22***.

Table 4.22   *Recalculations of CO₂ and PFC emissions from aluminium production [2004-2006]*

Year	2004	2005	2006
CO₂ Difference		-0.79	0.65
Impact on total emissions (excl LULUCF)		0.00	0.00
PFCs- Difference	-0.46	-0.57	0.89
Impact on total emissions (excl LULUCF)	0.00	0.00	0.00

Planned improvements

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

4.5   Production of halocarbons and SF$_6$

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 do not occur since 2006, since the plant manufacturing HCFC-22 has stopped operating since.

Table 4.23   *HFC-23 emissions (in kt CO$_2$ eq) from HCFC-22 production. for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HFC-23 (kt CO$_2$ eq)	935.06	1106.82	908.39	1606.64	2143.91	3253.07	3746.34	3960.22	4359.89	5023.04

Year	2000	2001	2002	2003	2004	2005	2006	2007
HFC-23 (kt CO$_2$ eq)	3735.11	3181.46	3194.57	2661.05	2550.60	2157.48	NO	NO

Methodology

According to the IPCC Good Practice Guidance, the analytical methodology (Tier 2) should be applied for the calculation of HFC-23 emissions from HCFC-22 production, as it constitutes a key source. This methodology is based on the collection and elaboration of on site 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.

Recalculations

Recalculations have been performed for 2005 and 2006. The production has been reported by the plant for 2005, whereas it has been reported as Not Occurring for 2006. For 2005, the difference between the previous and the current estimates is -15.41% and the impact on total emissions is -0.30 % (excl LULUCF). For 2006, the difference between the previous and the current estimates is -100 % and the impact on total emissions is -1.79 % (excl LULUCF).

Planned improvements

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

4.6   Consumption of halocarbons and SF6

Emissions of F-gases are generated during the manufacturing, operation/maintenance and final disposal of the following materials/equipment:

- ✤   Refrigerating and air conditioning equipment
- ✤   Foam blowing
- ✤   Fire extinguishers
- ✤   Aerosols / metered dose inhalers
- ✤   Solvents
- ✤   Semiconductor manufacture
- ✤   Electrical equipment

In order to obtain a reliable estimation of F-gases emissions, collection of detailed data for all 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, the estimations presented hereafter cover only a part of the materials/equipments mentioned above.

Specifically: (a) HFC emissions from refrigerating (including transport refrigeration) and air conditioning (including mobile air conditioning) equipment and of metered dose inhalers are included, which, however, are considered to represent the basic source of the respective emissions (b) emissions from the use of SF_6 in electrical equipment. It should also be noted that emissions from semiconductor manufacture are reported as Not Occuring, as According to members of the Hellenic Semiconductors Industry Association, in Greece there is no semiconductor manufacture at stages demanding the use of F-gases.

The consumption of F-gases is a key category. Emissions from the consumption of F-gases in 2007 (***Table 4.24***) accounted for 7.42% of total GHG emissions from *Industrial processes* and for 0.51% of total national emissions (without *LULUCF*). The average annual rate of emissions increase for the period 1995 – 2007 is estimated at 53.75%. The significant increase of emissions is attributed to the increased 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.

The demand of A/C equipment is highly dependent on the climatological conditions. Generally, the raise of temperature and the occasional extreme heatwaves increases the demand. The price is no longer a decisive factor, due to multiple credit systems made available by electrical stores and supermarkets. 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.

According to information provided by the National Association of Refrigerating and Cooling Technicians the use of F-gases started in 1993 as regards refrigeration equipment, in 2000 as regards stationary air-conditioning, in 1995 for mobile air-conditioning and in 2000 for transport refrigeration. 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.

Table 4.24   *HFC emissions (in kt CO$_2$ eq) per gas. from the consumption of F-gases for the period 1990 - 2007*

Year	HFC-32	HFC-125	HFC-134a	SF$_6$	TOTAL
1990				3.07	3.07
1991				3.16	3.16
1992				3.26	3.26
1993				3.35	3.35
1994				3.45	3.45
1995			1.15	3.59	4.73
1996			3.13	3.68	6.81
1997			9.24	3.73	12.97
1998			21.48	3.78	25.25
1999			39.84	3.87	43.71
2000	2.37	11.05	70.19	3.99	87.60
2001	4.16	19.44	102.88	4.06	130.55
2002	8.46	39.49	138.66	4.25	190.86
2003	14.08	65.74	201.12	4.25	285.20
2004	19.60	91.46	280.47	4.47	396.00
2005	26.08	121.67	323.20	6.45	477.40
2006	36.66	171.07	388.92	8.37	605.01
2007	41.84	195.09	428.64	9.92	675.49

4.6.1   Methodology

Refrigeration and air-conditioning

F-gases emissions are estimated according to the Tier 2a methodology described in the IPCC Good Practice Guidance. It 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, as the available information is not reported in the way required by these methodologies.

Total emissions are calculated as the sum of *assembly* emissions (emissions associated with product manufacturing, even if the products are eventually exported), *operation* emissions that include annual leakage from equipment stock in use (regardless of where they were manufactured) as well as servicing emissions and *disposal* emissions that include the amount of refrigerant released from scrapped systems, regardless of where they were manufactured, according to the following equation:

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

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

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

where, E_C is emissions related to the production, DOM is domestic production, CH is the initial charge, k is the leakage rate during manufacturing, E_O is emissions during operation, t_0 is the year of F-gases introduction in the market, T is the current year, IMP is imports, EXP is exports, x is the leakage rate during operation, E_D is emissions during disposal, n is lifetime, y is the remaining percentage from the initial charge of the equipment by the time of disposal, z is the percentage of recycling and DES is the amount of F-gases destroyed.

Assembly emissions are related to the number of units produced in the country (domestic production) that use F-gases as refrigerants, the amount of refrigerant used per unit and the losses during assembly. Operation emissions are related to the total number of equipment with F-gases as refrigerant (domestic production and imports) 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. 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
- Large commercial applications
- 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 4.25**) the following should be mentioned:

✍ Data on the air conditioning equipment stock for the period 1993 – 2007 are provided by market surveys (ICAP 2000, 2002, 2003, 2005, 2008).

✍ Data residential refrigeration equipment stock for the period 1993 – 2007 are provided by market surveys (ICAP 2000, 2002, 2006, 2008).

✍ Data on the commercial refrigeration equipment stock are provided from the elaboration of NSSG 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 Transport and Communications. Data for the years prior 1995 are not presented in table 4.18 as the use of F-gases for mobile air-conditioning started in 1995.

✍ Data on the number of transport refrigeration for 2000-2007 are provided by the Ministry of Transport.

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 4.26**. These value are based on expert judgement performed by members of the National Association of Refrigerating and Cooling Technicians

HFC emissions from the above mentioned applications are presented in **Table 4.27** for the period 1993-2007.

Table 4.25   ***Refrigeration and air conditioning equipment for the years 1993 – 2007***

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Refrigeration															
Residential	*311000*	*320000*	*335000*	*350000*	*355000*	*365000*	*360000*	*387000*	*376000*	*375000*	*390000*	*406000*	*402000*	*410000*	*421000*
Domestic production	80000	82000	90000	120000	185000	235000	260000	327000	324000	335000	368000	408000	431000	507200	390700
Imports	283000	315000	325000	350000	340000	340000	335000	340000	342000	340000	342000	320000	340000	313400	338000
Exports	52000	77000	80000	120000	170000	210000	235000	280000	290000	300000	320000	322000	369000	410600	307700
Large commercial applications			*31556*	*25832*	*24480*	*20284*	*26665*	*22852*	*15151*	*567*	*25825*	*4738*	*4738*	*12312*	*2049*
Domestic production			20820	14800	20520	17680	20200	16080	13050	7254	20310	23004	23004	17117	16383
Imports			14908	17410	13519	9532	18634	14795	17568	26114	21357	30000	30000	23306	17712
Exports			4172	6378	9559	6928	12169	8023	15467	32801	15842	48266	48266	28111	32046
Small commercial applications			*73642*	*74179*	*79243*	*67761*	*79885*	*73586*	*79347*	*48352*	*64395*	*51667*	*51781*	*62596*	*87362*
Domestic production			58640	71680	63730	57140	69090	61900	67168	51759	56461	54886	55000	57862	85689
Imports			16195	11062	24111	21231	19160	19868	20218	16835	18000	15000	15000	17487	12500
Exports			1193	8563	8598	10610	8365	8182	8039	20242	10066	18219	18219	12753	10827
Transport Refrigeration								223	399	645	910	1179	1291	1494	1663
In circulation								223	399	645	910	1179	1291	1494	1663
Stationary air-conditioning															
Split unit systems and semi-central systems	*89570*	*126730*	*154200*	*150880*	*188900*	*229550*	*330655*	*431385*	*617800*	*305750*	*503950*	*493100*	*430800*	*489520*	*574310*
Domestic production	12320	17550	22000	21200	2800	2250	1750	1750	1400	1250	500	700	300	220	210
Imports	82250	115180	141200	137380	189700	240000	342205	445035	647000	341000	626350	644500	522000	611000	726000
Exports	5000	6000	9000	7700	3600	12700	13300	15400	30600	36500	122900	152100	91500	121700	151900
Chillers	**1100**	**1080**	**1120**	**1180**	**1140**	**1240**	**1315**	**1585**	**2350**	**2850**	**2400**	**1950**	**1770**	**1580**	**1860**
Domestic production	350	380	400	430	420	500	600	950	1600	1800	1100	700	520	480	560
Imports	750	700	740	770	780	840	835	945	1500	1450	1650	1450	1400	1300	1600

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Exports	0	0	20	20	60	100	120	310	750	400	350	200	150	200	300
Other applications of air conditioning	*28800*	*31500*	*32000*	*35700*	*39850*	*43250*	*44830*	*48300*	*53800*	*67400*	*73200*	*48250*	*42100*	*44100*	*45950*
Domestic production	32900	33500	35200	34300	34500	37730	37900	39300	40100	37900	34500	26000	19350	16700	17100
Imports	4900	5300	6300	9300	9600	12120	12130	14200	18900	37300	48350	29600	25400	32000	36600
Exports	9000	7300	9500	7900	4250	6600	5200	5200	5200	7800	9650	7350	2650	4600	7750
Mobile air-conditioning			*133757*	*141589*	*166778*	*183857*	*268716*	*302620*	*289943*	*277567*	*273870*	*317508*	*344339*	*346551*	*316721*
Domestic production															
Imports			133757	141589	166778	183857	268716	302620	289943	277567	273870	317508	344339	346551	316721
Exports															

Table 4.26   ***Basic assumptions for the calculation of HFC emissions***

	Charge (kg/unit)	Leakage rate (%)		Lifetime (years)	Refrigerant used
		Charge	Operation		
Refrigeration - Residential	0.18	0.6	0.02	15	HFC-134a
Refrigeration – Large commercial applications	10	0.5	10	10	HFC-134a
Refrigeration – Small commercial applications	1.5	1.75	10	10	HFC-134a
Transport Refrigeration	2.38[a]	8	0.6	10	HFC-134a
Air conditioning – Split units and semi central systems	2	0.6	0.33	15	R-410a
Air conditioning – Chillers	50	0.6	20	10	R-407c
Air conditioning - Other applications of central air conditioning	12	0.6	20	10	R-407c
Mobile Air conditioning	1	0.5	0.55	8-10	HFC-134a

[a]In Greece, small transport refrigerations (for domestic transfer of products) is charged by 1 kg HFC134a/unit, while large transport refrigeration charge (for international transfer of products) is 6 kg HFC134a/unit. Provided that the number of transport refrigerations given by the ministry of Transport includes both categories, and given the fact that the majority concerns small transport refrigerations, the charge used in the calculations is 2.38 kg HFC134a/unit.

Table 4.27   ***HFC emissions (in t CO_2 eq) from refrigeration and air conditioning equipment for the period 1993 – 2007***

Year	Residential Refrigeration	Refrigeration - Large commercial applications	Refrigeration - Small commercial applications	Transport Refrigeration	Stationary air-conditioning	Mobile air-conditioning
1993	0.26					N.A.
1994	1.00					N.A.
1995	8.86	545.56	343.71			145
1996	21.85	1,636.39	943.41			398
1997	47.25	5,588.18	2,648.83			798
1998	95.84	13,567.06	6,236.56			1,356
1999	167.68	25,513.22	11,667.58			2,262
2000	334.24	36,117.67	17,002.59	23,790.72	11,054.82	6,053
2001	462.67	48,431.53	24,584.18	41,752.07	19,441.40	10,741
2002	541.15	57,048.32	30,969.22	84,656.95	39,486.09	12,746
2003	605.74	81,696.34	41,887.07	141,048.21	65,739.38	14,724
2004	680.90	99,282.56	53,154.41	196,106.46	91,459.56	40,829
2005	732.00	97,363.16	58,144.61	260,482.99	121,666.15	52,488
2006	858.17	95,700.30	61,196.80	366,371.53	171,065.39	70,306
2007	619.39	89,728.04	68,316.83	416,100.74	195,087.37	87,892

Aerosols

More aerosol packages contain hydrocarbons as propellants, but in a small fraction of the total HFCs and PFCs may also be used as propellants or solvents. Emissions from aerosols usually occur shortly after the production while 100% of the chemical is emitted. According to 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

Data on aerosols is very scarce in Greece. At the present inventory only estimation of emissions from metered dose inhalers is being performed (***Table 4.28***).

The percentage emission factor used is 100%, assuming that the charge will be escaped in one year from purchase. Activity data derive of data given by the NSSG on the imports and exports of metered dose inhalers and cover the years 1995-2007. The data received are in form of quantity (pieces) or weight (kg).

In absence of any information on the charge of the units, the estimation has been based on the assumption that the use of respiratory medicine in Greece is similar to that of other Mediterranean countries (Portugal, Spain), taking into account the country's population.

Table 4.28   ***HFC-134a emissions from MDIs (in kt CO_2 eq) for the period 1995 - 2007***

Year	Emissions (t CO2 eq)
1995	0.08
1996	0.10
1997	0.12
1998	0.17
1999	0.18
2000	0.20
2001	0.27
2002	0.21
2003	0.25
2004	0.35
2005	0.24
2006	0.26
2007	0.40

At the present additional information has been requested by the pharmaceutical brands of Greece concerning the propellants used, the year of HFC-134a, the charge and the quantities used in the years of the inventory. Some information has already been collected and data will be elaborated in the next months.

Electrical equipment

The use of SF_6, as dielectric, in the transmission and distribution system of electricity, is considered as the main source of SF_6 emissions. Emissions arise in cases of leakages and during the maintenance of sub-stations and circuit breakers, especially when the equipment is old.

The available information is not sufficient in order to apply the methodologies suggested by the IPCC Good Practice Guidance.

In the context of the present inventory emissions are estimated on the basis of information provided by PPC regarding losses in the transmission and in the distribution system. The data provided cover the period 1995 – 2007. Emissions estimates are being performed on the basis of the quantity of SF_6 consumed during the year, by the Directorate of Strategy and Planning of the PPC.

Emissions for the period 1990 – 1994 are estimated (by the inventory team) by mean of a linear extrapolation. SF_6 emissions from electrical equipment are presented in ***Table 4.29***.

Table 4.29   SF6 emissions (in kg) from electrical equipment for the period 1990 - 2007

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
Transmission	130	132	140	140	148	230	310	375
Distribution	37	38	38	38	39	40	40	40
Total	**167**	**170**	**178**	**178**	**187**	**270**	**350**	**415**

4.6.2   Recalculations

In the current inventory a strong effort has been made to improve the quality of information regarding the consumption of f-gases. The new information which led in recalculations includes the following:

Ä As requested by the ERT in the in-country review of September 2008 the assumptions regarding the penetration of f-gases in the refrigeration and A/C equipment have been re-evaluated. In order to do so, several meeting have taken place between members of the inventory team and experts, including members of the National Association of Refrigeration and Cooling Technicians, main refrigerant importers and employees of the NSSG in the External Trade

Section. In the joint meeting held on the 21rst of November 2008 the main assumptions have been investigated and re-estimated so as to depict the reality. All the time series have been recalculated according to the latest expert opinion.

✇ Updated data regarding the activity data of years 2004-2006 have been made available by using market surveys. These data regard the imports, exports and production of A/C and refrigeration equipment.

✇ The time-series of transport refrigeration and metered dose inhalers has been completed, using all available information by the Ministry of Transport, the Association of Motor Vehicle Importers Representatives and NSSG, respectively.

✇ Finally, data on the SF_6 consumption from electrical equipment has been provided by the PPC regarding years 2005-2007.

The difference between the previous and the current estimates and the impact on total emissions is presented in *Table 4.30* for HFC emissions and in *Table 4.31* for SF_6 emissions.

Table 4.30   *Recalculations of HFCs emissions from the consumption of f-gases and SF_6 [Years 1995-2006]*

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Difference	-98.63	-98.28	-96.77	-94.37	-92.63	-88.87	-86.94	-84.11	-82.71	-78.52
Impact on Total Emissions (Exl LULUCF	-0.07	-0.16	-0.23	-0.29	-0.41	-0.52	-0.66	-0.77	-1.02	-1.09

Year	2005	2006
Difference	-76.79	-74.69
Impact on Total Emissions (Exl LULUCF	-1.18	-1.38

Table 4.31   *Recalculations of SF_6 emissions from the consumption of f-gases and SF_6 [Years 2005-2006]*

Year	2005	2006
Difference	30.74	46.57
Impact on Total Emissions (Exl LULUCF	-0.00	-0.00

4.6.3   Planned improvements

In the present a strong effort is being made to make use of all possible available information on the f-gases emissions. This effort has already given some results (see previous paragraphs) and is expected to ensure completeness and accuracy in the next submission.

In particular, the improvements planned and implemented are the following:

1. Various steps have been taken in order to resolve the issue of completeness in the areas of foam blowing and fire extinguishers. As regards to foam blowing, the main industries in Greece are four. Questionnaires on the use of f-gases have been sent to all of them and an estimation of the emissions will possibly be performed in the next submission. 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 is gathering all available information on the industries involved.

2. The approach of potential emissions activity data seems to be the more time-consuming Firstly, imports and exports have been provided by the NSSG (External Trade Section). However all the codes refer to totals of HFCs and PFCs, making the distinction of f-gases very difficult. In order to resolve this issue the inventory team is, at the present, into communications with NSSG in order to raise the confidentiality issues and get access to the list of importers involved in the imports and exports of such gases in the inventory years. The prepared request will have to be examined by a special Committee of the NSSG. After the importers are come to the knowledge of the inventory team, all available information will be collected. As regards to activity data regarding the disposal of f-gases from various types of equipment, questionnaires have been sent to the Appliances Recycling SA and information is still being gathered.

3. In order to improve accuracy in the metered dose inhalers category, questionnaires have been sent to all the pharmaceutical companies of Greece. The inventory team has also come into communication with the National Organisation for Medicines in order to make sure that all companies involved are included in the list of receivers. Collected data are planned to be cross-checked with data received by NSSG, concerning the imports and exports of metered-dose inhalers throughout the inventory years.

4. Since data are quite scarce in Greece in the sector of A/C and refrigeration equipment, the inventory team considers that they are prone to be uncertain. Provided that the sector is a key one, the possibility of coming into communication with the manufacturing and importing companies is being examined. In order to do so, all available information existing in the market surveys will be used. The purpose of such an activity will be improvement of the quality assurance of the report.

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

5.1   Overview

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 CO_2. This sector also includes evaporative emissions of greenhouse gases arising from other types of product use (e.g. N_2O 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 CO_2 and NMVOC emissions from the sector *Solvents and other products use*. Carbon dioxide emissions in 2007 were 160.34kt (0.1% of the total GHG emissions in Greece, without *LULUCF*), while NMVOC emissions have been estimated at 53.9 kt, accounting for approximately 26% of the total NMVOC emissions in the country.

CO_2 and NMVOC emissions in 2007 decreased by 5.5% and 4.8% respectively compared to 1990 levels, due to a decrease in the amount of products processed with solvents (e.g. fat, edible and non edible oil extraction, wood preservation).

Table 5.1   *NMVOC and CO$_2$ emissions (in kt) from Solvents and other products use for the period 1990 – 2007*

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

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 [1]	NMVOC	CO$_2$	CH$_4$	N$_2$O	HFC	PFC	SF$_6$
A. Paint application							
1. Vehicle manufacture and Vehicle refinishing	NE [3]	NE		NE			
2. Domestic use and construction	☒	☒		NE			
3. Shipping-paint applications	NE	NE		NE			
4. Wood paint applications	NE	NE		NE			
5. Other paint applications in industry	NE	NE		NE			
6. Other non-industrial paint applications	NE	NE		NE			
B. Degreasing and dry cleaning							
1. Metal degreasing	NE	NE		NE			
2. Dry cleaning	☒	☒		NE			
3. Industry of electric equipment	NE	NE		NE			
4. Other cleaning applications in Industry	NE	NE		NE			
C. Chemical Products. Manufacture and Processing							
1. Production of chemical and pharmaceutical products	☒						
D. Other	NE						
1. Domestic use (except 5.A.2)							
2. Wood preservation	☒						
3. Fat edible and non edible oil extraction	☒						
4. Printing industry	☒						
5. Use of N$_2$O in medicine [2]	☒						
6. N$_2$O from fire extinguishers [2]				NE			
7. N$_2$O from aerosol cans [2]				NE			
8. Other use of N$_2$O [2]				NE			

NE: Not Estimated

[1] Disaggregation of IPCC source categories is based on the CORINAIR methodology

[2] 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 Methodology

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. N_2O 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 National Statistical Service of Greece, 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).

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 16.30% between 1990 and 2007 (***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 pubic incentives for the use of synthetic fertilizers.

Emissions from *Agriculture* and especially N_2O emissions from agricultural soils are characterized by intense fluctuations during the period 1990 – 2007. 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 National Statistical Service of Greece (NSSG), 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), while previous submissions data were obtained from FAO for 1990-2002 and provisional data for the rest years. It should be noted that there are no significant differences between confirmed obtained from PHAPFPD and the data used in previous submissions as far as the quantities of synthetic fertilizers are concerned.

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 CO_2 eq) per gas from Agriculture, for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N₂O	10027	9882	9678	8889	8725	9043	9143	9010	9020	8898	8705
CH₄	3470	3436	3424	3455	3479	3504	3522	3530	3532	3538	3553

Year	2001	2002	2003	2004	2005	2006	2007
N₂O	8631	8548	8433	8457	8114	7949	7748
CH₄	3577	3589	3557	3527	3518	3527	3549
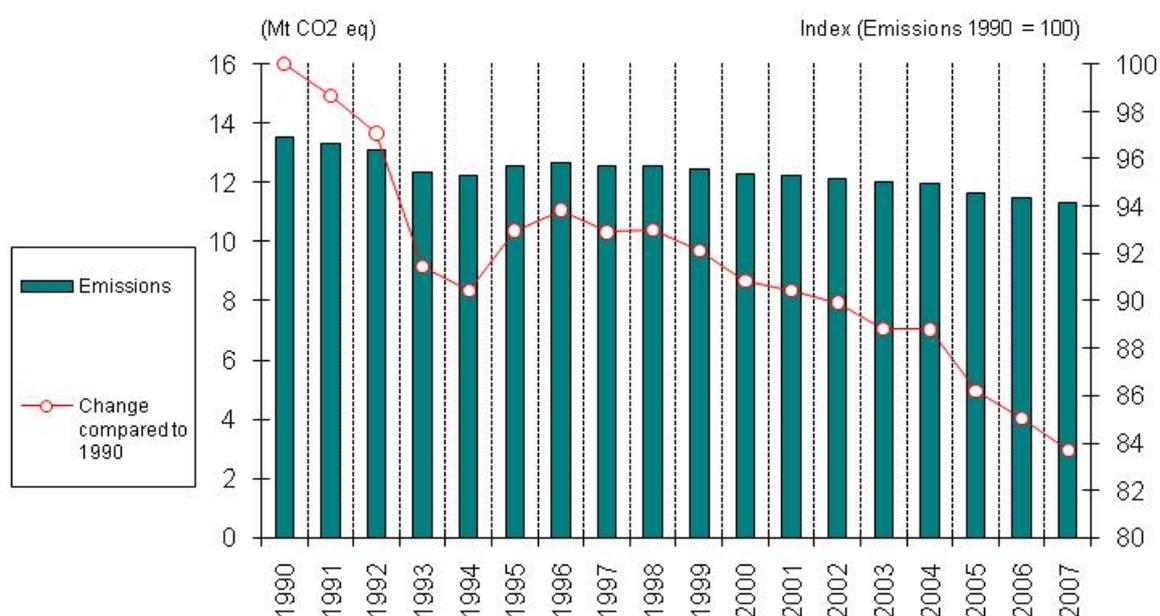
Figure 6.1   *Total GHG emissions (in kt CO_2 eq) from Agriculture for the period 1990 – 2007*

Nitrous oxide represents the main GHG from *Agriculture*, with a contribution ranging from 74.3% to 68.6%. Nitrous oxide emissions in 2007 decreased by 22.72% compared to 1990 levels with an average annual rate of decrease estimated at 1.34%.

Agricultural soils are the main source of emissions from *Agriculture* (***Figure 6.2***), accounting for 65.9% - 72% of the total emissions from the sector.
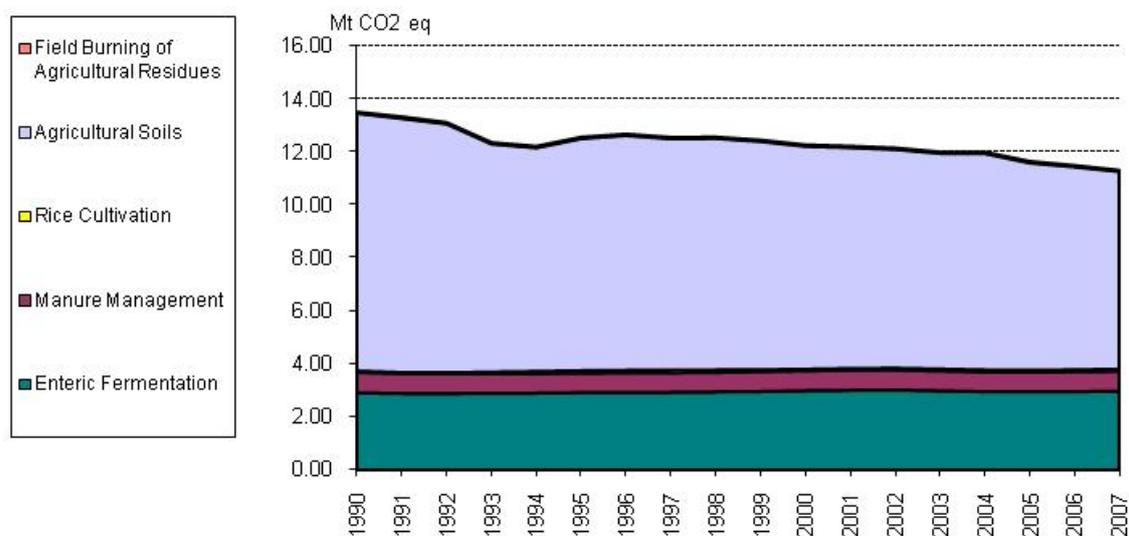
Figure 6.2   ***GHG emissions (in kt CO₂ eq) from Agriculture per source category, for the period 1990 – 2007***

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 NSSG, 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, agricultural production and areas for 2007 are provisional estimations, due to delay from the time the relative statistical data are collected until their elaboration and publication as final 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).

Table 6.2   *Methodologies for the estimation of emissions from Agriculture*

	CH₄		N₂O	
	Method	**Emission factor**	**Method**	**Emission factor**
Enteric fermentation	T2,T1	CS, D		
Manure management	T1	D	D	D
Rice cultivation	D	D		
Agricultural soils			D,T1a, T1b	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

Key categories

Enteric fermentation, agricultural soils and animal production are the key categories identified in the sector of *Agriculture* (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).

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, the Tier 2 methodology is applied at least for the animal species that account for a significant part of the emissions from this source category. In Greece, enteric fermentation of sheep is responsible for 39% of methane emissions from this source and therefore the Tier 2 methodology is used in this case. Concerning agricultural soils both simple and detailed methodologies (Tier 1a and Tier 1b) as well as their combination are proposed, depending on data availability.

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV.

6.1.3   Completeness

Table 6.3 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 6.3   *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

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 (CH_4 emissions) is a key category. As already mentioned, the Tier 2 methodology is applied for the estimation of methane emissions from enteric fermentation of 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 animal species.

Methane emissions from enteric fermentation in 2007 account for 25.94% of total GHG emissions from *Agriculture* and for 2.22% of total national emissions (excluding *LULUCF*). The average annual rate of increase of emissions from enteric fermentation for the period 1990 – 2007, is estimated at 0.11% (increase by 1.84% in 2007 compared to 1990). Emissions from enteric fermentation are presented in **Table 6.4**.

Table 6.4   *CH_4 emissions (kt) from enteric fermentation. for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 emissions (kt)	137.02	135.54	135.47	135.94	136.32	137.19	137.59	137.80	138.44	139.22	140.57
Year	2001	2002	2003	2004	2005	2006	2007				
CH_4 emissions (kt)	141.41	141.89	140.45	138.90	138.39	138.97	139.55				

Methodology for 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.

The first step is the "enhanced" livestock characterization, which intends to define livestock sub-categories based on the age of animals, their sex, weight, feeding situation and the various management systems used. Additionally, the estimation of feed intake in terms of energy (MJ/day) is required for each sub-category and each activity animals perform, such as growth, lactation and pregnancy. 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 CH_4 (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 CH_4. In certain cases the emission factor was not calculated for a full year period, but rather for the period that actually corresponds to the given activity.

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

$$GE_i = \begin{cases} \dfrac{NE_i/NE_{ma}/DE}{DE/100} & \text{, maintenance} \\[2em] \dfrac{NE_i/NE_{ga}/DE}{DE/100} & \text{, growth} \end{cases}$$

where, NE_i is the net energy for each activity, 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 and NE_{ga}/DE is the similar ratio for growth. The first equation concerns activities related to animal maintenance, activity, lactation, milk production and pregnancy. The second equation concerns animal growth and wool production.

The characterization and classification of sheep was based on data from NSSG 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 6.5*. It should be noted that there is not always a one-to-one correspondence between the sub-categories presented in the following table and the activities mentioned above. The data for the period 1999-2006 were updated with confirmed data from NSSG because in the previous submission provisional data were used.

The average bodyweight of sheep at weaning is estimated at 15 kg. The average weight of lambs at one year of age or at slaughter is estimated at 35 kg. The average weights of milking ewes and the rest of mature sheep are estimated at 53 kg and 70 kg respectively. The average milk production for domestic and in flock and for nomadic sheep is 0.48 kg/day and 0.43 kg/day respectively. Wool production is estimated at 4 kg/sheep/year, while, due to lack of data, all births are assumed singles. Default methane conversion rates (*Ym*) 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.

The duration of lamb's growth is estimated at 315 days, which correspond to the period between effective weaning and one year of age, lLactation lasts 50 days, while pregnancy lasts 147 days.

The average feed intake, which is calculated by dividing the total gross energy with the total sheep population, is more or less 22.36 MJ/day. The number of animals is a three-year average centred at the year of reference.

Table 6.5   *Number of sheep (in 1000s) for each sub-category (three-year average), for the period 1990 – 2007*

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milking ewes	5650	5637	5647	5671	5715	5756	5774	5787	5799	5822	5865
Other female sheep > 1 year old	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
Grazing flat pasture	2148	2155	2159	2164	2175	2188	2187	2180	2171	2176	2190
Grazing hilly pasture	5623	5594	5604	5634	5686	5721	5750	5780	5820	5849	5894
Housed fattening lambs	921	924	925	927	932	938	937	934	930	933	939
Domestic / in flock sheep milked	7647	7708	7711	7780	7904	8000	8056	8073	8148	8198	8267
Nomadic sheep milked	1013	984	955	927	898	869	840	811	782	753	724
For wool production	2408	2418	2627	2677	2399	2395	2371	2348	2348	2353	2412
Births	8490	8487	8590	8664	8728	8787	8841	8855	8882	8910	8966
Total population (at the end of each year)	8660	8692	8666	8706	8802	8869	8896	8884	8930	8951	8991

Sub-categories	2001	2002	2003	2004	2005	2006	2007†
Milking ewes	5888	5891	5826	5768	5731	5728	5735
Other female sheep > 1 year old	765	766	757	750	745	745	746
Males > 1 year old	412	412	408	404	401	401	401
Female lambs	1594	1595	1577	1562	1552	1551	1553
Male lambs	399	399	394	390	388	388	388
Grazing flat pasture	2209	2218	2220	2217	2221	2226	2231
Grazing hilly pasture	5904	5894	5791	5706	5644	5633	5636
Housed fattening lambs	947	951	951	950	952	954	956
Domestic / in flock sheep milked	8432	8401	8343	8227	8214	8281	8266
Nomadic sheep milked	695	657	657	600	577	549	524
For wool production	2382	2393	2306	2269	2246	2217	2388
Births	9005	9039	9038	9024	9008	8992	8991
Total population (at the end of each year)	9127	9058	9002	8827	8792	8830	8816

† Provisional data

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.

The application of this methodology requires livestock population data and emission factors per animal species. Population data were obtained from the NSSG. The provisional data for the period 1999-2006 used in previous submissions were updated with confirmed data from NSSG. Emission factors used were the ones suggested by IPCC Guidelines (*for non dairy cattle*: Eastern European countries. Table 4-4, IPCC 1997 - for the rest animal categories: Developed countries, Table 4-3, IPCC 1997). For dairy cattle, the emission factor used was an interpolation between Eastern Europe and West Europe respective factors, based on average annual milk production. This procedure was performed for the first time in the current submission, due to the availability of corfimed data from NSSG concerning daily cattle milk production, According to Table 4-4, IPCC 1997, the emission factor is about 81 and 100 kg/head/yr for milk production 2550 kg/head/yr (Eastern Europe) and 4200 kg/head/yr (Western Europe), respectively. Thus, the emission factor was calculated according to the following equation:

$$\text{Emission Factor}\left(\frac{\text{kg CH}_4}{\text{head}\cdot\text{yr}}\right) = \text{Milk Production}\left(\frac{\text{kg Milk}}{\text{head}\cdot\text{yr}}\right)\cdot 0.0115 + 51.64$$

The number of animals used for the calculation of methane emissions (***Table 6.6***) is a three-year average centred at the year of reference.

Table 6.6   *Number of animals (in 1000s) by category (three-year average), for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy cows	246	242	238	235	233	230	229	227	226	226	225
Other cattle	380	363	351	346	347	350	351	354	362	374	387
Buffalo	1	1	1	1	1	1	1	1	1	1	1
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

Year	2001	2002	2003	2004	2005	2006	2007†
Dairy cows	226	227	225	221	218	217	216
Other cattle	394	396	392	393	399	413	419
Buffalo	1	1	1	1	1	1	1
Goats	5658	5652	5600	5517	5444	5397	5384
Horses	29	28	28	27	27	27	27
Mules and ashes	90	84	79	74	69	64	62
Swine	946	937	939	942	930	915	898

† Provisional data

Recalculations

CH$_4$ emissions from enteric fermentation have been recalculated because of the availability of updated activity data regarding animal population for the period 1999-2006. Moreover, emissions from sheep were recalculated due to confirmed data regarding milking ewes, population of other female sheep > 1 year old, males > 1 year old, female lambs, male lambs, grazing flat pasture, grazing hilly pasture, housed fattening lambs, domestic / in flock sheep milked, nomadic sheep milked, wool production and births. Finally emissions from dairy cattle for the whole period (1990-2006) were recalculated by applying emission factors based on the confirmed milk production data. The deviation of the emissions from enteric fermenation 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 6.7.

Table 6.7   Recalculations of CH$_4$ emissions from enteric fermentation

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	0.405	0.536	1.045	1.520	1.614	1.804	1.853	1.864	1.948	1.868	1.980
Impact on total emissions (excl LULUCF)	0.011	0.014	0.028	0.040	0.042	0.046	0.046	0.045	0.045	0.044	0.045
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**					
Difference	2.508	2.955	2.319	1.077	2.627	3.056					
Impact on total emissions (excl LULUCF)	0.057	0.067	0.051	0.024	0.056	0.068					

Planned improvements

The possibility of applying Tier 2 methodology for the estimation of methane emissions from the enteric fermentation of cattle is under examination.

6.3   Manure management

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.

CH_4 and N_2O from manure management in 2007 accounted for 4.31% and 2.60% of total GHG emissions from *Agriculture* respectively, and for 0.37% and 0.22% of total national emissions respectively (without *LULUCF*). CH_4 emissions in 2007 decreased by 1.98% compared to 1990 levels, with an average annual rate of decrease estimated at 0.12% for the period 1990 - 2007. N_2O emissions in 2007 decreased by 2.43% compared to 1990 levels, with an average annual rate of decrease estimated at 0.14%. CH_4 and N_2O emissions from manure management for the period 1990 – 2007 are presented in *Table 6.8*.

Table 6.8   *CH_4 and N_2O emissions (in kt) from manure management, for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 (kt)	23.66	23.30	23.15	23.11	23.07	23.01	23.00	23.03	23.15	23.27	23.25
N_2O (kt)	0.97	0.95	0.93	0.92	0.91	0.91	0.91	0.91	0.92	0.93	0.94
Year	2001	2002	2003	2004	2005	2006	2007				
CH_4 (kt)	23.27	23.16	23.12	23.10	23.09	23.21	23.19				
N_2O (kt)	0.94	0.95	0.94	0.93	0.93	0.94	0.95				

Methodology

CH_4 emissions from manure management were estimated according to the IPCC Tier 1 methodology, which is similar to the one used for the enteric fermentation. Livestock population has been already presented in *Table 6.6*, while poultry and sheep population are presented in *Table 6.9*. The choice of emission factors follows the same criteria as for the case of enteric fermentation (IPCC 1997, Tables 4-5 and 4-6).

Table 6.9   *Livestock population (in 1000) for poultry and sheep (three-year average), for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Poultry	28747	28648	28972	29151	29231	29198	29266	29482	30005	30480	30150
Sheep	8692	8673	8688	8725	8792	8856	8883	8904	8922	8958	9023
Year	2001	2002	2003	2004	2005	2006	2007†				
Poultry	29937	29312	29936	30429	31251	31993	32207				
Sheep	9059	9062	8962	8874	8816	8813	8823				

† Provisional data

In order to calculate N_2O emissions from manure management, the default IPCC methodology was used, according to the following equation.

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

where E is N_2O 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 N_2O emission factor for system S.

The emission factors for N excretion and N_2O-N/N are those suggested by the IPCC Guidelines. Especially for N excretion, the values referring to Mediterranean countries were chosen (IPCC 1997, Table 4-20). The shares of manure management systems per animal species (*Table 6.10),* 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 – 2007.

Table 6.10   *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 ashes	0%	0%	0%	0%	100%	0%
Goats	0%	0%	0%	0%	100%	0%

Recalculations

CH_4 and N_2O emissions from manure management have been recalculated because of the availability of updated activity data as far as the population of the animals for 1999 to 2006 is concerned. 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 6.11 for CH_4 and in Table 6.12 for N_2O.

Table 6.11   *Recalculations of CH₄ emissions from manure management*

Year	1999	2000	2001	2002	2003	2004	2005	2006
Difference	-0.091	-0.716	0.365	0.157	-0.351	-0.395	0.645	-0.209
Impact on total emissions (excl LULUCF)	0.000	-0.003	0.001	0.001	-0.001	-0.001	0.002	-0.001

Table 6.12   *Recalculations of N₂O emissions from manure management*

Year	1999	2000	2001	2002	2003	2004	2005	2006
Difference	-0.021	-0.193	1.386	2.509	3.032	2.889	-5.616	0.842
Impact on total emissions (excl LULUCF)	0.000	0.000	0.003	0.006	0.007	0.006	-0.013	0.002

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

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.

CH_4 emissions from rice cultivation in 2007 account for 0.93% of total GHG emissions from *Agriculture* and for 0.08% of total national emissions (without *LULUCF*). CH_4 emissions increased by 51.96 % in 2007 compared to 1990, with an average annual rate of increase of 3.06% for the period 1990 - 2007. CH_4 emissions from rice cultivation for the period 1990 – 2007 are presented in ***Table 6.13***.

Table 6.13   *CH_4 emissions (in kt) from rice cultivation for the period 1990 – 2007*

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				
CH_4	4.22	4.48	4.52	4.55	4.62	4.46	5.00				

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

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 CH_4 / m^2) 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.

Recalculations

No recalculations were performed.

6.5   Agricultural soils

Agricultural soils constitute the largest anthropogenic source of nitrous oxide emissions. N_2O is produced naturally in soils through the microbial processes of nitrification and denitrification. Agricultural activities add nitrogen to soils, increasing the amount of N_2O released in the atmosphere. Anthropogenic N_2O emissions from agriculture are produced either directly from nitrogen inputs to soils or indirectly, after the removal of nitrogen from soils. The N_2O emissions sources examined are the following:

✤   Pasture, range and paddock (animal production)

✤   Direct N_2O emissions

✤   Indirect N_2O emissions

Emissions from animal manure deposited to soils during pasture, range and paddock accounted for 29.91% of total GHG emissions from *Agriculture* and for 2.56% of total national emissions (without *LULUCF*) in 2007. Emissions decreased in 2007 by 19.32% compared to 1990 levels, with an average annual rate of decrease of 1.14% for the period 1990 – 2007. Direct N_2O emissions from agricultural soils in 2007 accounted for 12.85% of total GHG emissions from *Agriculture* and for 1.10% of total national emissions (without *LULUCF*). Direct emissions in 2007 decreased by 36.72% compared to 1990 levels, with an average annual rate of decrease of 2.16% for the period 1990 - 2007. Finally, indirect N_2O emissions in 2007 accounted for 23.13% of total GHG emissions from agriculture and for 1.98% of total national emissions (without LULUCF). Indirect emissions in 2007 decreased by 13.08% compared to 1990 levels, with an average annual rate of decrease estimated at 0.77% for the period 1990 – 2007. Emissions from agricultural soils for the period 1990 – 2007 are presented in ***Table 6.14***.

Table 6.14   *N_2O emissions (in kt) from agricultural soils for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Animal production	10.91	10.88	10.89	10.93	11.01	11.10	11.16	11.20	11.23	11.26	11.30
Direct emissions	8.84	8.66	8.27	6.79	6.43	6.93	7.06	6.79	6.76	6.51	6.12
Indirect emissions	11.58	11.34	11.10	10.00	9.76	10.20	10.32	10.13	10.16	9.98	9.69

Year	2001	2002	2003	2004	2005	2006	2007
Animal production	11.33	11.31	11.20	11.07	10.96	10.91	10.90
Direct emissions	5.96	5.82	5.69	5.87	5.34	5.05	4.68
Indirect emissions	9.57	9.46	9.33	9.37	8.91	8.70	8.43

The reduction of N_2O 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 – 2007.

6.5.1   Methodology

Animal production

The estimation of N_2O emissions from pasture, range and paddock was based on the methodology used for the calculation of N_2O from manure management, using the default factors suggested by IPCC Guidelines (see Paragraph 6.3). Nitrogen input from pasture, range and paddock and N_2O emissions for the period 1990 – 2007 are presented in **Table 6.15**.

Table 6.15   *Nitrogen input (in kt) and N_2O emissions (in kt) from pasture, range and paddock, for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	347.27	346.25	346.36	347.68	350.18	353.06	355.15	356.35	357.20	358.25	359.54
N_2O emissions	10.91	10.88	10.89	10.93	11.01	11.10	11.16	11.20	11.23	11.26	11.30
Year	2001	2002	2003	2004	2005	2006	2007				
N input	360.48	359.81	356.46	352.10	348.72	347.13	346.84				
N_2O emissions	11.33	11.31	11.20	11.07	10.96	10.91	10.90				

Direct N_2O emissions from agricultural soils

Direct N_2O 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

For the estimation of N_2O 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 volatised in ammonia and nitrogen oxides, the relevant conversion factor suggested by IPCC was used (IPCC 1997, Table 4-19). The amount of synthetic nitrogen applied to soils and the subsequent N_2O emissions for the period 1990 – 2007 are presented in **Table 6.16**.

Table 6.16   *Synthetic nitrogen applied (in kt) and N_2O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2007*

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_2O 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				
N input	234.00	227.70	222.30	229.50	201.60	189.00	171.00				
N_2O emissions	4.60	4.47	4.37	4.51	3.96	3.71	3.36				

The basic methodology was also applied for the estimation of N_2O 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 volatises 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 6.17** nitrogen input to soils from animal manure and subsequent N_2O emissions are presented, for the period 1990 – 2007.

Table 6.17   *Nitrogen input to soils from animal manure (in kt) and N_2O emissions (in kt) from animal manure used as fertilizers, for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	39.49	38.76	38.40	38.24	38.11	37.94	37.87	37.90	38.08	38.30	38.29
N_2O emissions	0.78	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.75	0.75	0.75
Year	2001	2002	2003	2004	2005	2006	2007				
N input	38.37	38.25	38.17	38.11	38.07	38.27	38.22				
N_2O emissions	0.75	0.75	0.75	0.75	0.75	0.75	0.75				

For the estimation of N_2O 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 significamnt 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.

N_2O emissions from N-fixing crops and crop residues for the period 1990 – 2007 are presented in **Table 6.18**.

Table 6.18   *N_2O emissions (in kt) from N-fixing crops and crop residues, for the period 1990 – 2007*

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
N-fixing crops	0.021	0.021	0.020	0.019	0.019	0.019	0.020
Crop residues	0.506	0.493	0.474	0.512	0.525	0.485	0.470

Estimation of N_2O emissions from the organic soils (0.084 kt) was based on the cultivated area (6.7 kHa. constant for the entire period examined) 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 N_2O emissions from agricultural soils

Indirect N_2O emissions from agricultural soils derive from:

↳   Volatilisation of nitrogen included in synthetic fertilizers and animal manure (used as fertilizers) as NO_x and NH_3, followed by atmospheric deposition as NO_x, HNO_3 and NH_4 on soils and surface waters and subsequent N_2O formation.

✍   Leaching and runoff of nitrogen contained in applied fertilizers (synthetic and animal manure).

For both sources of N_2O emissions, the Tier 1a methodology suggested by IPCC Good Practice Guidance has been applied. The activity data on the amount of nitrogen from synthetic fertilizers and animal manure are those used for the calculation of direct emissions. The emission factors used are the default ones suggested by IPCC (IPCC 1997, Table 4-23). The emission factor for atmospheric deposition reflects the fraction of nitrogen that volatiles as ammonia and nitrous oxides, while for leaching and runoff it reflects the fraction of nitrogen that leaks from synthetic fertilizers and animal manure. The amount of nitrogen deposited and the indirect N_2O emissions for the period 1990 – 2007 are presented in **Table 6.19**.

Table 6.19   *Deposited nitrogen (in kt) and indirect N_2O emissions (in kt) from agricultural soils, for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atmospheric deposition											
N deposited	121.73	119.74	117.87	109.80	108.16	111.70	112.80	111.45	111.76	110.52	108.48
N_2O emissions	1.91	1.88	1.85	1.73	1.70	1.76	1.77	1.75	1.76	1.74	1.70
Leaching/ Runoff											
N deposited	246.19	240.81	235.31	210.75	205.14	214.95	217.65	213.22	213.84	209.74	203.22
N_2O emissions	9.67	9.46	9.24	8.28	8.06	8.44	8.55	8.38	8.40	8.24	7.98
Year	2001	2002	2003	2004	2005	2006	2007				
Atmospheric deposition											
N deposited	107.69	106.82	105.54	105.45	101.66	99.99	97.92				
N_2O emissions	1.69	1.68	1.66	1.66	1.60	1.57	1.54				
Leaching/ Runoff	200.53	198.19	195.35	196.42	186.09	181.49	175.39				
N deposited	7.88	7.79	7.67	7.72	7.31	7.13	6.89				

6.5.2   Recalculations

N_2O emissions from agricultural soils have been recalculated because of the availability of updated activity data concerning the population of the animals for the period 1999-2006, synthetic

fertilizers for the period 1990-2006 and the agricultural production per crop for 2006. 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 6.20.

Table 6.20   *Recalculations of N$_2$O emissions from agricultural soils*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	-0.345	-0.040	-0.307	-2.297	-6.409	0.110	-1.815	0.000	1.796	0.214	-1.787
Impact on total emissions (excl LULUCF)	-0.032	-0.004	-0.027	-0.191	-0.533	0.009	-0.144	0.000	0.125	0.015	-0.120

Year	2001	2002	2003	2004	2005	2006
Animal production	-0.183	-0.425	-1.008	0.133	-2.029	-3.248
Indirect emissions	-0.012	-0.028	-0.063	0.008	-0.123	-0.200

6.6   Field burning of agricultural residues

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 CH$_4$, N$_2$O, CO and NO$_x$.

CH$_4$ and N$_2$O emissions from field burning of agricultural residues in 2007 accounted for 0.33% of total GHG emissions from *Agriculture* and for 0.028% of total national emissions (without *LULUCF*). Emissions in 2007 increased by 0.51% compared to 1990 levels with an average annual rate of increase estimated at 0.03%. CH$_4$ and N$_2$O emissions from field burning of agricultural residues for the period 1990 – 2007 are presented in *Table 6.21*.

Table 6.21   *GHG emissions (in kt) from field burning of agricultural residues, for the period 1990 – 2007*

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
CH$_4$ emissions	1.42	1.38	1.27	1.42	1.43	1.32	1.28
N$_2$O emissions	0.04	0.03	0.03	0.04	0.04	0.03	0.03

Methodology

For the estimation of CH_4 and N_2O 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).

Recalculations

CH_4 and N_2O emissions from field burning of agricultural residues have been recalculated because of the availability of updated activity data concerning the agricultural production per crop for 2006. The difference (in %) between the present and previous submission estimates is 0.05% for CH_4 emissions and 0.07% N_2O emissions respectively, while the impact on total emissions is 10^{-5} (excl. LULUCF) for CH_4 emissions and $6 \cdot 10^{-6}$ (excl. LULUCF) for N_2O emissions.

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 introduces new categories for estimating and reporting emissions and removals of CO_2 and other greenhouse gases, based on six top-level land-use[13] categories:

↳   Forest land

↳   Cropland

↳   Grassland

↳   Wetlands

↳   Settlements

↳   Other land

Carbon stock changes in five carbon pools (Aboveground Biomass, Belowground Biomass, Dead Wood, Litter and Soil Organic Matter) and emissions of non-CO_2 gases from these land-use categories have been 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.

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 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.

7.1.1   Emissions/Removals trends

The *Land Use, Land Use Change and Forestry* sector is a net sink of greenhouse gases during the period 1990 – 2007. The magnitude of this sink increased from approximately 3.19 Mt CO_2 eq in 1990, to 3.65 Mt CO_2 eq in 2007 (***Figure 7.1***), i.e. an increase of 14%.

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[13] 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.

GHG removals from the *LULUCF* sector are characterized by large fluctuations, reaching a minimum value of 2.45 Mt CO_2 eq in 2000 and a maximum value of 5.27 Mt CO_2 eq in 2002, that are mainly attributed to fluctuation in areas of Forest Land burnt by wildfires each year.
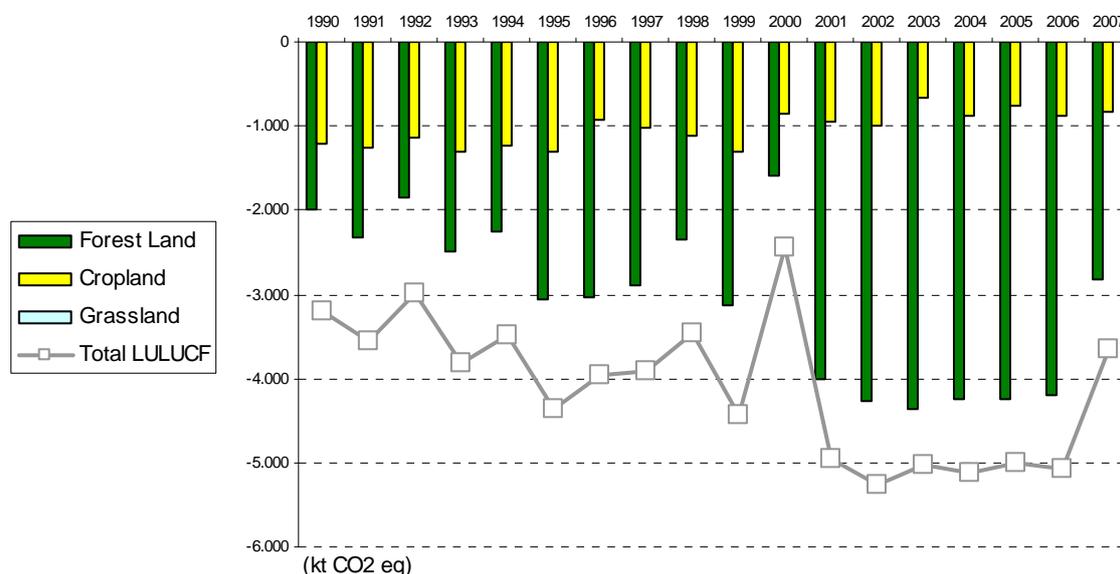
Figure 7.1   *Net GHG emissions / removals (in kt CO_2 eq) from the Land Use. Land Use Change and Forestry sector by category (bars) and total (line) for the period 1990 – 2007*

CO_2 is the main greenhouse gas emitted and removed to / from the atmosphere following carbon stocks changes in different carbon pools. Non-CO_2 greenhouse gases (CH_4 and N_2O) 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 – 2007. 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, the afforestation programmes started in 1994 and to a lesser degree to the smaller area burnt by wildfires the last years, with the exception of years 2000 and 2007 which were disastrous for Greece as concerns wildfires (for that reason a decrease of net GHG removals is observed for these years compared to other years).

Removals from Cropland, caused by changes in management practices and crop type, fluctuates between 0.69 - 1.3 Mt CO_2 eq yr^{-1}. Grassland category appears as a small source of CH_4 and N_2O due to emissions during wildfires. Emissions / removals per gas and category from this sector are presented in *Table 7.1*.

Table 7.1   *GHG emissions / removals (in kt CO$_2$ eq) from the Land Use Change and Forestry sector by category and gas for the period 1990 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Net CO$_2$ emissions / removals																		
A. Forest land	-2042.79	-2344.80	-1928.95	-2568.79	-2323.52	-3091.47	-3056.80	-2931.93	-2487.01	-3139.82	-1772.33	-4037.95	-4272.12	-4361.03	-4265.66	-4250.35	-4224.98	-2975.39
B. Cropland	-1205.41	-1251.23	-1146.04	-1310.96	-1229.90	-1315.50	-936.42	-1025.06	-1103.81	-1296.61	-863.76	-945.94	-1005.91	-668.05	-874.38	-751.07	-867.98	-832.57
C. Grassland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
CH$_4$ emissions																		
A. Forest land	48.08	23.51	71.83	64.09	56.52	33.68	18.89	38.63	117.77	8.81	159.01	20.83	2.97	3.90	10.77	6.93	16.56	134.94
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
C. Grassland	1.80	1.97	3.57	2.26	5.73	1.07	2.86	8.01	7.33	0.90	7.10	2.04	0.24	0.58	0.57	0.00	0.18	7.76
N$_2$O emissions																		
A. Forest land	4.88	2.39	7.29	6.50	5.74	3.42	1.92	3.92	11.95	0.89	16.14	2.11	0.30	0.40	1.09	0.70	1.68	13.69
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
C. Grassland	0.18	0.20	0.36	0.23	0.58	0.11	0.29	0.81	0.74	0.09	0.72	0.21	0.02	0.06	5.02	0.03	0.02	0.79
TOTAL LULUCF	**-3193.27**	**-3567.97**	**-2991.93**	**-3806.66**	**-3484.86**	**-4368.69**	**-3969.27**	**-3905.62**	**-3453.02**	**-4425.74**	**-2453.13**	**-4958.70**	**-5274.51**	**-5024.15**	**-5122.58**	**-4993.74**	**-5074.53**	**-3650.78**

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

7.1.2   Methodology

The calculation 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 Rural Development and Food 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_2O	
	Method	Emission factor	Method	Emission factor	Method	Emission factor
A. Forest Land						
A1. Forest Land remaining Forest Land	D. CS. T2. T1	CS. D	T1	D	T1	D
Living Biomass	D. T2. CS	CS. D	T1	D	T1	D
Dead Organic Matter	T1. T2	CS. D	T1	D	T1	D
Soils	T1					
A2. Land converted to Forest Land	T1. T2	D	T1	D	T1	D
B. Cropland						
B1. Cropland remaining Cropland	T2. T1	CS. D				
Living Biomass	T2	CS				
Soils	T1	D				
C. Grassland						
C1. Grassland remaining Grassland	NA	NA	T1	D	T1	D
C2. Land converted to Grassland	NA	NA	T1	D	T1	D

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

CS: Country specific methodology and emission factor

D: IPCC default methodology and emission factor

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).

Each of these key categories comprises several subcategories the significance of which has been evaluated according to the GPG LULUCF. The Living Biomass subcategory was identified as key subcategory in all three categories.

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 activities 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_2O
A. Forest Land			
1. Forest Land remaining Forest Land	☒	☒	☒
2. Land converted to Forest Land	☒	☒	☒
B. Cropland			
1. Cropland remaining Cropland	☒	NO	NO
2. Land converted to Cropland	NO	NO	NO
C. Grassland			
1. Grassland remaining Grassland	☒	☒	☒
2. Land converted to Grassland	☒	☒	☒
D. Wetlands			
1. Wetlands remaining Wetlands [1]			
2. Land converted to Wetlands	NE	NE	NE
E. Settlements			
1. Settlements remaining Settlements [1]			
2. Land converted to Settlements	NE	NE	NE
F. Other Land			
1. Other Land remaining Other Land [1]			
2. Land converted to Other Land [3]			

NO: Not Occurring

NE: Not Estimated

[1] Parties do not have to prepare estimates for these categories

7.1.4   Representation of land areas

The information used for land representation of Greece was the following:

✥   the first National Forest Inventory (1st NFI) prepared by the General Secretariat of Forests and Natural Environment (GSFNE, 1992, 1994) of the Ministry of Rural Development and Food

✥   the "Agricultural Statistics of Greece" of the National Statistical Service of Greece (NSSG, annual census)

✥   the afforestation registry and statistics of the Greek Ministry of Rural Development and Food

✥   the "Distribution of the Country's Area by Basic Categories of Land Use" of the National Statistical Service of Greece (NSSG, decennial survey)

The various forms of land uses in 2000 are presented in *Figure 7.2*.
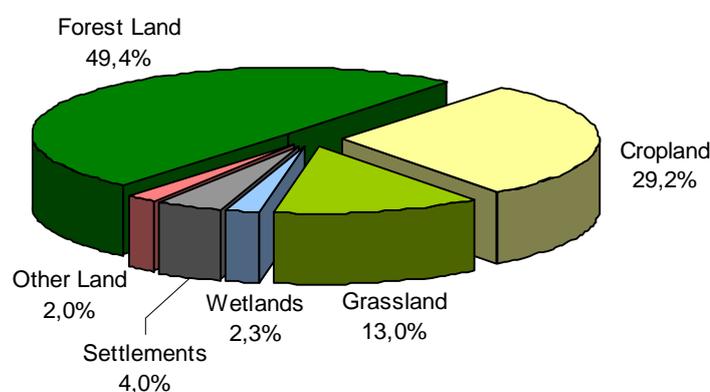
Figure 7.2   Distribution of the area of Greece in 2000 by land-use category

In Greece, there is no advance system for the monitoring of land uses convenient for the implementation of LULUCF inventory by following an approach 2 or 3. Therefore, for the accounting of the areas and their change a mix of Approach 1 and 2 was used, by combining data from the above-mentioned sources. However, in order to construct the land use matrix, given that a second national forest inventory has never been implemented, supplementary data to 1st NSI were used (e.g. croplands converted to forest land by afforestation) and some assumptions were made according to available data. In *Table 7.5* the information and assumptions used for the construction of land use matrix are presented.

Table 7.5   *Information for the Construction of Land Use Matrix.*

Inventory year (year X)	Previous year (year X-1)	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land
Forest land		X(1)	X(2)	NE	NO	NO	NO
Cropland		NO	X(3)	NO	NO	NO	NO
Grassland		NE	X(4)	X(5)	NO	NO	NO
Wetlands		NE	NE	NE	X(6)	NE	NE
Settlements		NE	NE	NE	NO	X(7)	NE
Other land		NE	NO	NE	NO	NO	X(8)

X(i): reported areas
NE: Not Estimated
NO: Not Occuring

The area values and notation keys of land use matrix are based on the following arguments and assumptions:

1. The table's cells highlighted with light green color are activities that should also be reported under article 3.3 and 3.4 of KP. A system for reporting emissions/removals under the article 3.3 and 3.4 of KP is being developed by Ministry of Rural Development and Food (to be available before 2010). Thus, the activity data of these activities will be significantly improved.

2. The area of forest land remaining forest land is assumed to have the same value as the one calculated in 1st NFI, the total value of which is **X(1) = 6,513.068 kha**. More disaggregated area data per forest type are included in the following chapters and working files.

3. The croplands that have been abandoned and converted naturally to forests are not determined. The areas of croplands that converted to forest lands since 1994 under the EEC Regulations 2080/92 and 1257/99 are recorded and used in the inventory. **X(2) = 50.136.420 ha**.

4. The grassland areas, where the grazing intensity was reduced and converted naturally to forest, are not estimated, since no data are available.

5. Cropland areas that have been abandoned are assumed that they converted to grassland. These areas are estimated by the difference of the total cropland area between the inventory year and 20 years earlier (data obtained from NSSG). **X(4) = 180.46 kha.**

6. There is no convenient system for the recording of forest areas that are deforested. However, as above-mentioned, it is expected that such a system will be developed by Ministry of Rural Development and Food before 2010, in order to cover the needs of Greece for the reporting under the article 3.3 and 3.4 of KP. Thus, areas of forest land converted to Grassland, Wetlands, Settlements and other land are reported in land use

matrix as NE. Since, in Greece is not a practice to convert forest areas to cropland, forest land converted to cropland in land use matrix is reported as NO.

7. Croplands areas remaining cropland were estimated by using data from NSSG. Thus, **X(3) = 3720.7 kha**. More disaggregated area data per forest type are included in the following chapters and working files.

8. **X(5)=1,636.172 kha, X(6)=299.60kha, X(7)=530.32kha and X(8)=265.28kha** (data obtained from NSSG "Distribution of the Country's Area by Basic Categories of Land Use").

9. Areas that converted to wetlands or settlements have not been estimated (NE), due to lack of data.

10. The rest cases of land use change are reported as NO, since it is assumed that even if these activities exist their extent will be negligible.

11. The sum of X(i), where I =1 to 8 is the total area of Greece, which is 13,195.74 kha according to the "Distribution of the Country's Area by Basic Categories of Land Use" of the National Statistical Service of Greece (1995).

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 7.6* is the land-use matrix of year 2007.

Table 7.6 **Land-Use Matrix of Year 2007(land in kHa).**

Inventory year (2007) / Previous Year (2006)	Forest land (FL)	Land converted to FL	Cropland (CL)	Land converted to CL	Grassland (GL)	Land converted to GL	Wetlands (WL)	Land converted to WL	Settlements (S)	Land converted to S	Other land (OL)	Land converted to OL	Total area in 2007
Forest land (FL)	6513.07												6513.07
Land converted to FL		47.87	2.27										50.14
Cropland (CL)			3720.70										3720.70
Land converted to CL													0.00
Grassland (GL)					1636.17								1636.17
Land converted to GL			37.18			143.29							180.46
Wetlands (WL)							299.60						299.60
Land converted to WL													0.00
Settlements (S)									530.32				530.32
Land converted to S													0.00
Other land (OL)											265.28		265.28
Land converted to OL													0.00
Total area in 2006	6513.07	47.87	3760.15	0.00	1636.17	143.29	299.60	0.00	530.32	0.00	265.28	0.00	13195.74 13195.74
Net change	0.00	2.27	-39.45	0.00	0.00	37.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.2 Forest land

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-CO_2 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 – 2007 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). Carbon stocks decrease occurred in the biomass pool by wildfires (in form of CO_2 and CH_4 during burning, and as CO_2 from subsequent decomposition of dead wood) and by fellings (commercial roundwood fellings and fuelwood gathering). Additionally, non-CO_2 greenhouse gases released to the atmosphere during biomass burning. Estimates of emissions / removals in this category are presented in **Table 7.7**.

The sink capacity of Forest Land has increased from 1990 kt CO_2 eq in 2043 to 2975 kt CO_2 eq in 2007, i.e. an increase of about 46%. This rising trend is attributed mainly to the reduction in fellings observed since 1990 (by 50%), and to a lesser degree to the augmented biomass increment, and the afforestation programmes started in 1994 (**Figure 7.3**). A main feature of this category is the large variation in net emissions / removals between years, which is attributed to the variation in areas burnt every year. It is characteristic that in 2000 wildfires burnt 45 times larger area of Forest land than in 2002, when the larger and smaller area burnt during the last forty years was recorded.
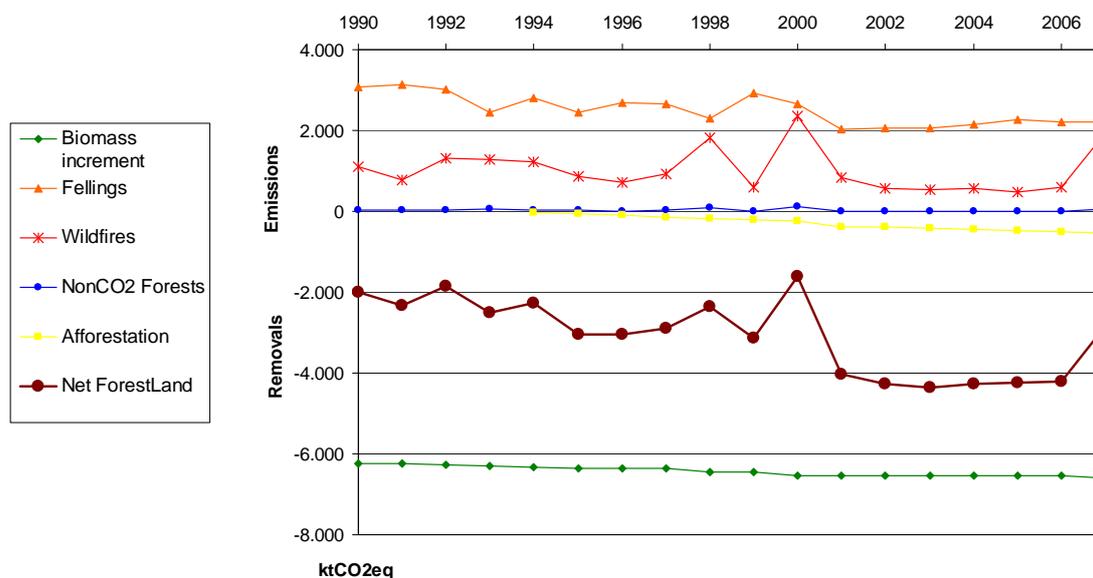
Figure 7.3   Emissions / removals of GHG (in CO2 eq) from different activities (lines) and
net removals from the Forest Land category (bars)

Table 7.7   Net GHG emissions / removals (kt CO$_2$ eq) from Forest Land by subcategory for the period 1990 - 2007

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Forest land remaining forest land	**-2042.79**	**-2344.80**	**-1928.95**	**-2568.79**	**-2298.45**	**-3032.99**	**-2966.99**	**-2779.47**	**-2315.74**	**-2926.79**	**-1534.47**	**-3663.68**	**-3873.82**	**-3936.26**	**-3815.82**	**-3774.28**	**-3725.11**	**-2451.82**
Biomass	-2100.25	-2628.80	-1809.82	-2503.69	-2336.52	-3187.71	-3299.96	-2859.17	-1548.85	-3335.98	-467.29	-4079.47	-4397.72	-4389.64	-4167.21	-4118.76	-3962.00	-1811.16
Dead organic matter	57.46	284.00	-119.13	-65.10	38.06	154.72	332.97	79.70	-766.90	409.20	-1067.18	415.79	523.90	453.38	351.39	344.48	236.89	-640.66
Soils	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
Land converted to forest land	**0.00**	**0.00**	**0.00**	**0.00**	**-25.06**	**-58.48**	**-89.81**	**-152.47**	**-171.26**	**-213.03**	**-237.86**	**-374.27**	**-398.31**	**-424.77**	**-449.84**	**-476.07**	**-499.86**	**-523.57**
Biomass	0.00	0.00	0.00	0.00	-25.06	-58.48	-89.81	-152.47	-171.26	-213.03	-237.86	-374.27	-398.31	-424.77	-449.84	-476.07	-499.86	-523.57
Dead organic matter	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
Soils	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
Total	**-2042.79**	**-2344.80**	**-1928.95**	**-2568.79**	**-2323.52**	**-3091.47**	**-3056.80**	**-2931.93**	**-2487.01**	**-3139.82**	**-1772.33**	**-4037.95**	**-4272.12**	**-4361.03**	**-4265.66**	**-4250.35**	**-4224.98**	**-2975.39**

IE: Included Elsewhere

7.2.2   Methodology

The definition of forest land used in this inventory is the definition used in the 1st National Forest Inventory (GSFNE 1992):

✤ **Forest Land** includes: (a) areas larger than 0.5 ha or strips more than 30 m wide with tree crown cover (stand density) of more than 10% of the area, or areas with 250 trees of reproductive age per hectare, able to produce wood or other products or services and are not used for any other land-use (b) areas where trees are removed to below 10% of stand density and are not given for other land-use (c) reforested areas and (d) scrublands (areas covered by broadleaved evergreens).

✤ Forest Land is divided into Forests and Other Wooded Lands: **Forests** are characterised by forest trees (high and coppice forests) that produce or are able to produce at least 1 m^3 of commercial timber per hectare per year. **Other Wooded Lands** are characterised by branchy dwarf trees and scrubs (usually broadleaved evergreens), do not currently produce commercial timber and are valuable mainly for providing protection, forage and fuelwood.

According to the GPG LULUCF definition, all forest lands of the country are considered as managed and therefore carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass and soil organic carbon on these lands are estimated and reported.

Forest plantations – mainly consisted of poplar trees - account for a small area of about 10 000 ha and are considered as Cropland. According to the methodology used in the Cropland category, when no changes in the species or management practices take place it was assumed that carbon uptake from biomass increment is offset by carbon losses during fellings, and consequently no changes in carbon stocks are estimated.

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-CO_2 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 default method described in the IPCC Guidelines (Method 1 of GPG LULUCF) and relies on the carbon flux approach, since information from one NFI only is available. This is Tier 2 approach with a country specific approach to deal with carbon emissions / removals caused by wildfires.

$$\Delta C_{FF_{LB}} = \Delta C_{FF_G} - \Delta C_{FF_L}$$

where, ΔC_{FF_G} is the annual increase in carbon stocks due to biomass growth, t C yr^{-1} and ΔC_{FF_L} is the annual decrease in carbon stocks due to biomass loss, t C yr^{-1}.

The annual increase in carbon stocks due to biomass growth is the sum of the annual increase due to biomass increment in areas not affected by wildfires for the last 35 years and the biomass increment due to regrowth of vegetation on areas affected by wildfires.

$$\Delta C_{FF_G} = [\ \sum_i (A_i \bullet G_{TOTAL_i}) \bullet CF\ ] + \Delta C_{FF_{GR}}$$

where, A_i is the area of forest land remaining forest land, by forest type ($i = 1$ to 6), 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.)$^{-1}$ and $\Delta C_{FF_{GR}}$ is the annual increase in carbon stocks due to regrowth of vegetation on areas affected by wildfires, by forest type, t C yr^{-1}.

Data on the area of forest land remaining forest land (A_i) were obtained from the 1st NFI disaggregated by forest type in six broad categories. 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:

$$G_{TOTAL} = G_W \bullet (1 + R)$$

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):

$$G_W = I_V \bullet D \bullet BEF_1$$

where, I_V is the average net annual increment in volume suitable for industrial processing, m^3 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.

Data for the average net annual increment in volume suitable for industrial processing for the six forest types were obtained from the 1st NFI, while appropriate IPCC default factors for root/shoot ratio, wood density and biomass expansion factor were selected from tables 3A.1.8, 3A.1.9-1 and 3A.1.10 of LULUCF GPG respectively. Activity data and emission factors used are presented in *Table 7.8.* It is noticed that, with exception of the *Picea abies* forest type which constitute a minor fraction of Forest Land, the average net annual increment of Greek forest is low compared with the

equivalent of other European countries. This is due to the low density, quality and quantity of growing stock, a result of human induced activities of the past as wildfires, grazing, illegal felling, as well as the lack of systematic silvicultural treatment.

Table 7.8   *Activity data and emission factors used to estimate the annual increase in carbon stocks due to biomass increment*

Forest type	A (kha)	Iv ($m^3\ ha^{-1}\ yr^{-1}$)	D (t d.m. m^{-3})	BEF_1	R
Abies sp.	543.31	1.47	0.40	1.15	0.46
Picea abies	2.75	10.69	0.40	1.15	0.23
Pinus sp. & other Conifers	883.55	1.23	0.42	1.05	0.46
Fagus sp.	336.64	2.77	0.58	1.20	0.43
Quercus sp.	1.471.84	0.47	0.58	1.20	0.35
Other Deciduous	121.10	2.21	0.55	1.20	0.43

The methodology and assumptions used to estimate the annual increase in carbon stocks due to regrowth of vegetation on areas affected by wildfires ($\Delta C_{FF_{GR}}$) are presented at the end of this section, since they depend upon estimates of carbon stocks before the disturbance

The annual carbon loss in living biomass was estimated as the sum of losses due to commercial roundwood fellings, fuelwood gathering and wildfires. Wildfires constitute the most significant disturbance to Greek forests. Other disturbances (e.g. windstorms, pest and disease outbreaks) occur rarely and are of low magnitude, because of the structure and the natural character of them (GSFNE, 2000). Hence, carbon losses from other disturbances were assumed to be negligible. Prescribed fires take place in a very small scale only for fuel load management and their effects are discussed in the next section under changes in carbon stock in the dead organic matter pool. Illegal fellings, which mainly consist of illegal fuelwood gathering, have been determined to be less than 1% of the legal ones (data from the Ministry of Rural Development and Food). The annual carbon loss in living biomass was estimated as:

$$\Delta C_{FF_L} = L_{F+FG} + L_{Wildfires}$$

where, ΔC_{FF_L} is the annual decrease in carbon stocks due to biomass loss in forest land remaining forest land, t C yr^{-1}, L_{F+FG} is the annual carbon loss due to commercial fellings and fuelwood gathering, t C yr^{-1} and $L_{Wildfires}$ is the annual carbon losses due to wildfires, t C yr^{-1}.

The equation used to estimate annual carbon losses due to commercial fellings and fuelwood gathering is:

$$L_{F+FG} = \sum_{t=1}^{7} (H_i\ /\ UB + FG_i) \bullet D_i \bullet BEF_{2\,i} \bullet CF$$

where, H_i is the annual volume of commercial fellings, by forest species category (i = 1 to 7), underbark roundwood, $m^3\ yr^{-1}$, UB is the underbark fraction of tree stem, FG_i is the annual volume of fuelwood gathering, by forest species category, overbark roundwood, $m^3\ yr^{-1}$, D_i is the basic wood density, by forest species category, t d.m. m^{-3}, $BEF_{2\,i}$ is the biomass expansion factor for

converting volumes of extracted roundwood to total aboveground biomass (including bark), by forest species category and CF is the carbon fraction of dry matter, t C (t d.m.)$^{-1}$.

For the estimation of carbon losses from commercial harvest and fuelwood gathering the IPCC default assumption, that all carbon in harvested biomass is oxidized in the year of removal, was made, implying that there is not any biomass left to decay in forest (transferred to DOM). Data for the annual volume of commercial fellings and fuelwood gathering were obtained from the statistics of the Ministry of Rural Development and Food (GDPDFNE, 2001), disaggregated by seven species categories, and had been augmented by 1% to encompass illegal fellings. The underbark volume of commercial fellings had to be converted to overbark volume for use with BEF_2 .The IPCC default factor (UB = 0.85) was used for all species categories. 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.

Under this sector only carbon dioxide emissions from fuelwood gathering are presented. However, during off-site fuelwood burning, non-CO_2 trace gases (CH_4, CO, N_2O, NO_x) are released, that, according to IPCC Guidelines, are reported under the Energy sector.

CO_2 emissions from commercial felling and fuelwood gathering varied during the period 1990-2007 between 3132 kt CO_2 in 1991 and 2197 kt CO_2 in 2007. During this period there has been a considerable reduction in total wood harvest that corresponded to a similar reduction in the amount of CO_2 released to the atmosphere. This reduction, that was sharper in fuelwood category than in commercial felling, is due mainly to the substitution of wood as heating source by liquid fuels and electricity.

GPG LULUCF recommends that when methods applied do not capture removals by regrowth after natural disturbances, it is not necessary to report the CO_2 emissions associated with these events. The assumption suggested that removals from regrowth offset emissions from wildfires is realistic, given that area burnt fully recover the biomass lost, if biomass burnt every year – or more properly, every decade, because of the high annual variation of the phenomenon - remains constant. This is because emissions of CO_2 in wildfires are not synchronous with the rate of uptake by regrowing vegetation. It may take 10 to 100 or more years to sequester the quantity of carbon released in a wildfire, depending on the type of the ecosystem.

Greek laws prohibit the land use change of forest land. Forest land burnt by wildfires is proclaimed to be under reforestation and the change of its forest character is prohibited. The majority of forest land burned recovers naturally, while in areas where natural regeneration is not sufficient (lack of seeds, soil degraded by repeated burning), artificial regeneration activities, supervised by the Forest Service, are carried out. Hence, it was assumed that biomass burnt reaccumulates to the initial extent. However, the average area of forest land burnt annually in 1980s and 1990s had increased approximately four times since 1960s, that means that enhanced carbon lost lately has not been uptaken yet from regrowing vegetation (*Figure 7.4*). This increase in the area burnt resulted in net emissions of greenhouse gases from the phase difference of the two processes discussed above, which has been quantified in this inventory.
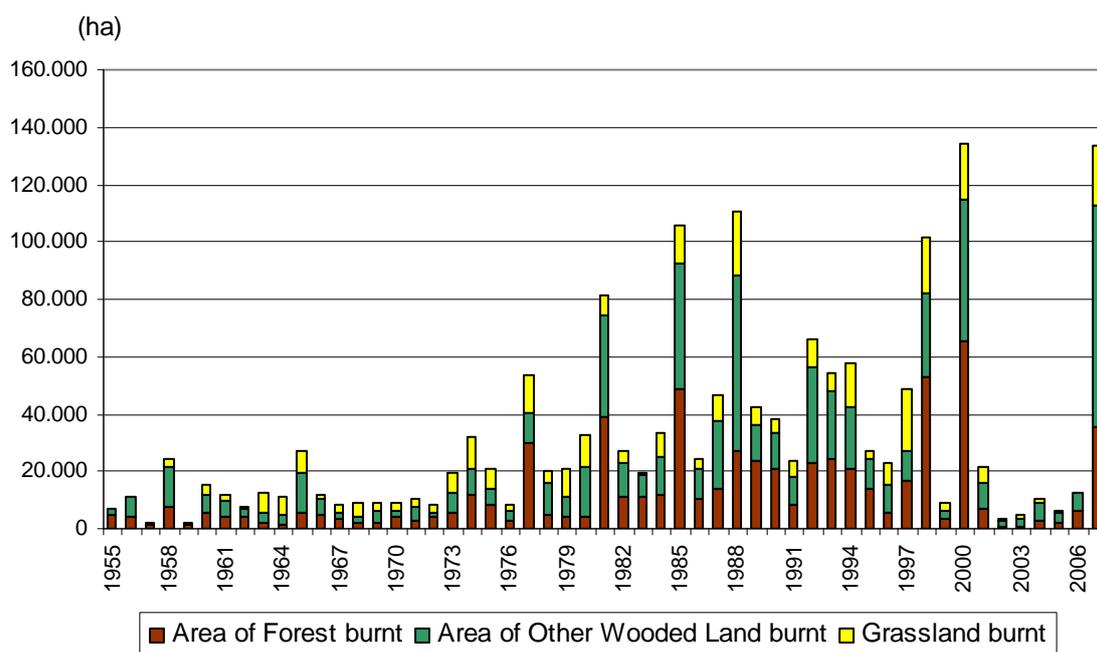
Figure 7.4   Areas of Forest. Other Wooded Land and Grassland burnt since 1955

The annual carbon loss in living biomass from wildfires was estimated as the sum of carbon oxidised directly to the atmosphere and the carbon in biomass left to decay on site (transferred to dead organic matter, Tier 2 approach). It was assumed a complete destruction of forest biomass in area affected, i.e. there was not any biomass left alive in the area.

$$L_{Wildfires} = Lw_{oxid} + Lw_{trans}$$

where, Lw_{oxid} is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere, t C yr^{-1} and Lw_{trans} is the annual decrease in carbon stocks due to biomass transferred to dead organic matter, t C yr^{-1}.

These carbon losses were estimated as:

$$Lw_{oxid} = \sum_t A_{disturbance\,i} \cdot Bw_i \cdot (1 - f_{BL\,i}) \cdot CF \; \text{και}$$

$$Lw_{trans} = \sum_t A_{disturbance\,i} \cdot Bw_i \cdot f_{BL\,i} \cdot CF$$

where, $A_{disturbance\,i}$ 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.)$^{-1}$.

Data on area affected by wildfires since 1955 were obtained from the statistics of the Ministry of Rural Development and Food (GDPDFNE, 2001), disaggregated by two general categories –forests and other wooded lands. 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. 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; $f_{BL} = 0.55$ for forests and $f_{BL} = 0.28$ for other wooded land.

The average biomass stock of each forest type was calculated from the average volume of growing stock given in the 1st NFI and the average biomass stock in the understorey vegetation, with the following equation:

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

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

The average biomass stock of understorey vegetation was acquired from a study reviewing relevant articles and the data of the 1st NFI (Kokkinidis, 1989). Appropriate IPCC default factors for wood density and biomass expansion factor were selected from Tables 3A.1.9-1 and 3A.1.10 of LULUCF GPG respectively.

In order to estimate the annual increase in carbon stocks due to regrowth of vegetation, it was assumed that biomass burnt reaccumulates to the initial extent in an average of 35 years, for all ecosystem types. Consequently, following the assumption that carbon sequestration is linear, the annual increase in carbon stocks due to regrowth of vegetation (ΔC_{FFGR}) is the sum of 1/35th of the annual carbon losses due to wildfires ($L_{Wildfires}$) in each of the last 35 years.

$$\Delta C_{FFGR} = \sum_{i=k-34}^{k} {}_i\,(1/35) \cdot L_{Wildfires\,i}$$

where k is the inventory year.

The regrowth process was simply characterised for emissions estimation purposes. The average value used for the regrowth period (35 yr) is an expert judgement and was limited by the availability of activity data necessary for these calculations (reliable data on area burnt to estimate $L_{Wildfires}$ exist since 1955)

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 not affected by wildfires, 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 practised in Greece.

However, carbon stock changes in dead wood in areas affected by wildfires were considered to be significant, as discussed above, and thus they were estimated here, using a Tier 2 method. The annual change in carbon stock was calculated from the difference of annual transfer of carbon into and out of the pool:

$$\Delta C_{FF_{DW}} = \Delta C_{FF_{DWinto}} - \Delta C_{FF_{Dwout}}$$

where, $\Delta C_{FF_{DW}}$ is the annual change in carbon stocks in dead wood in areas affected by wildfire, t C yr^{-1}, $\Delta C_{FF_{DWinto}}$ is the annual increase in carbon stocks due to biomass transferred into dead wood in areas affected by wildfire, t C yr^{-1} and $\Delta C_{FF_{DWout}}$ is the annual decrease in carbon stocks due to dead wood transferred out of pool in areas affected by wildfire, t C yr^{-1}.

The biomass transferred into the dead wood pool in areas affected by wildfires is the biomass of vegetation killed by fire but not emitted at the same time, and hence, the annual increase in carbon stocks due to biomass transferred into the dead wood pool ($\Delta C_{FF_{DWinto}}$) is equal to the annual decrease in carbon stocks in living biomass due to biomass transferred to dead organic matter (Lw_{trans}) estimated above.

The dead wood that stays on site after fire and decomposes was assumed to oxidise fully in the following 10 years (IPCC Guidelines default factor). Assuming that decomposition during this decade is linear, 1/10th of this amount oxidises to the atmosphere each of the following ten years. Therefore, the carbon released in the Inventory Year is a function of area burnt during the past ten years. The annual decrease in carbon stocks due to dead wood transferred out of pool ($\Delta C_{FF_{DWout}}$) is the sum of 1/10th of the annual increase in carbon stocks due to biomass transferred into the dead wood pool ($\Delta C_{FF_{DWinto}}$) in each of the past ten years:

$$\Delta C_{FF_{DWinto}} = Lw_{trans}$$

$$\Delta C_{FF_{DWout}} = \sum_{i=k-9}^{k} {}_i (1/10) \cdot \Delta C_{FF_{DWinto\ i}}$$

where k is the inventory year.

The net effect of wildfires in the balance of emissions and removals between both the living biomass and dead organic matter, and the atmosphere is presented in *Figure 7.5*.
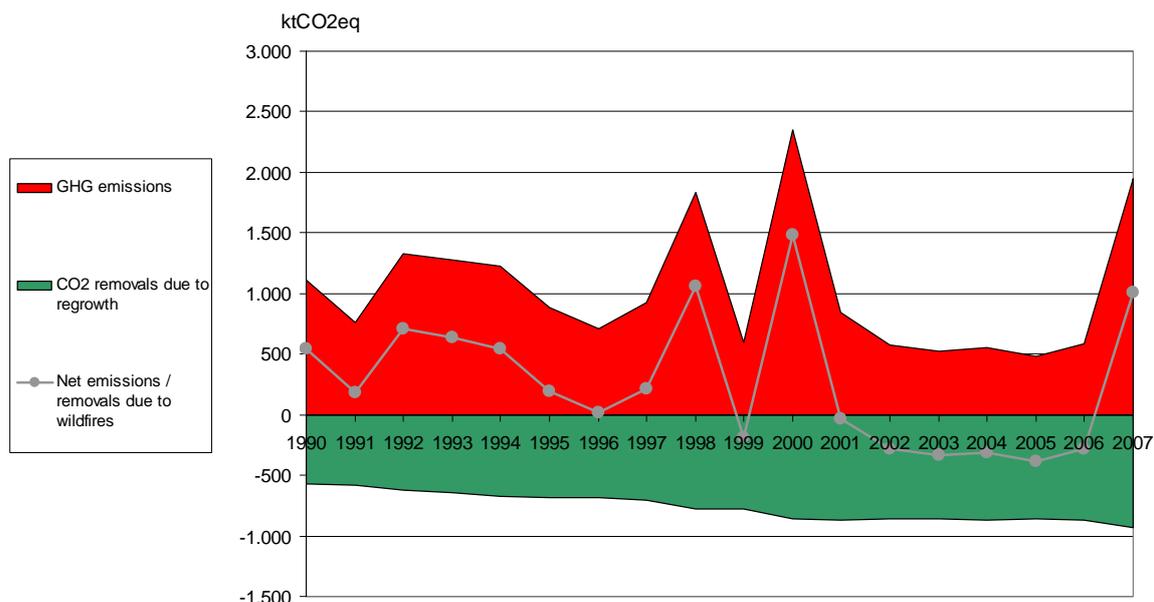
Figure 7.5   *GHG emissions and removals (in CO2 eq) from wildfires (various processes and their net effect)*

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. CO_2 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. Change in the occurrence of wildfires that has been discussed above is expected to have altered the forest soil carbon pool. However, the effect of this change in the disturbance regime on the soil carbon stock has not been well studied and appropriate factors – developed in Greece or suggested by GPG LULUCF - are not available in order to proceed to Tier 2 and estimate the relevant carbon stock changes.

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.

Non - CO$_2$ greenhouse gas emissions

N$_2$O and NO$_x$ are mainly 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.

According to IPCC Guidelines, CH$_4$ and CO emissions from wildfires were estimated as ratios to carbon released during burning (Lw$_{oxid}$), and N$_2$O 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).

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

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

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

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

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.

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.

$$\Delta C_{LF} = (\Delta C_{LF_{LB}} + \Delta C_{LF_{DOM}} + \Delta C_{LF_{Soils}})$$

where, ΔC_{LF} is the annual change in carbon stocks in land converted to forest land, t C yr^{-1}, $\Delta C_{LF_{LB}}$ 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}, $\Delta C_{LF_{DOM}}$ 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 $\Delta C_{LF_{Soils}}$ 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 a mix of Tier 1 and Tier 2 method:

$$\Delta C_{LF_{LB}} = (\Delta C_{LF_{GROWTH}} + \Delta C_{LF_{CONVERSION}} - \Delta C_{LF_{LOSS}})$$

where, $\Delta C_{LF_{GROWTH}}$ is the annual increase in carbon stocks in living biomass due to biomass growth in land converted to forest, t C yr^{-1}, $\Delta C_{LF_{CONVERSION}}$ is the annual change in carbon stocks in living biomass due to actual conversion to forest land, tC yr^{-1} and $\Delta C_{LF_{LOSS}}$ 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 using the methods set out in Paragraph 7.2.2 Forest Land remaining Forest Land. Data on area afforested were obtained from the statistics of the Ministry of Rural Development and Food (GDPDFNE, 2001), disaggregated by twenty four forest types. 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 ($\Delta C_{LF_{CONVERSION}}$) 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 ($\Delta C_{LF_{LOSS}}$) are caused by commercial fellings, fuelwood gathering and disturbances. In lands afforested since 1994 harvest has not taken place yet, while carbon losses due to wildfires, if any, have been estimated and reported under the 'Forest Land remaining Forest Land' category, since areas of these lands burnt are aggregated in the national statistics. Hence, no decreases in carbon stocks due to biomass loss in land converted to forest land are reported.
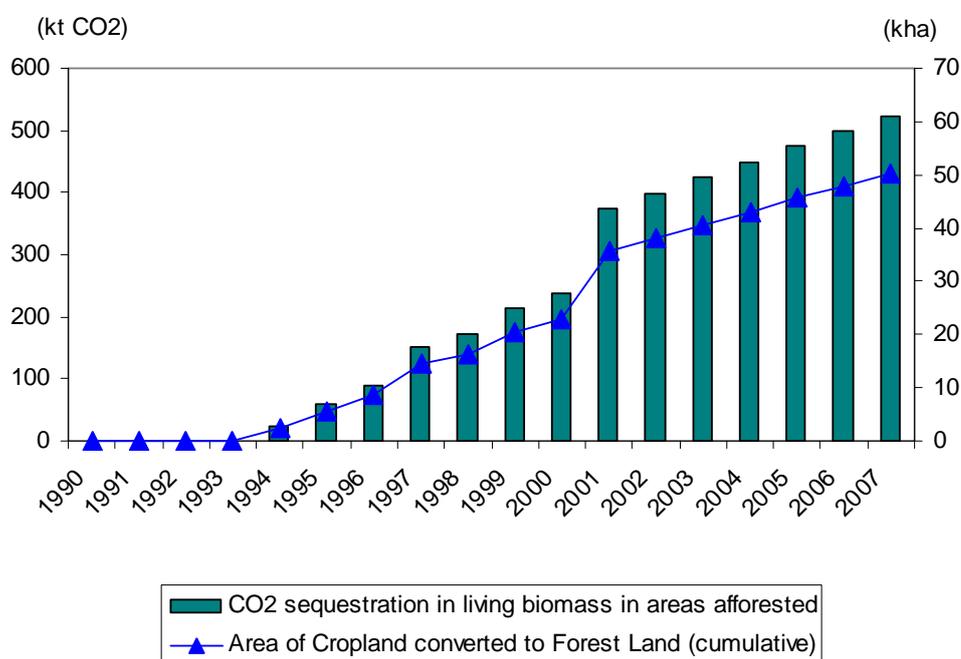
Figure 7.6   Carbon sequestration in living biomass and area of Croplands converted to Forest land during 1990-2007

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:

$$\Delta C_{LF_{Soils}} = \Delta C_{LF_{Mineral}} = [\sum_t (SOC_{REF} - SOC_{Cropland\,i}) \cdot A_{aff\,i}] / T_{aff}$$

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.

Certain amount of N fertiliser is used in afforestations, producing emissions of N_2O. These emissions are reported in the Agriculture sector since there is not available disaggregated activity data on fertiliser applied to these lands from that applied to agriculture.

7.2.3   Recalculations

CH_4 and N_2O emissions from wildfires of Forests and Other Wooden Lands have been recalculated because of the availability of updated - more accurate activity data for years 2004 and 2005, concerning the areas burnt due to wildfires. The change in activity data concerning wildfires influences the carbon stock change in living biomass and dead organic matter of Forest Land, and consequently the CO_2 removals.

Moreover, recalculations of carbon stock change in living biomass were performed for the years 2005 and 2006 due to availability of updated activity data of fellings and fuelwood from Ministry of Rural Development and Food.

The difference (%) between present and previous emission estimations, along with the impact of recalculation on total emissions including LULUCF are presented in **Table 7.9.** As presented in the table. the impact on total emissions is rather low.

Table 7.9 *Recalculations of CO$_2$ removals and CH$_4$ and N$_2$O emissions (%) of Forest Lands for year 2005*

Gas	Difference (%)	Impact on total emissions incl LULUCF (%)
CO$_2$	-5.41	0.19
CH$_4$	-12.52	<0.00%
N$_2$O	-12.52	<0.00%

7.3 Cropland

7.3.1 Category description

The total area of cropland in Greece decreased during the last 20 years, and therefore carbon stock changes were estimated and reported only under the category *Cropland remaining Cropland*. Carbon stock changes in living biomass and soil 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 CH$_4$ and N$_2$O from these lands were estimated as part of *Agriculture* (Chapter 6). The net CO$_2$ emissions / removals from each subcategory are presented in **Table 7.10.**

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 0.75-1.4 Mt CO$_2$ yr^{-1} during the period 1990 – 2007. 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 CO$_2$ per year during the period 1990 – 2007. Cultivation of organic soils resulted in net emissions of 244 kt CO$_2$ yr^{-1} during the same period, and therefore soils accounted for net emissions of 20 kt CO$_2$ yr^{-1}. In previous reports the activity data for the period 2000 – 2006 used were provisional and hence, estimated figures of GHG emissions / removals were provisional as well. In this report updated activity data were used, and thus recalculations were performed for years 2000-2006. However, the activity data for year 2007 were provisional.

Table 7.10 *Net CO$_2$ emissions / removals (kt CO$_2$) from Cropland by subcategory for the period 1990 - 2007*

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cropland	-1205.41	-1251.23	-1146.04	-1310.96	-1229.90	-1315.50	-936.42	-1025.06	-1103.81	-1296.61	182.19	-945.94	-1005.91	-668.05	-874.38	-751.07	-867.98	-832.57
Biomass	-1226.07	-1271.89	-1166.69	-1331.61	-1250.56	-1336.15	-957.08	-1045.72	-1124.47	-1317.26	161.54	-966.60	-1026.57	-688.71	-895.03	-771.72	-888.63	-853.22
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	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	20.65	20.65	20.65	20.65	20.65	20.65	20.65

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

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 7.7*.
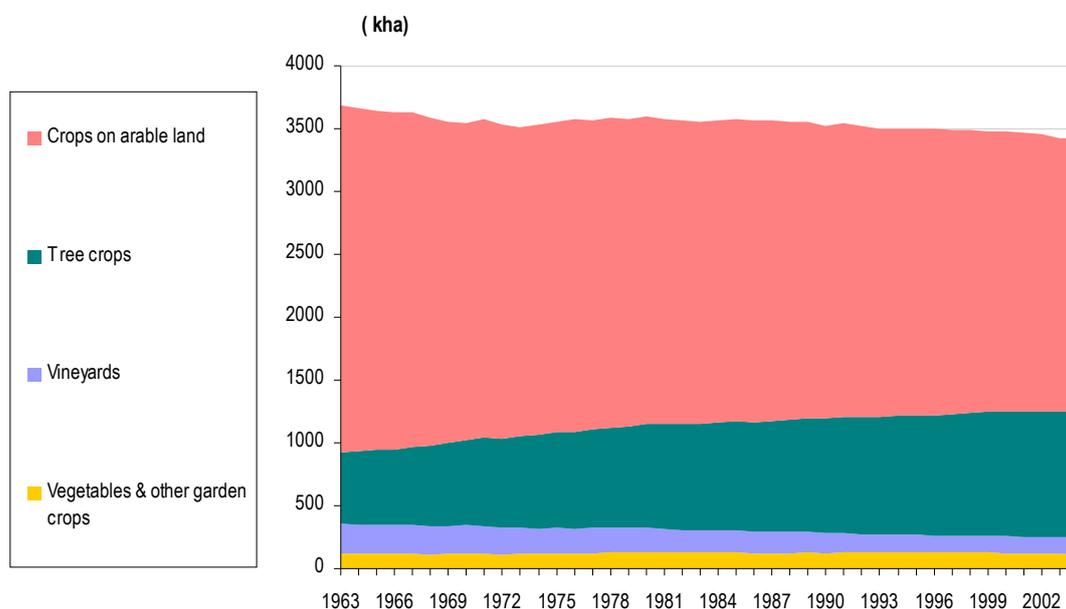
Figure 7.7   *Areas of cropland in Greece since 1963 (fallow land excluded)*

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 of 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 7.8**). 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:

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

where, $A_{planted_{ij}}$ is the area where new plantations were established, by crop type ($i = 17$), ha yr^{-1}, G_{W_i} is the growth rate in new plantations, by crop type, t d.m. ha^{-1} yr^{-1}, CF is the carbon fraction of dry matter, t C (t d.m.)$^{-1}$, k is the inventory year, B_{M_i} is the average biomass stock at maturity, by crop type, d.m. ha^{-1} and λ_i is the average replacement cycle, by crop type, yr.
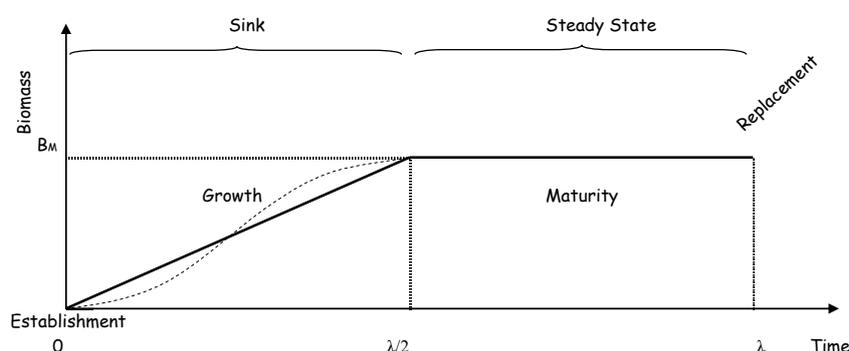
Figure 7.8　　　　*Assumed biomass accumulation in new plantations*

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_{CCL}) was estimate as:

$$\Delta C_{CCL} = \sum_i A_{eradicated_i} \cdot B_{M\,i}$$

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 National Statistical Service of Greece, disaggregated by 17 crop types (16 tree crops and vineyards). Data on the factors B_M and λ for these crops were obtained from the Ministry of Rural Development and Food (Ministry of Agriculture, 1981) and expert judgment and are presented in *Table 7.11*.

Table 7.11   *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. biter 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[14]	71.5	50

Change in carbon stocks in soils

A Tier 1 methodology was used for the estimation of carbon stock changes in soil, with country specific data for areas and IPCC default coefficients. The annual change in carbon stocks in soils in cropland remaining cropland ($\Delta C_{CCSoils}$, tonnes C yr^{-1}) was estimated as the difference in the

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[14] Olive groves constitute the majority of new plantations (approximately 90%) during 1990-2004. 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.

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 CO_2 when applied to soil. These materials are proved to be more efficient, since limestone ($CaCO_3$) has large diameter that result in small / slow dissolubility under the Greek dry conditions. CO_2 is produced in the production of lime and hydrated lime, but these emissions are estimated and reported under the Industrial Processes Sector (Chapter 4).

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:

$$\Delta C_{CC_{Mineral}} = [\; \textstyle\sum_{i}(SOC_0 \cdot A)_{\,i} - \sum_{i}(SOC_{(0-T)} \cdot A)_{\,i} \;] \, / \, T$$

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

where, SOC_0 is the soil organic carbon stock in the inventory year, t C 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, ($i = 13$), 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 7.12.*

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.

Table 7.12   *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

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.

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

where, $\Delta C_{CC_{Organic}}$ represents CO_2 emissions from cultivated organic soils in cropland remaining cropland,, t C yr^{-1}, $A_{Organic}$ is the land area of cultivated organic soils, ha and EF is the emission factor for cultivated organic soils, t C ha^{-1}yr^{-1}.

All cultivated organic soils are found under warm temperate climate, hence one climate type was considered when choosing the emission factor (EF = 10 tonnes C ha^{-1}yr^{-1}, Table 3.3.5, GPG

LULUCF). Area of cultivated organic soils was obtained from a study of the Soil Science Institute of Athens (SSIA, 2001).

7.3.3   Recalculations

As mentioned above, in previous reports the activity data used for the period 2000 – 2006, concerning the perennial woody crops plantation areas, were provisional and hence, estimated figures of GHG emissions / removals were provisional as well. In this report updated activity data were used, and thus recalculations were performed for years 2000-2006. The difference of CO_2 removals between present and previous emission estimations were from -40 to 10%, with an impact on total emissions including LULUCF from -0.07 to 0.4%.

7.4   *Grassland*

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 only Non-CO_2 emissions from wildfires are reported (***Table 7.13***). Changes in soil carbon stock in Cropland converted to Grassland are estimated and reported in the Cropland remaining Cropland category.

Table 7.13   *Emissions / removals of greenhouse gases (in kt CO$_2$ eq) from Grassland for the period 1990 - 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO$_2$	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
CH$_4$	1.80	1.97	3.57	2.26	5.73	1.07	2.86	8.01	7.33	0.90	7.10	2.04	0.24	0.58	0.57	0.34	0.18	7.76
N$_2$O	0.18	0.20	0.36	0.23	0.58	0.11	0.29	0.81	0.74	0.09	0.72	0.21	0.02	0.06	0.06	0.03	0.02	0.79
Total	**1.98**	**2.17**	**3.93**	**2.49**	**6.31**	**1.18**	**3.15**	**8.83**	**8.08**	**0.99**	**7.82**	**2.25**	**0.26**	**0.63**	**0.63**	**0.37**	**0.19**	**8.55**

IE: Included Elsewhere

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 and aboveground grass biomass was only considered for estimating emissions from wildfires.

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, CO_2 released is assumed to be removed by photosynthesis of vegetation regrowing during the subsequent year and therefore only emissions of non-CO_2 gases are reported. For these estimations an average biomass stock was considered ($Bw_{grassland}$ = 2.2 tonnes d.m. ha^{-1}, Kokkinidis, 1989). Data on area of grasslands burnt were obtained from the statistics of the Ministry of Rural Development and Food (GDPDFNE, 2001).

According to Tier 1 approach, 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 $\Delta C_{CC_{Mineral}} = 0$, i.e. the annual change in carbon stocks in mineral soils was zero. Changes in carbon stocks of organic soils are associated with drainage and other management perturbations of these soils. In Greece, areas of organic soils under the grassland classification are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered. CO_2 emissions from liming of grasslands were not considered since liming is not applied on these lands. Non-CO_2 emissions from other sources (e.g. CH_4 emissions from grazing livestock on grassland) were estimated and reported in the *Agriculture* sector (Chapter 6).

Land converted to Grassland

Croplands that have been abandoned and converted to grassland were 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. Croplands on organic soils have not been abandoned. Non-CO_2 emissions from wildfires on Lands converted to Grassland are reported under the category Grassland remaining Grassland.

7.4.1   Recalculations

CH_4 and N_2O emissions from wildfires of Grasslands have been recalculated because of the availability of updated - more accurate activity data for year 2004 and 2005, concerning the area burnt due to wildfires. The difference (%) between present and previous emission estimations, along with the impact of recalculation on total emissions including LULUCF were rather low.

7.5   Wetlands – Settlements – Other land

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 N_2O and CH_4 emissions associated with organic soils managed for peat extraction and flooded lands in the category Land converted to Wetlands have to be reported[15]. 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 biomass decomposition in these areas. This loss has not been estimated due to lack of sufficient data, but it is expected to be relative small since area flooded after 1990 is small.

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 Settlements[16], however this category has not been estimated yet due to lack of sufficient information.

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). According to GPG LULUCF, parties do not have to prepare estimates for this category. This land-use category is included to allow the total of identified land areas to match the national area.

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

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

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 2007 GHG emissions from *Waste* decreased by 28.4% compared to 1990 levels (***Figure 8.1***). while the average annual rate of decrease of emissions for the period 1990 – 2007 is estimated at 1.67%.
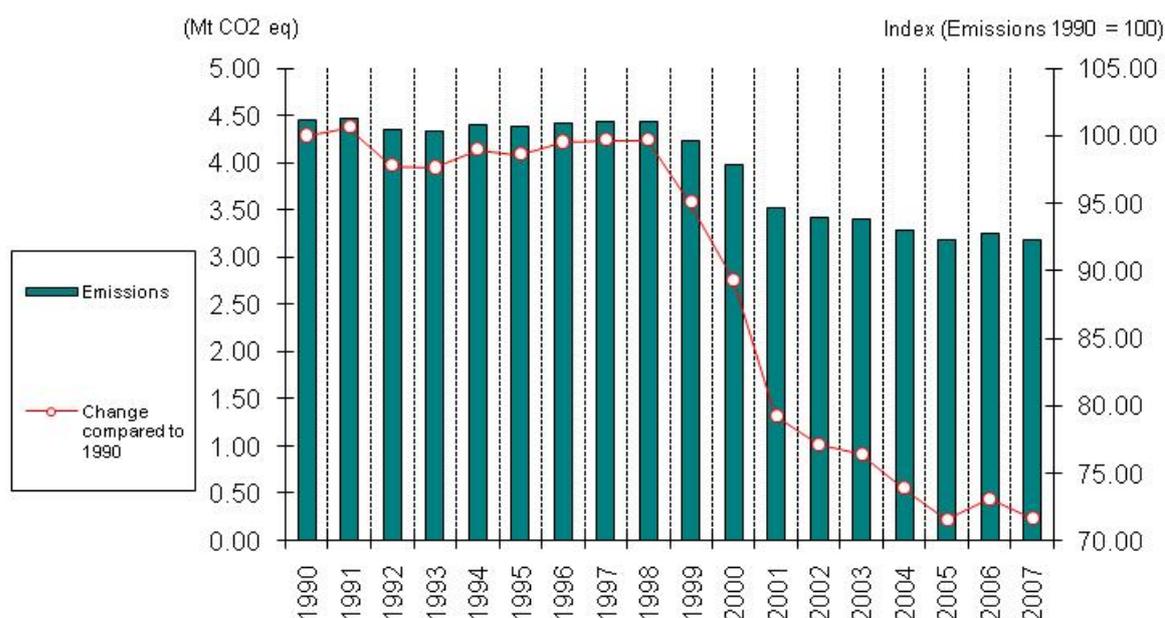
Figure 8.1   *Total GHG emissions (in kt CO₂ eq) from Waste for the period 1990 – 2007*

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 – 2007***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
CH_4	4125.77	4147.58	4013.83	4007.93	4055.23	4034.69	4076.95	4078.18	4075.63	3862.49	3607.81
N_2O	325.05	331.23	338.10	337.30	350.79	353.84	352.63	360.46	361.06	369.82	367.63
Total	4450.97	4478.96	4352.09	4345.39	4406.17	4388.68	4429.72	4438.79	4436.84	4232.46	3975.59

Year	2001	2002	2003	2004	2005	2006	2007
CO_2	0.15	0.41	0.79	0.98	1.87	2.26	3.06
CH_4	3160.22	3066.43	3032.03	2919.03	2809.37	2875.64	2807.19
N_2O	364.97	365.30	366.34	367.42	373.31	375.01	376.94
Total	3525.34	3432.14	3399.16	3287.43	3184.55	3252.90	3187.19

Methane represents the major greenhouse gas from *Waste*, with a contribution which, however, decreased from 92.69% in 1990 to 88.08% in 2007. Overall, CH_4 emissions in 2007 decreased by 28.39% compared to 1990 levels, with an average annual rate of -1.67%.

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.

As a result, the major source category from *Waste* (***Figure 8.2***) since 2000 is solid waste disposal on land with a contribution increasing from 40.59% in 1990 to 76.85% in 2007. On the contrary, GHG emissions from wastewater handling present a declining trend, with an average annual rate of -4.25% for the period 1990 – 2007. Carbon dioxide emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2007; though the contribution of this source to total GHG emissions of the sector is negligible.
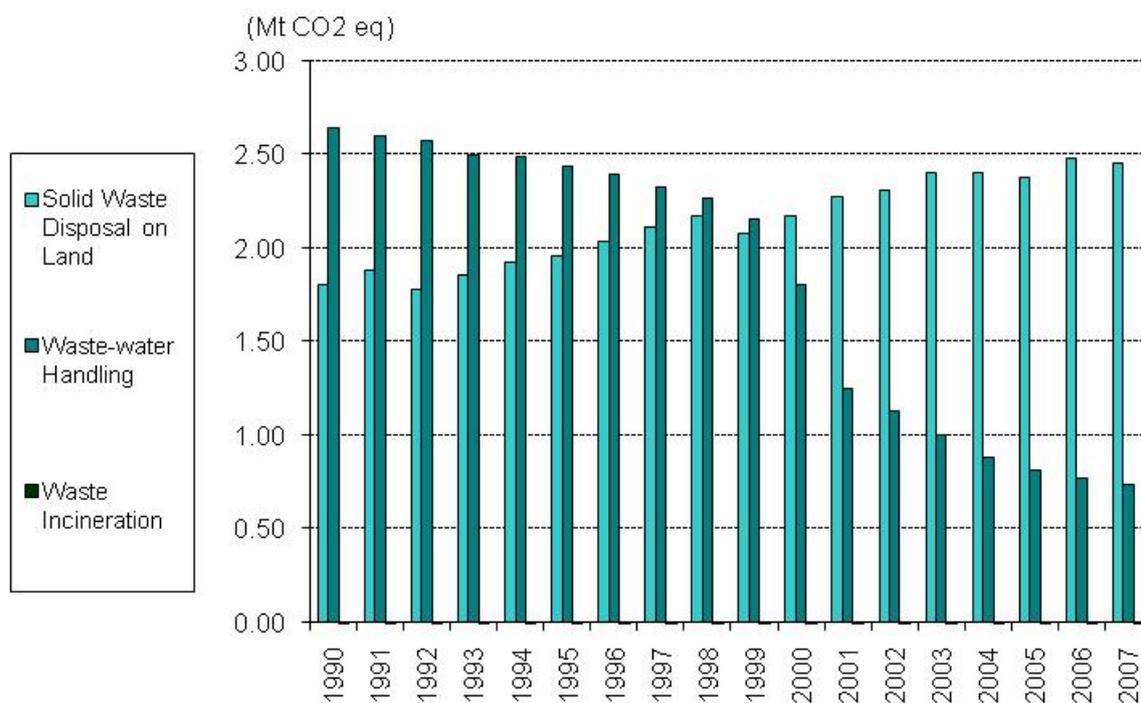
Figure 8.2   *Greenhouse gases emissions (in kt CO₂ eq) from Waste per source category*
for the period 1990 – 2007

The emissions from the waste sector decrease for the period 1999-2005 and increase for the period 2005 and 2007. This is observed because, as it is shown in Figure 8.2. GHG emissions from solid waste disposal on land increase, on the contrary to GHG emissions from wastewater handling which decrease or remain almost constant. Thus their sum presents small fluctuations.

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 for the Environment, Physical Planning and Public Works (MINENV).

✥ Data on population used in the calculations are provided by the National Statistical Service of Greece. 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 for the Environment, Physical Planning and Public Works, 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.

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_2O	
	Methodology	Emission Factor	Methodology	Emission Factor	Methodology	Emission Factor
Solid waste disposal on land			T2	D, CS		
Wastewater handling			D	D	D	D
Waste Incineration	D	D				

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		☒

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.

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.

CH_4 and N_2O emissions from the incineration of clinical waste have not been estimated because there are not available methodologies for their calculation. However, according to the IPCC Good

Practice Guidance these emissions are likely to be of a minor importance. Industrial wastewater is a possible source of N_2O emissions, but the lack of available methodologies does not allow for an estimation of these emissions.

Table 8.4   Completeness of the GHG inventory for the waste sector

	CO₂	CH₄	N₂O
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	☒	
B. Wastewater treatment			
1. Industrial wastewater		☒	NE
2. Domestic and commercial wastewater		☒	☒
C Waste incineration	☒	NE	NE

NO: Not Occurring
NE: Not Estimated

8.2   Solid waste disposal on land

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. Methane emissions were calculated using the First Order Decay (FOD) method (Tier 2).

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 SWDS of the country, in Athens, in which the waste landfilled in 2007 represent the 50% of the total waste disposed in managed sites.

Moreover, methane emissions from sewage sludge (generated during municipal wastewater handling) landfilled are estimated. Data related to the annual sludge generated in the wastewater treatment facilities of Attica region and the amounts landfilled in the SWDS serving Athens, derive from Waste management sector of the Ministry for the Environment, Physical Planning and Public Works (MINENV), EYDAP and ACMAR.

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, 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.

During the preparation of this submission an effort was made to confirm the data regarding the quantities of waste generated and sent to landfills, the share of them sent to managed and to unmanaged sites as well as the composition of the municipal solid waste disposal to managed and unmanaged sites in collaboration to the Waste management sector by the Ministry for the Environment, Physical Planning and Public Works (MINENV). As a result the official data provided by MINENV regarding these were used for the period 2001-2007. Concerning the data for the period 1960-2000, the same values as for the previous submission (2008) was used for the total quantities of generated waste because they are estimated according to studies by the Waste management sector of the Ministry for the Environment, Physical Planning and Public Works for this period (Quantification of objectives of directive 31/99 E.C. on landfill of wastes (p. 195 of the National Inventory Report -Waste Sector)).

In *Figure 8.3* the methane emissions from solid waste disposal on land were estimated using the old method, this used in previous submission, for the estimation of total solid generation and the new data obtained from MINENV is presented. As it is shown, the diference on the estimations are minimal, lower than 3.0%, and the estimations before 2001 and after 2001 are consistent.
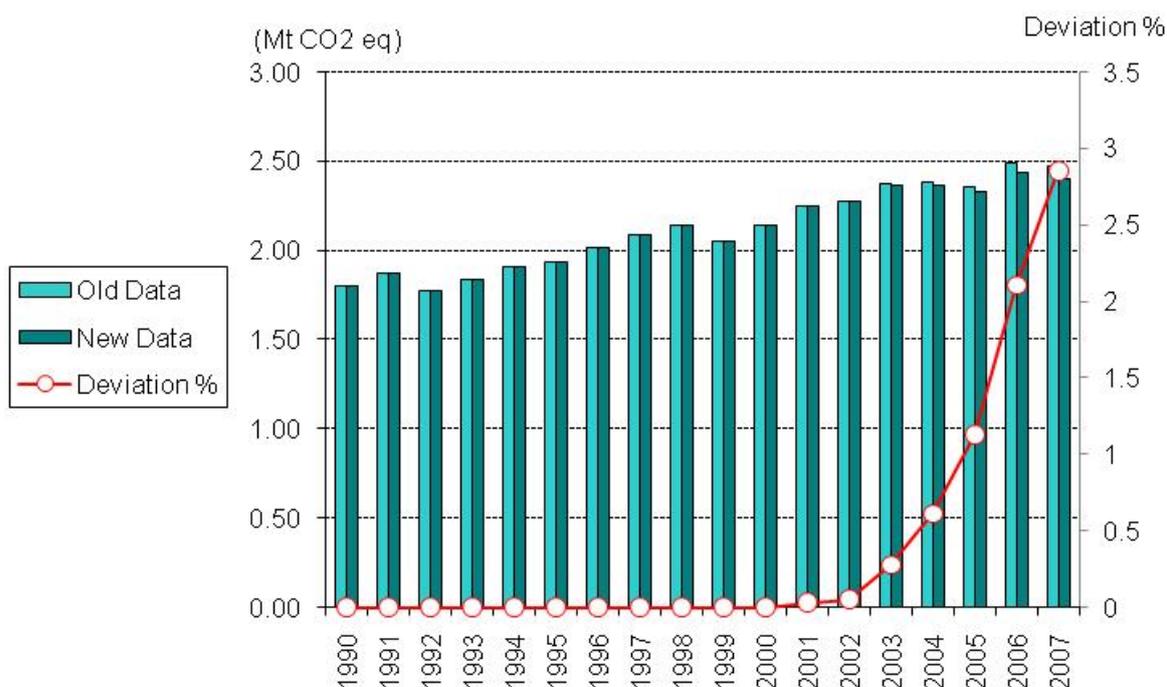
Figure 8.3   *Methane emissions from solid waste disposal on land, estimated using old*
                     method for the estimation of total solid generation and the new data obtained
                     from MINENV.

CH4 emissions from solid waste disposal on land in 2007 accounted for 76.85% of total GHG emissions from Waste and for 1.86% of total national emissions (without LULUCF). The average annual rate of increase of emissions from solid waste disposal on land, for the period 1990 – 2007 is estimated at 2.09% (35.6 % total increase between 1990 and 2007). CH4 emissions from managed and unmanaged solid waste disposal sites are presented in *Table 8.5*.

CH_4 emissions from managed SWDS in 2007 increased by 805% compared to 1990 levels, while emissions from unmanaged SWDS decrease by 4.3%. This difference is due to the reduction of the number of the unmanaged SWDS in operation. Emissions from sewage sludge disposal in 2007 are 14 times higher compared to 1990, while since 2002 the increase is restricted due to a number of issues raised concerning the transfer and disposal of sludge in the managed waste disposal site of

Athens. During this period, most of the sewage sludge remains in the wastewater treatment facility of Athens, stored under aerobic conditions with negligible methane production.

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	3.96	7.87	3.47	6.76	10.09	11.39	14.81	18.17	20.48	15.90	20.24
Unmanaged SWDS	81.91	81.27	80.91	80.76	80.72	80.82	81.06	81.33	81.59	81.74	81.89
Sludge treatment	0.17	0.33	0.48	0.61	0.75	0.90	1.01	1.10	1.19	1.27	1.37
Year	2001	2002	2003	2004	2005	2006	2007				
Managed SWDS	25.23	26.50	30.79	31.33	30.54	36.24	35.88				
Unmanaged SWDS	81.77	81.74	81.87	81.32	80.54	79.63	78.35				
Sludge treatment	1.46	1.57	1.68	1.80	2.00	2.21	2.41				

8.2.1   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. In the previous submissions the starting year of the first managed SWDS is assumed to be 1965, however this assumption was reconsidered taking into account the specific 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.

The equations used for the estimation of CH₄ emissions are the following:

CH₄ generated at year t: $P_t = \sum_{x=x_0}^{t} \left(A \cdot k \cdot MSW_T(x) \cdot MSW_F(x) \cdot Lo(x) \right) \cdot e^{-k \cdot (t-x)}$

$$CH_4 \text{ emissions at year t: } E_t = \left(P_t - R_t\right) \cdot \left(1 - OX\right)$$

$$Lo(x) = MCF \cdot DOC \cdot DOC_F \cdot F \cdot {}^{16}\!/\!_{12}$$

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 CH_4, 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 CH_4 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 even at present, a large number of unmanaged SWDS exists: in 1987 and for a number of about 6000 local authorities, almost 4690 unmanaged SWDS were registered (MINENV 1987). According to the Ministry for the Environment, Physical Planning and Public Works, 2182 unmanaged SWDS were still operating in 2000 (MINENV 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 in progress and is expected to be completed in the next year, 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. In the same context, the development of a national database with detailed data regarding the solid waste management in each managed SWDS is planned.

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. In the previous submission the quantities of municipal solid wastes for the whole period 1960-2006 was carried out, 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. In the current submission

similar methodology was followed for the period 1960-2000, while for the rest of the period 2001-2007 more accurate data for the quantities of municipal solid wastes was used as they were provided by the waste management sector of the Ministry for the Environment, Physical Planning and Public Works (MINENV).

In *Table 8.6* the estimated data on population served for the whole period 1960-2007 is presented.

Table 8.6   *Total population served (in thousands)*

Year	Permanent population	Tourists (in equivalent permanent)	Total population served
1960	8350.54	79.73	8.430.27
1965	8540.59	81.75	8.622.34
1970	8730.63	83.83	8.814.46
1975	9157.35	85.96	9.243.31
1980	9643.24	88.14	9.731.38
1985	9948.21	97.24	10.045.45
1990	10156.90	99.45	10.256.35
1991	10256.29	83.62	10.339.91
1992	10369.87	101.09	10.470.96
1993	10465.53	101.67	10.567.19
1994	10553.04	113.49	10.666.53
1995	10634.39	106.22	10.740.61
1996	10709.17	97.25	10.806.43
1997	10776.50	108.80	10.885.30
1998	10834.88	115.53	10.950.41
1999	10882.58	124.61	11.007.19
2000	10917.48	127.18	11.044.66
2001	10949.96	119.05	11.069.01
2002	10987.54	110.55	11.098.09
2003	11019.04	110.71	11.129.74
2004	11050.62	111.97	11.162.60
2005	11103.92	111.60	11.215.53
2006	11148.46	117.96	11.266.42
2007	11192.85	131.73	11.324.58

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 for the Environment, Physical Planning and Public Works: the MSW generation rate was assumed to change annually by 0.028 kg/ capita and day, while a higher

figure (annual increase by 0.035 kg/capita and day) was assumed for the regions of Athens, Central Macedonia, Crete and the islands of South Aegean. A higher figure for MSW generation rate (2.1 kg/ capita and day) was considered for foreign visitors. For the period 1960 – 1990 the rates of annual per capita waste increase are lower (0.8% - 1.5% depending on the region). The average values of daily waste generation rates estimated, are presented In *Table 8.7*.

Table 8.7   *Waste generation rates (kg/cap/day) of permanent population and tourists*

Year	Permanent population	Tourists	Total population
1960	0.566	1.400	0.573
1965	0.611	1.530	0.620
1970	0.656	1.659	0.666
1975	0.697	1.789	0.707
1980	0.735	1.919	0.746
1985	0.772	2.048	0.785
1990	0.809	2.100	0.821
1991	0.816	2.100	0.827
1992	0.844	2.100	0.856
1993	0.872	2.100	0.884
1994	0.901	2.100	0.913
1995	0.929	2.100	0.940
1996	0.957	2.100	0.967
1997	0.985	2.100	0.996
1998	1.017	2.100	1.029
1999	1.050	2.100	1.062
2000	1.082	2.100	1.094
2001	1.118	2.100	1.128
2002	1.136	2.100	1.145
2003	1.150	2.100	1.159
2004	1.164	2.100	1.174
2005	1.176	2.100	1.186
2006	1.189	2.100	1.198
2007	1.200	2.100	1.210

On the basis of the above, the following MSW quantities for the years 1990 – 2007 were estimated (*Table 8.8*). However, in the current submission for the quantities of waste generated and sent to landfills for the period 2001-2007, confirmed data was obtained from the Waste management sector of the Ministry for the Environment, Physical Planning and Public Works (MINENV) as it is mentioned above. These data is presented in *Table 8.8*. As it clear, the deferences between data estimated with the old method and the data obtained by MINENV are similar especially for the

years 2001-2003 which are close to the 1997 year where the old method was based. For the rest of the years (2004-2007) the differences increase, thus the reconsideration of the calculated data with the official data was considered useful.

Table 8.8   *Quantities of MSW generated by year (in kt)*

Year	Quantities according old method estimation	Official data from MINENV
1960	1765†	
1965	1951†	
1970	2142†	
1975	2384†	
1980	2651†	
1985	2877†	
1990	3075†	
1991	3119†	
1992	3273†	
1993	3410†	
1994	3556†	
1995	3686†	
1996	3815†	
1997	3958†	
1998	4112†	
1999	4266†	
2000	4411†	
2001	4543	4559†
2002	4680	4640†
2003	4823	4710†
2004	4967	4781†
2005	5121	4854†
2006	5276	4927†
2007	5405	5002†

†used on the estimations

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, MINENV 1999). Recent estimates of the composition of MSW at national level exist only for 1997 (MINENV 1998).

In the current submission is attempted to include wood and textiles in the composition of the generated municipal solid waste. It was considered that in previous submissions these components were included in putrescibles. For this procedure an analysis obtained by ACMAR was used. This analysis was performed at the Attica region during 2007. The estimated values were confirmed with the data used by other parties to be similar.

In order to estimate the composition of MSW generated on an annual basis the following assumptions were made (MINENV 2001a). considering the estimation for 1997 (national level) as base:

✥   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 wood and textiles is assumed to be constant because for both the value was low, 1% and 3.25% respectively.

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**.

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 2007, the percentage of MSW recycled is estimated at 16 %, significantly higher than this of 2000, which was about 7%, 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**.

According to the most recent data by the Ministry for the Environment, Physical Planning and Public Works (10/2004), out of the various existing disposal sites, 37 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 wet sewage sludge disposed in the managed site of Athens is also presented in **Table 8.11**. The solid content of sludge is estimated to be 30%, while 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%.

Table 8.9   *Estimated composition (%) of MSW generated for the period 1990 - 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Putrescibles	44.85	44.55	44.25	43.95	43.65	43.35	43.05	42.75	42.45	42.15	41.85
Textiles	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Wood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Paper	18.60	18.80	19.00	19.20	19.40	19.60	19.80	20.00	20.20	20.40	20.60
Plastics	7.10	7.30	7.50	7.70	7.90	8.10	8.30	8.50	8.70	8.90	9.10
Metals	5.20	5.10	5.00	4.90	4.80	4.70	4.60	4.50	4.40	4.30	4.20
Glass	4.64	4.62	4.60	4.58	4.56	4.54	4.52	4.50	4.48	4.46	4.44
Rest	15.36	15.38	15.40	15.42	15.44	15.46	15.48	15.50	15.52	15.54	15.56

Year	2001	2002	2003	2004	2005	2006	2007
Putrescibles	41.55	41.25	40.95	40.65	40.35	40.05	39.75
Textiles	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
Paper	20.80	21.00	21.20	21.40	21.60	21.80	22.00
Plastics	9.30	9.50	9.70	9.90	10.10	10.30	10.50
Metals	4.10	4.00	3.90	3.80	3.70	3.60	3.50
Glass	4.42	4.40	4.38	4.36	4.34	4.32	4.30
Rest	15.58	15.60	15.62	15.64	15.66	15.68	15.70

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

evaportranspiration (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 and 9 years for sewage sludge disposed on land.

Table 8.10   *Estimated composition of MSW disposed for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Putrescibles	49.52	49.12	48.61	48.11	47.60	47.14	46.68	45.84	45.42	44.99	44.58
Textiles	3.59	3.58	3.57	3.56	3.54	3.53	3.52	3.55	3.54	3.53	3.52
Wood	1.10	1.10	1.10	1.09	1.09	1.09	1.08	1.09	1.09	1.09	1.08
Paper	11.56	11.89	12.47	12.97	13.46	13.89	14.31	14.87	15.29	15.71	16.09
Plastics	7.84	8.04	8.24	8.42	8.61	8.80	9.00	9.12	9.28	9.45	9.63
Metals	5.74	5.62	5.39	5.24	5.10	4.98	4.85	4.78	4.65	4.52	4.39
Glass	3.69	3.68	3.71	3.73	3.75	3.76	3.76	3.81	3.82	3.83	3.83
Rest	16.96	16.96	16.92	16.88	16.84	16.81	16.79	16.93	16.91	16.88	16.86

Year	2001	2002	2003	2004	2005	2006	2007
Putrescibles	45.57	45.22	44.56	44.71	44.58	45.94	47.25
Textiles	3.56	3.56	3.54	3.57	3.59	3.73	3.86
Wood	0.86	0.86	0.86	0.87	0.88	0.33	0.36
Paper	14.88	15.17	16.00	15.19	14.99	14.28	11.35
Plastics	10.01	10.21	10.35	10.68	10.96	11.12	11.77
Metals	4.25	4.12	3.97	3.90	3.82	2.53	2.53
Glass	3.79	3.76	3.73	3.88	3.88	4.07	4.21
Rest	17.09	17.10	17.00	17.20	17.30	17.99	18.66

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 (wet)	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	60.00	24.00
1991	1198.41	166.44	1630.78	226.49	60.00	24.00
1992	1246.11	174.92	1733.21	243.29	60.00	24.00
1993	1295.02	183.30	1820.73	257.71	60.00	24.00
1994	1406.12	200.64	1854.26	264.59	65.00	26.00
1995	1477.90	212.31	1911.78	274.64	71.40	28.56
1996	1544.44	223.33	1973.34	285.36	61.00	24.40
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	83.40	33.36
2005	2824.04	410.53	1470.51	213.77	116.81	46.72
2006	2875.51	408.22	1419.55	201.53	125.97	50.39
2007	2926.99	388.74	1280.36	170.05	128.63	51.45

Biogas flaring

According to data from the Ministry for the Environment, Physical Planning and Public Works, 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 3 of these sites (in Patra, Thessalonica and Larissa) the collection of data on the amount of biogas flared has not been possible yet. The estimation of biogas recovered in these sites was based on the assumption that for technical reasons, 60% of biogas released is finally recovered and flared. Detailed measurements data have been collected only for the SWDS of Athens, in which almost 50% of total waste going to managed sites is disposed. In *Table 8.12*, quantities of waste disposed in the 3 sites for which the

CH$_4$ recovery is based on assumptions, the volume of biogas flared in the SWDS of Athens and methane that is totally recovered, are presented.

For the estimation of methane recovered in the SWDS of Athens, the fraction of methane in landfill gas (*F*) was calculated at 0.5 and methane density at 0.7 kg CH$_4$/m^3, based on the data collected.

Table 8.12   *CH$_4$ 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. Thessalonica and Larissa (kt)	241.0	247.0	260.7	274.4	288.2	365.8	382.7	401.8	421.9	497.0	520.4
Biogas flared in the SWDS of Athens (10^6 m^3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	21.90	21.90
Total CH$_4$ recovery (kt)	0.00	0.00	8.31	8.93	9.72	12.60	13.43	14.47	16.93	26.80	28.08

Year	2001	2002	2003	2004	2005	2006	2007
Waste landfilled in the SWDS of Patra. Thessalonica and Larissa (kt)	538.8	563.9	590.2	618.0	652.6	681.8	701.7
Biogas flared in the SWDS of Athens (10^6 m^3)	21.00	30.00	30.00	42.05	56.90	53.42	67.61
Total CH$_4$ recovery (kt)	28.94	33.40	34.81	40.65	47.95	48.43	54.35

Other parameters

✎   Methane Correction Factor (*MCF*): 1 for managed SWDS, 0.6 for unmanaged SWDS (the particular conditions in the various disposal sites are unknown)

✎   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) and 0.4 for sewage sludge.

✎   Fraction of DOC dissimilated (*DOC$_F$*): 0.77 (default value) for solid waste, 0.4 for sewage sludge.

✎   Fraction of methane in landfill gas (*F*): 50% (default value) for solid waste, 0.6 for sewage sludge.

✎   Oxidation factor (*OX*): 0 (default value).

8.2.2   Recalculations

CH$_4$ emissions from solid waste disposal on land have been recalculated for the period 1990-2006 due to reconsideration of the starting day of managed solid waste sites, from 1965 to 1990.

availability of confirmed data regarding the quantities of MSW, sludges and methane recovery and reconsideration of the composition of MSW including textiles and wood. 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 8.13.*

Table 8.13   *Recalculations of CH4 emissions from solid waste disposal on land %*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Difference	0.326	1.884	-5.565	-4.356	-3.234	-2.243	-1.264	-0.513	0.177	0.886	1.530
Impact on total emissions (excl LULUCF)	0.006	0.033	-0.099	-0.080	-0.059	-0.041	-0.023	-0.009	0.003	0.015	0.026
Year	2001	2002	2003	2004	2005	2006					
Difference	1.631	1.583	1.446	1.172	-2.573	-6.331					
Impact on total emissions (excl LULUCF)	0.029	0.028	0.026	0.021	-0.048	-0.131					

8.2.3   Planned improvements

Futher investigation regarding composition of disposed wastes is planed. Moreover the emitted biogas carried out by the responsible governmental agencies, local authorities etc. The development of a central database which will include most of the above data has already been scheduled by the Ministry for the Environment, Physical Planning and Public Works 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. Finally, the collection of data on the sewage sludge disposed in other large managed SWDS of the country is among the future plans, in order to improve the completeness of the emissions inventory for the *Waste* sector.

8.3   Wastewater handling

Domestic and industrial wastewater handling under anaerobic conditions produces CH_4. 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. CH_4 emissions from wastewater handling in 2007 accounted for 0.28% of total GHG emissions and for 11.23% of GHG emissions from *Waste*.

N_2O emissions from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) are also included in the wastewater handling source category. N_2O emissions from this source in 2007 account for 0.29% of total greenhouse gases emissions and 11.83% of greenhouse gases emissions from *Waste*.

Wastewater handling is a key category of CH_4 emissions, which have a substantial contribution in emissions trends (trend assessment). In ***Table 8.14*** CH_4 and N_2O emissions from wastewater handling for the period 1990 – 2007 are presented.

Table 8.14   *CH_4 and N_2O emissions (in kt) from wastewater handling*

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Domestic and commercial wastewater	CH_4	105.31	103.74	101.53	97.34	96.03	94.15	92.19	89.06	85.19	80.49	62.50
Industrial wastewater	CH_4	5.12	4.29	4.75	5.38	5.52	4.87	5.07	4.55	5.63	4.52	5.80
Human sewage	N_2O	1.05	1.07	1.09	1.09	1.13	1.14	1.14	1.16	1.16	1.19	1.19

Year		2001	2002	2003	2004	2005	2006	2007
Domestic and commercial wastewater	CH_4	35.87	30.62	25.07	19.14	15.87	13.49	11.89
Industrial wastewater	CH_4	6.16	5.59	4.96	5.41	4.83	5.36	5.15
Human sewage	N_2O	1.18	1.18	1.18	1.19	1.20	1.21	1.22

CH_4 emissions from industrial wastewater and indirect N_2O emissions increased in 2007 by 0.55% and 15.97% respectively compared to 1990. On the contrary, CH_4 emissions from domestic wastewater handling in 2007 decreased by 88.71% compared to 1990 levels, with an average annual rate of decrease estimated at 5.22%. 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 for the Environment, Physical Planning and Public Works the penetration of such facilities increased from 32% (of total population served) in 1999 and to 90.2% in 2007.

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 serve. Emissions from 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 for the first time in the present inventory. 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.

8.3.1 Methodology

CH_4 and N_2O emissions from wastewater handling were estimated according to the default methodologies suggested by IPCC.

Domestic and commercial wastewater handling

Methane emissions from domestic and commercial wastewater handling are calculated using the following equations:

$$CH_4 \text{ emissions} = TOW * EF - MR$$

$$TOW = P*D_{dom}$$

$$EF = Bo*MCFs$$

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*** (suggested value for Europe 0.6 kg CH_4/kg BOD) and the weighted average of the methane conversion factors (***MCFs)***, for the different wastewater treatment systems used in the country. 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 – 2007, is presented.

The calculation of BOD from sludge removed and disposed on land (Table 8.15) is based on the amounts of sludge transferred in the managed SWDS of Athens (Table 8.11) and the following parameters:

✥   Dry matter of sludge: 30%

✎   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 CH_4/ m3

✎   Fraction of methane in sludge biogas (F): 0.6

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 for the Environment, Physical Planning and Public Works on the implementation of EU Directive 91/71 regarding the collection, treatment and disposal of municipal wastewater.

Table 8.15   *BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2007*

Year	Wastewater	Sludge	Total
1990	184.75	2.43	187.18
1991	186.27	2.43	188.70
1992	188.66	2.43	191.09
1993	190.42	2.43	192.85
1994	192.03	2.64	194.66
1995	193.12	2.89	196.02
1996	194.74	2.47	197.22
1997	196.18	2.47	198.66
1998	197.44	2.40	199.85
1999	198.44	2.44	200.88
2000	198.88	2.69	201.57
2001	199.26	2.75	202.01
2002	199.39	3.15	202.54
2003	199.88	3.23	203.12
2004	200.34	3.38	203.72
2005	199.95	4.74	204.68
2006	200.51	5.11	205.61
2007	201.46	5.21	206.67

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 National Statistical Service of Greece) regarding industrial production of approximately 25 industrial sectors / sub-sectors for the period 1990 – 2007. Data on

industrial production for 2007 were not available and for this reason production was estimated through linear extrapolation.

✧   Calculation of wastewater generated, by using the default factors per industrial sector (m³ of wastewater/t product) suggested by the IPCC Good Practice Guidance.

✧   Calculation of degradable organic fraction of waste, by using the default factors (kg COD/m³ wastewater) suggested by the IPCC Good Practice Guidance 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 for the Environment, Physical Planning and Public Works (2001b). The maximum methane production potential factors Bo and the methane conversion factors for aerobic and anaerobic treatment, which were used for the final estimation of methane emissions, are similar to those used for domestic wastewater handling.

In *Table 8.16* the degradable organic waste (as COD) for the period 1990 – 2007, is presented.

Table 8.16   *Total COD (in kt) from industrial wastewater for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
COD (kt)	20.48	17.17	19.01	21.52	22.10	19.48	20.30	18.19	22.52	18.09	23.22
Year	2001	2002	2003	2004	2005	2006	2007				
COD (kt)	24.64	22.36	19.85	21.66	19.33	21.44	20.59				

Indirect N₂O emissions from human consumption of food

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

$$N_2O \text{ emissions} = Protein * P * Frac_{NPR} * EF (N_2O\text{-}N/N)$$

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 8.17* the consumption of protein (kg/person/year) for the period 1990 – 2007, is presented.

Table 8.17   *Annual protein consumption (in kg/person) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Protein (kg/capita)	40.66	41.10	41.43	40.95	42.19	42.27	41.87	42.49	42.30	43.11	42.71
Year	2001	2002	2003	2004	2005	2006	2007				
Protein (kg/capita)	42.30	42.23	42.23	42.23	42.71	42.71	42.71				

8.3.2   Recalculations

CH_4 emissions from Domestic and commercial wastewater handling have been recalculated because of the availability of updated activity for the period 1997-2006. Regarding domestic wastewater handling data concerning the sludge emissions was updated while for commercial wastewater handling the industrial production for several industrial sectors were updated too. 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 8.18.*

N_2O emissions from this sector have been recalculated because of the availability of updated activity for the period 2005-2006 because updated date concerning Annual protein consumption. For both years the deviation on estimations is 0.894% and the impact on total emissions (excl LULUCF) are 0.003%.

Table 8.18   ***Recalculations of CH4 emissions from domestic and commercial wastewater handling***

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Difference	0.973	0.986	0.974	0.821	0.739	0.559	-0.342	-0.430	-16.245	-23.737
Impact on total emissions (excl LULUCF)	0.016	0.015	0.014	0.009	0.005	0.003	-0.002	-0.002	-0.064	-0.096

8.3.3   Planned improvements

The treatment conditions of the industrial wastewater and the distribution of different wastewater treatment systems are examined in order to use a more detailed methodology on the estimation of the emissions from industrial wastewater.

8.4   Waste incineration

Carbon dioxide emissions from the incineration of clinical waste produced in the Attica region have been estimated. Incineration of clinical waste in a central plant is still limited, despite the fact that the facilities existed are planned to cover the total daily needs of hospitals in Athens. For the estimation of CO_2 emissions, the default method suggested by the IPCC Good Practice Guidance was used. CH_4 and N_2O emissions have not been estimated because there are not any available relevant emission factors. However, according to the IPCC Good Practice Guidance, these emissions are not likely to be significant.

Data related to the amount of clinical waste incinerated derive from the ACMAR, which is operating the incinerator. 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:

$$CO_2 \text{ emissions} = CW * CCW * FCF * EF * 44/12$$

where, *CW* is the amount of clinical waste, *CCW* is the fraction of carbon content in the waste (60%), *FCF* is the fraction of fossil carbon (40%) and *EF* is the burn out efficiency of combustion of the incinerator (95%).

In ***Table 8.19***. the amount of clinical waste incinerated and CO2 emissions released for the period 1990 – 2007 are presented.

Table 8.19   *Clinical waste (in kt) and CO$_2$ emissions (in kt) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Clinical waste	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Emissions	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Year	2001	2002	2003	2004	2005	2006	2007				
Clinical waste	0.18	0.49	0.94	1.17	2.23	2.70	3.67				
Emissions	0.15	0.41	0.79	0.98	1.87	2.26	3.06				

8.4.1   Recalculations

CO$_2$ emissions from waste incineration sector have been recalculated because of the availability of updated activity data regarding clinical waste production for the period 2005-2006. The deviation of the emissions estimated in the current submission compared to the emissions estimated in the previous submission were 85.93% and 125.02% and the impact on total emissions (excl LULUCF) of recalculations are $7 \cdot 10^{-4}$% and $10 \cdot 10^{-4}$% for 2005 and 2006 respectively.

9.   Recalculations and improvements

9.1   Overview of recalculations

A number of recalculations have been performed since the previous inventory submission in order to improve consistency with UNFCCC reporting guidelines and IPCC guidelines. The recalculations made are driven by the results of Greece's QA/QC system and the various review processes (mainly the in-country review from 8 to 13 September 2008), while prioritisation is based on the key source analysis and the availability of resources.

The reasons for recalculations made, can be classified as follows:

1. ***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.

2. ***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.

3. ***Allocation***. Changes in allocation of emissions to different sectors or sources/sub-sources.

4. ***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.

The justification of the recalculations made in the present submission 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*

IPCC source / sink categories		Gas	Explanation	
1.AA.1.A	Public Electricity and Heat Production	CO_2 / CH_4 / N_2O		Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007).
			M	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
				NCV of lignite corrected acc to updated national energy balance for 2009 submission.
1.AA.1.B	Petroleum Refining	CO_2 / CH_4 / N_2O		Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007).
			M	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
				Updated activity Data.
1.AA.1.C	Manufacture of Solid Fuels and Other Energy Industries	CO_2 / CH_4 / N_2O	M	EF was changed in order to include CO2 emissions from sour gas cleaning operation.
				Updated activity data.
1.AA.2.A	Iron and Steel	CO_2 / CH_4 / N_2O		Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007).
			M,E	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
				Correction of EF used.
1.AA.2.B	Non-Ferrous Metals	CO_2 / CH_4 / N_2O		Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007).
			M	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
				Updated activity data.
1.AA.2.C	Chemicals	CO_2 / CH_4 / N_2O		Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007).
			M,A, E	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
				NG for NH3 production is moved and accounted in industrial processes sector.
				Correction of EF used.
1.AA.2.D	Pulp. Paper and Print	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and

IPCC source / sink categories	Gas		Explanation
			IPCC default EFs for the whole time series (1990-2007). Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion.
1.AA.2.E	Food Processing. Beverages and Tobacco	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007). Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion. Updated activity Data.
1.AA.2.F	Manufacturing Industries and Construction. Other	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data (ETS reports) and IPCC default EFs for the whole time series (1990-2007). Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion. Updated activity Data.
1.AA.3.A	Civil Aviation	CO_2 / CH_4 / N_2O	M	Conservativeness factor applied for adjustments of base year emissions was removed according to ERT suggestion. Updated activity Data..
1.AA.3.B	Road Transportation	CO_2 / CH_4 / N_2O	M	Updated activity Data and NCVs of fuels.
1.AA.3.C	Railways	CO_2 / CH_4 / N_2O	M	Updated activity Data and NCVs of fuels.
1.AA.3.D	Navigation	CO_2/ CH_4	M	Updated activity Data and NCVs of fuels.
1.AA.3.E	Other Transportation	CO_2 / CH_4 / N_2O	E	Error in crf compilation.
1.AA.4.A	Commercial/Institutional	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs for the whole time series (1990-2007).
1.AA.4.B	Residential	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs for the whole time series (1990-2007).
1.AA.4.C	Agriculture/Forestry/Fisheries	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs for the whole time series (1990-2007). Updated activity data.
1.B	Fugitive emissions from fuels	CO_2 / CH_4 / N_2O	E, M	Correction of erros. Updated activity data.
2.A.1	Cement Production	CO_2	M	Use of the overlap method to improve time-series consistency and move by T2 to CS method.
2.A.2	Lime Production	CO_2	M	The overlap recalculation method has been used to ensure consistency between the time-series. NSSG data on hydraulic lime production have been made available.

IPCC source / sink categories		Gas	Explanation	
2.A.3	Limestone and dolomite use	CO$_2$	E	Detection of error in the working files for 2006. concerning the activity data.
2.A.7.1	Glass Production	CO$_2$		Activity data of 1994-2000 are recalculated by means of linear interpolation (Correction of error in the implementation of the method).
			E, M	Plant specific activity data for years 2005-2007 have been given by the one glass industry in Greece.
				The overlap recalculation method has been used to ensure consistency between the time-series.
2.B.1	Ammonia Production	CO2		Emissions calculated for the first time.
			A,M	Correction of the reporting of AD (NSSG informed the inventory team that ammonia production is expressed in kt N. The difference derives from changing to kt NH3.)
2.B.2	Nitric acid Production	N2O	E	According to information provided by the plant. the EF has to be changed. as the plant is working in medium pressure conditions.
2.C.1.1	Steel Production	CO$_2$	M	Country-specific emission factor instead of the default used in the previous years. As suggested by the ERT the EF used is country specific and derives from the average of years 2005-2007. making use of the detailed reports of emissions in the context of the EU ETS.
2.C.3	Aluminium Production	CO2	M	Updated activity data given by the one aluminium plant of Greece for years 2005-2006.
2.C.3	Aluminium Production	PFCs	M	The plant has provided the average emissions per year. based on it's measurements for years 2004-2006.
2. E	Production of Halocarbons and SF$_6$	HFCs	M	New updated activity data. The one plant existing in Greece closed in 2006.
2.F.1	Refrigeration and A/C equipment	HFCs	M	New activity data became available by market surveys. Regarding Transport Refrigeration, new data have been collected in order to fill the timeseries. According to the National Association of refrigerating and Cooling Technicians, the previous assumptions did not depict the truth and had to be changed, according to new information concerning the penetration of HFCs and substitution of ozone depleting substances.
2. F. 4	Aerosols/ MDIs	HFCs	M	Data on the imports and exports of MDIs have been collected by the NSSG to fill the time-series.
4.A	Enteric Fermentation / Dairy Cattle	CH$_4$	M	Updated emission factor based on milk production data.
4.B	Manure Management	CH$_4$ / N$_2$O	M	Updated activity data (animal population).
4.D	Agricultural Soils	N$_2$O	M	Updated activity data (animal population. agricultural crop production. amount of synthetic fertilizer).

IPCC source / sink categories		Gas	Explanation	
4.F	Field Burning of Agricultural Residues	CH_4 / N_2O	M	Updated activity data (agricultural crop production).
5.A.1	Forest Land remaining Forest Land	CO_2 / CH_4 / N_2O	M	Updated activity data
5.A.2	Land converted to forestland	CO_2	M	Updated activity data
5.B.1	Cropland	CO_2	M	Updated activity data
5.C.1	Grassland	CH_4 / N_2O	M	Updated activity data.
6.A	Solid Waste Disposal on Land	CH_4	M	Updated activity data (generated solid waste. amount of solid waste sent to managed and unmanaged disposal sites. composition of waste).
6.B.1	Wastewater Handling / Industrial Wastewater	CH_4	M	Updated activity data (industrial production).
6.C.2	Waste Incineration / Incineration of hospital wastes	CO_2	M	Updated activity data (amount of clinical waste incineration).

E: Correction of errors. M: Change or refinement of methodology. NS: new sources. A: allocation to different sectors

9.2   Implications for emissions levels

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) and sector is presented in *Tables 9.2 – 9.5.*

Table 9.2   *Recalculation of CO_2 emissions (differences compared to previous submission, in kt)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	843.15	70.55	-0.55	-0.61	-0.63	-0.67	-0.72	-0.81	-120.33	-205.71	-190.79
Fuel Combustion Activities	843.15	70.55	-0.55	-0.61	-0.63	-0.67	-0.72	-0.81	-120.33	-205.71	-190.79
Energy Industries	704.15										
Manufacturing Industries and Construction	8.07	71.06							-130.18	-204.72	-189.70
Transport	130.93	-0.51	-0.55	-0.61	-0.63	-0.67	-0.72	-0.81	-0.83	-0.99	-1.09
Other Sectors									10.68		
Fugitive Emissions from Fuels											
Oil and Natural Gas											
Industrial processes	-185.68	-173.47	-123.10	-286.45	-280.47	-303.91	-275.77	-462.93	-55.73	-157.07	-53.49
Mineral Products	-75.55	-64.18	-20.64	-172.77	-172.82	-179.31	-177.30	-337.70	-101.79	-186.05	-197.46
Chemical Industry									195.28	158.63	294.37
Metal Production	-110.13	-109.29	-102.46	-113.68	-107.65	-124.60	-98.47	-125.22	-149.22	-129.65	-150.40
Waste	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Waste Incineration	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Emissions from Biomass	220.41									1.06	
Land Use. Land-Use Change and Forestry	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	526.46
Forest Land											
Cropland	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	20.65	526.46
TOTAL	**678.27**	**-82.11**	**-102.86**	**-266.26**	**-260.29**	**-283.77**	**-255.68**	**-442.94**	**-155.25**	**-341.97**	**282.33**

Year	2001	2002	2003	2004	2005	2006
Energy	-90.36	-126.54	-193.59	-213.26	267.09	-359.08
Fuel Combustion Activities	-90.36	-126.54	-193.59	-213.26	267.28	-359.02
Energy Industries					133.59	744.12
Manufacturing Industries and Construction	-91.42	-131.11	-196.24	-208.39	696.67	-335.52
Transport	1.06	4.57	2.65	-4.86	-579.61	-780.39
Other Sectors					16.63	12.77
Fugitive Emissions from Fuels					-0.19	-0.06
Oil and Natural Gas					-0.19	-0.06
Industrial processes	-295.84	-280.13	-204.34	-238.62	279.37	316.54
Mineral Products	-229.17	-196.19	-255.75	-255.81		
Chemical Industry	137.13	187.90	293.03	311.18	285.24	314.89
Metal Production	-203.80	-271.83	-241.62	-293.99	-5.86	1.64
Waste	0.15	0.41	0.79		0.86	1.25
Waste Incineration	0.15	0.41	0.79		0.86	1.25
Emissions from Biomass	72.57	108.74	64.14	74.24	53.54	354.46
Land Use. Land-Use Change and Forestry	360.38	202.35	525.03	295.14	242.90	124.16
Forest Land				4.67	242.89	207.05
Cropland	360.38	202.35	525.03	290.47	0.01	-82.88
TOTAL	**-25.67**	**-203.90**	**127.89**	**-156.74**	**790.23**	**82.88**

Table 9.3   Recalculation of CH$_4$ emissions (differences compared to previous submission. in kt CO$_2$ eq)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	1.59	-14.99	-13.56	-13.43	-13.56	-12.75	-12.83	-12.56	-11.46	-7.45	-7.21
Fuel Combustion Activities	1.59	-14.99	-13.56	-13.43	-13.56	-12.75	-12.83	-12.56	-11.46	-7.45	-7.21
Energy Industries	5.48	5.75	5.74	5.85	5.96	6.12	5.78	6.20	6.45	6.52	7.33
Manufacturing Industries and Construction	-9.81	-10.30	-9.39	-9.35	-9.22	-9.55	-8.87	-8.58	-8.91	-7.17	-7.39
Transport	0.16	-0.15	-0.16	-0.18	-0.18	-0.20	-0.21	-0.24	-0.24	-0.29	-0.32
Other Sectors	5.76	-10.29	-9.75	-9.76	-10.12	-9.12	-9.53	-9.94	-8.76	-6.51	-6.84
Fugitive Emis. from Fuels											
Oil and Natural Gas											
Industrial processes					-0.03	-0.01	0.02	-0.02	-0.06	-0.33	-0.43
Chemical Industry					-0.03	-0.01	0.02	-0.02	-0.06	-0.33	-0.43
Agriculture	11.61	15.17	29.44	42.74	45.48	51.06	52.56	52.96	55.55	53.15	53.79
Enteric Fermentation	11.61	15.17	29.44	42.74	45.48	51.06	52.56	52.96	55.55	53.60	57.31
Manure Management										-0.45	-3.52
Field Burning of Agricultural Residues											
Land Use. Land-Use Change and Forestry											
Forest Land											
Cropland											
Waste	5.87	34.75	-105.01	-84.28	-64.25	-44.87	-26.05	8.05	22.44	35.46	44.42
Solid Waste Disposal on Land	5.87	34.75	-105.01	-84.28	-64.25	-44.87	-26.05	-10.89	3.82	18.24	32.74
Waste-water Handling								18.94	18.62	17.22	11.68
TOTAL	19.07	34.93	-89.13	-54.97	-32.36	-6.56	13.71	48.43	66.47	80.83	90.56

Year	2001	2002	2003	2004	2005	2006
Energy	-18.00	-22.13	-29.16	-36.87	-48.01	-72.90
Fuel Combustion Activities	-18.00	-22.13	-29.16	-41.13	-57.97	-82.93
Energy Industries	7.23	7.22	7.64	7.28	0.02	0.02
Manufacturing Industries and Construction	-7.88	-5.44	-4.73	-3.92	-1.94	-1.24
Transport	-11.13	-22.10	-31.63	-42.94	-54.32	-89.02
Other Sectors	-6.22	-1.80	-0.44	-1.55	-1.73	7.31
Fugitive Emis. from Fuels				4.26	9.97	10.04
Oil and Natural Gas				4.26	9.97	10.04
Industrial processes	-0.68	-0.69	-0.71	-0.74	-0.74	-0.74
Chemical Industry	-0.68	-0.69	-0.71	-0.74	-0.74	-0.74
Agriculture	74.42	86.27	65.14	29.15	77.49	85.52
Enteric Fermentation	72.64	85.51	66.85	31.07	74.39	86.53
Manure Management	1.78	0.76	-1.71	-1.92	3.11	-1.02
Field Burning of Agricultural Residues						0.01
Land Use. Land-Use Change and Forestry				0.26	-1.36	
Forest Land				0.42	-0.99	
Cropland				-0.15	-0.36	
Waste	43.02	40.17	32.07	25.60	-147.05	-290.82
Solid Waste Disposal on Land	36.55	35.94	34.24	27.83	-62.71	-167.60
Waste-water Handling	6.47	4.23	-2.16	-2.23	-84.34	-123.23
TOTAL	**98.77**	**103.62**	**67.35**	**17.40**	**-119.66**	**-278.93**

Table 9.4　　　　　*Recalculation of N$_2$O emissions (differences compared to previous submission, in kt CO$_2$ eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Energy	-152.63	-277.53	-270.03	-261.21	-259.29	-278.23	-355.17	-368.94	-383.45	-388.40	-431.32
Fuel Combustion Activities	-152.83	-277.72	-270.19	-261.34	-259.42	-278.33	-355.30	-369.05	-383.53	-388.41	-431.39
Energy Industries	47.25	-0.80	-0.70	-0.66	-0.76	-0.73	-0.77	-1.65	-6.81	-15.55	-23.48
Manufacturing Industries and Construction	-7.97	-73.78	-71.60	-69.54	-68.23	-81.43	-90.92	-94.23	-90.73	-92.80	-106.35
Transport	1.93	0.29	0.31	0.34	0.36	0.38	0.40	0.46	0.47	0.56	0.61
Other Sectors	-194.04	-203.43	-198.21	-191.49	-190.78	-196.55	-264.01	-273.63	-286.45	-280.61	-302.17
Fugitive Emissions from Fuels	0.20	0.20	0.16	0.13	0.13	0.11	0.12	0.11	0.08	0.00	0.07
Oil and Natural Gas	0.20	0.20	0.16	0.13	0.13	0.11	0.12	0.11	0.08	0.00	0.07
Industrial processes	396.09	326.57	341.50	324.30	315.30	313.75	358.29	314.68	258.95	268.91	275.38
Chemical Industry	396.09	326.57	341.50	324.30	315.30	313.75	358.29	314.68	258.95	268.91	275.38
Agriculture	-33.67	-3.85	-28.86	-202.04	-577.26	9.62	-163.56		153.94	18.27	-153.48
Manure Management										-0.06	-0.56
Agricultural Soils	-33.67	-3.85	-28.86	-202.04	-577.26	9.62	-163.56		153.94	18.33	-152.92
Field Burning of Agricultural Residues											
Land Use. Land-Use Change and Forestry											
Forest Land											
Cropland											
Waste											
Waste-water Handling											
TOTAL	**209.78**	**45.20**	**42.61**	**-138.95**	**-521.25**	**45.14**	**-160.44**	**-54.26**	**29.44**	**-101.22**	**-309.42**

Year	2001	2002	2003	2004	2005	2006
Energy	-462.89	-548.59	-668.91	-720.89	-218.33	-218.41
Fuel Combustion Activities	-462.94	-548.64	-668.94	-720.89	-218.33	-218.41
Energy Industries	-23.08	-24.61	-27.20	-29.58	1.64	1.50
Manufacturing Industries and Construction	-108.15	-112.38	-106.66	-105.41	-79.06	-78.39
Transport	0.58	-68.15	-131.51	-192.02	-297.58	-308.96
Other Sectors	-332.29	-343.50	-403.57	-393.87	156.67	167.43
Fugitive Emissions from Fuels	0.05	0.05	0.03		0.00	0.00
Oil and Natural Gas	0.05	0.05	0.03		0.00	0.00
Industrial processes	231.46	222.83	205.68	195.55	-87.88	-190.98
Chemical Industry	231.46	222.83	205.68	195.55	-87.88	-190.98
Agriculture	-11.25	-28.04	-74.19	18.93	-179.03	-254.22
Manure Management	4.00	7.18	8.57	8.13	-17.23	2.44
Agricultural Soils	-15.25	-35.21	-82.77	10.79	-161.80	-256.67
Field Burning of Agricultural Residues						0.01
Land Use. Land-Use Change and Forestry				4.99	-0.10	
Forest Land				0.04	-0.10	
Cropland				4.94	0.00	
Waste					3.31	3.32
Waste-water Handling					3.31	3.32
TOTAL	-242.68	-353.80	-537.42	-501.43	-482.04	-660.29

Table 9.5   ***Recalculation of F-gases emissions (differences compared to previous submission, in kt CO$_2$ eq)***

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC						-82.46	-179.14	-277.22	-360.13	-501.13	-667.29
PFC											
SF$_6$											
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-82.46**	**-179.14**	**-277.22**	**-360.13**	**-501.13**	**-667.29**

Year	2001	2002	2003	2004	2005	2006
HFC	-842.13	-987.77	-1343.96	-1431.14	-1951.54	-4051.36
PFC				-0.33	-0.41	0.63
SF6						
TOTAL	**-842.13**	**-987.77**	**-1343.96**	**-1431.47**	**-1951.95**	**-4050.73**

In ***Table 9.6*** the effect of the recalculations made on the total GHG emissions in Greece excluding LULUCF on a per gas basis is presented.

Table 9.6   *Comparison of the 2008 inventory results with the results of the present inventory (in Mt CO2 eq)*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2 emissions											
2008 submission	79.22	79.36	81.62	80.63	83.07	82.63	85.30	90.17	95.19	93.77	100.52
2009 submission	79.90	79.28	81.52	80.36	82.81	82.34	85.05	89.73	95.04	93.43	100.80
Change (%)	0.86	-0.10	-0.13	-0.33	-0.31	-0.34	-0.30	-0.49	-0.16	-0.36	0.28
CH_4 emissions											
2008 submission	9.03	9.00	9.10	9.05	9.13	9.10	9.24	9.22	9.34	9.02	9.01
2009 submission	9.05	9.04	9.01	9.00	9.09	9.09	9.25	9.27	9.41	9.10	9.10
Change (%)	0.21	0.39	-0.98	-0.61	-0.35	-0.07	0.15	0.53	0.71	0.90	1.01
N_2O emissions											
2008 submission	12.01	11.85	11.70	11.03	11.25	10.99	11.45	11.14	10.97	11.03	11.11
2009 submission	12.22	11.90	11.74	10.89	10.73	11.04	11.29	11.08	11.00	10.92	10.80
Change (%)	1.75	0.38	0.36	-1.26	-4.63	0.41	-1.40	-0.49	0.27	-0.92	-2.79
F-gases emissions											
2008 submission	1.20	1.37	1.16	1.76	2.24	3.42	4.00	4.42	4.95	5.70	4.64
2009 submission	1.20	1.37	1.16	1.76	2.24	3.34	3.82	4.14	4.59	5.20	3.97
Change (%)	0.00	0.00	0.00	0.00	0.00	-2.41	-4.47	-6.28	-7.28	-8.79	-14.39
Total emissions											
2008 submission	104.68	105.17	106.59	106.30	109.19	110.53	113.98	118.88	123.92	123.96	128.26
2009 submission	105.56	105.15	106.42	105.82	108.36	110.18	113.38	118.13	123.48	123.08	127.13
Change (%)	0.85	-0.02	-0.16	-0.45	-0.76	-0.32	-0.53	-0.63	-0.36	-0.71	-0.88

Year	2001	2002	2003	2004	2005	2006
CO_2 emissions						
2008 submission	100.68	100.20	104.35	104.77	105.26	104.45
2009 submission	100.65	100.00	104.47	104.61	106.05	104.53
Change (%)	-0.03	-0.20	0.12	-0.15	0.75	0.08
CH_4 emissions						
2008 submission	8.47	8.42	8.34	8.30	8.27	8.42
2009 submission	8.57	8.52	8.41	8.31	8.15	8.14
Change (%)	1.17	1.23	0.81	0.21	-1.45	-3.31
N_2O emissions						
2008 submission	10.87	10.86	10.91	10.79	10.41	10.32
2009 submission	10.63	10.51	10.37	10.29	9.93	9.66
Change (%)	-2.23	-3.26	-4.93	-4.65	-4.63	-6.40
F-gases emissions						
2008 submission	4.25	4.46	4.37	4.45	4.66	4.72
2009 submission	3.40	3.47	3.02	3.02	2.71	0.68
Change (%)	-19.84	-22.14	-30.77	-32.17	-41.88	-85.68
Total emissions						
2008 submission	129.59	129.42	133.51	133.73	133.83	133.12
2009 submission	128.21	127.78	131.30	131.35	131.83	128.09
Change (%)	-1.06	-1.27	-1.66	-1.77	-1.50	-3.78

9.3   Implications for emissions trends

Total GHG emissions (without LULUCF) in the current submission are a little higher for the period 1990 to 1991 and lower for period 1992 to 2006 compared to emissions reported in the 2008 submission. Taking into consideration that in most cases the recalculations concerned the whole period, emissions trends have not been affected significantly (Figure 1). The most significant decrease has been identified between years 2005 and 2006 mainly due to the cease of halocarbons production (HCFC-22).

Thus, the average annual rate of emissions increase for the period 1990 – 2006 in the present inventory is calculated to be similar compared to the one that had been calculated in the previous inventory (1.32% and 1.60% respectively).
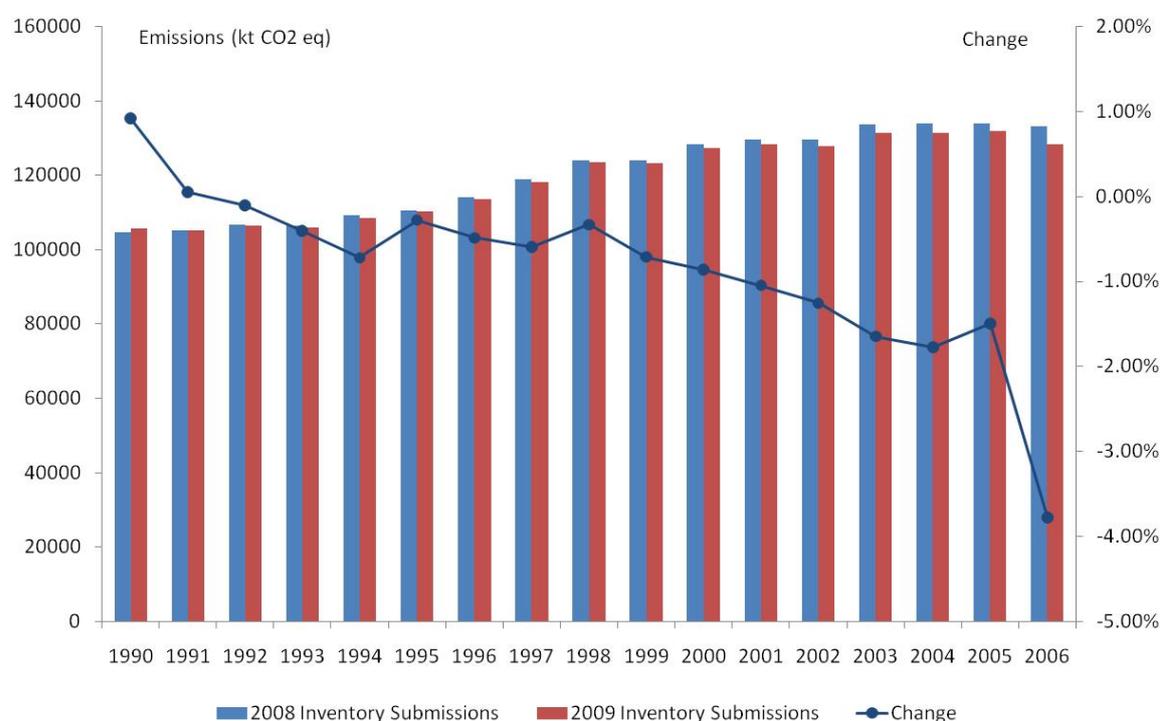
Figure 9.1   GHG emissions trends in Greece for the period 1990 – 2006 (without LULUCF) according to the inventories submitted in 2008 &2009

9.4   Planned improvements

Details on the improvements planned per source/sink category have been presented in the respective chapters (Chapters 3 – 8). Furthermore, the improvement of the completeness of the GHG emissions inventory will be further investigated, along with the possibility to implement methodologies consistent with the IPCC Good Practice Guidance for some key categories.

In year 2009 an internal inventory review by an independent national expert will take place. Based on the finding of this review improving actions will be planned and executed. Moreover, the further reallocation of emissions to the correct sector consistent to UNFCCC guidelines is under process (e.g. non-energy fuels used as feedstock to be included from energy to industrial processes sector).

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.

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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.

5. The use of source category-specific good practice methods is preferable, unless resources are unavailable.

6. 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. 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, which in case of Greece is 1990 for CO_2, CH_4 and N_2O and 1995 for the F-gases.

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***).

Table I.1   *Key categories analysis without LULUCF – Level assessment for 2007*

IPCC source categories	GHG	Base year (Gg CO2 eq)	Current year (Gg CO2eq)	Level Assessment	Cumulative total
Stationary Combustion Solid fuels	CO2	39,873.31	44,767.97	33.95	33.95
Stationary Combustion Liquid fuels	CO2	21,484.24	29,887.31	22.67	56.62
Road Transportation	CO2	11,761.40	19,785.00	15.01	71.62
Stationary Combustion Gaseous fuels	CO2	295.94	7,336.03	5.56	77.19
Cement Production	CO2	5,640.90	6,272.31	4.76	81.95
Animal Production	N2O	3,383.45	3,379.25	2.56	84.51
Enteric fermentation	CH4	2,877.43	2,930.48	2.22	86.73
Indirect N2O from nitrogen used in agr.	N2O	3,591.25	2,612.99	1.98	88.71
Solid waste disposal on land	CH4	1,806.88	2,443.87	1.85	90.57
Navigation	CO2	1,824.81	2,113.06	1.60	92.17
Direct N2O from agr. Soils	N2O	2,740.61	1,451.72	1.10	93.27
Coal Mining (surface)	CH4	1,095.27	1,402.72	1.06	94.33
Civil Aviation	CO2	716.84	1,347.83	1.02	95.36
ODS substitutes	HFC	1.15	665.57	0.50	95.86
Manure management	CH4	496.76	486.91	0.37	96.23
Lime Production	CO2	431.97	468.98	0.36	96.59
Nitric Acid Production	N2O	1,109.04	439.53	0.33	96.92
Wastewater handling	N2O	325.05	376.94	0.29	97.20
Stationary Combustion Liquid fuels	N2O	385.19	368.75	0.28	97.48
Wastewater handling	CH4	2,318.94	357.81	0.27	97.76
Ammonia Production	CO2	0.00	321.45	0.24	98.00
Limestone & Dolomite Use	CO2	285.60	296.97	0.23	98.23
Manure management	N2O	301.45	294.11	0.22	98.45
Aluminium Production	CO2	231.96	257.32	0.20	98.64
Iron and Steel Production	CO2	92.70	229.71	0.17	98.82
Road Transportation	N2O	122.76	226.98	0.17	98.99
Stationary Combustion Solid fuels	N2O	155.33	173.11	0.13	99.12
Solvent and other product use	CO2	169.71	160.34	0.12	99.24
Oil, Natural Gas and Other sources	CH4	91.59	158.21	0.12	99.36
Railways	CO2	202.69	118.00	0.09	99.45
Solid fuels – Other	CO2	0.00	106.79	0.08	99.53
Rice Production	CH4	69.10	105.00	0.08	99.61
Road Transportation	CH4	108.19	100.19	0.08	99.69
Stationary Combustion Biomass	CH4	81.62	74.55	0.06	99.75
Ferroalloys	CO2	47.36	61.91	0.05	99.79
Aluminium Production	PFCs	82.97	58.66	0.04	99.84
Stationary Combustion Biomass	N2O	41.71	40.14	0.03	99.87
Field burning of agr.residues	CH4	27.06	26.94	0.02	99.89
Stationary Combustion Liquid fuels	CH4	17.03	24.68	0.02	99.91
Other Mineral (Glass)	CO2	20.20	17.38	0.01	99.92
Navigation	N2O	14.21	16.62	0.01	99.93
Civil Aviation	N2O	7.71	14.46	0.01	99.94
Railways	N2O	24.22	14.22	0.01	99.95
Field burning of agr.residues	N2O	10.05	10.35	0.01	99.96
SF6 from electrical equipment	SF6	3.59	9.92	0.01	99.97
Stationary Combustion Solid fuels	CH4	7.02	7.97	0.01	99.98
Other transportation	CO2	0.00	7.44	0.01	99.98
Oil, Natural Gas and Other sources	CO2	70.23	6.96	0.01	99.99
Stationary Combustion Gaseous fuels	N2O	0.51	6.51	0.00	99.99

IPCC source categories	GHG	Base year (Gg CO$_2$ eq)	Current year (Gg CO$_2$eq)	Level Assessment	Cumulative total
Waste incineration	CO2	0.15	3.06	0.00	99.99
Stationary Combustion Gaseous fuels	CH4	0.10	2.79	0.00	100.00
Railways	CH4	2.38	1.40	0.00	100.00
Navigation	CH4	3.61	0.70	0.00	100.00
Civil Aviation	CH4	0.26	0.47	0.00	100.00
Other transportation	N2O	0.00	0.06	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.02	0.00	100.00
Other transportation	CH4	0.00	0.00	0.00	100.00
Other Chemicals	CH4	0.52	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	0.00	0.00	100.00
		107,707.25	131,850.45		

Table I.2   *Key categories analysis with LULUCF – Level assessment for 2007*

IPCC source categories	GHG	Current year (Gg CO₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Stationary Combustion Solid fuels	CO2	44,768.0	32.96	32.96
Stationary Combustion Liquid fuels	CO2	29,887.3	22.01	55.0
Road Transportation	CO2	19,785.0	14.57	69.5
Stationary Combustion Gaseous fuels	CO2	7,336.0	5.40	74.9
Cement Production	CO2	6,272.3	4.62	79.6
Animal Production	N2O	3,379.3	2.49	82.0
Enteric fermentation	CH4	2,930.5	2.16	84.2
Indirect N2O from nitrogen used in agr.	N2O	2,613.0	1.92	86.1
Forest Land remaining Forest Land	CO2	2,451.8	1.81	87.9
Solid waste disposal on land	CH4	2,443.9	1.80	89.7
Navigation	CO2	2,113.1	1.56	91.3
Direct N2O from agr. Soils	N2O	1,451.7	1.07	92.4
Coal Mining (surface)	CH4	1,402.7	1.03	93.4
Civil Aviation	CO2	1,347.8	0.99	94.4
Cropland remaining Cropland	CO2	832.6	0.61	95.0
ODS substitutes	HFC	665.6	0.49	95.5
Conversion to Forest Land	CO2	523.6	0.39	95.9
Manure management	CH4	486.9	0.36	96.2
Lime Production	CO2	469.0	0.35	96.6
Nitric Acid Production	N2O	439.5	0.32	96.9
Wastewater handling	N2O	376.9	0.28	97.2
Stationary Combustion Liquid fuels	N2O	368.8	0.27	97.4
Wastewater handling	CH4	357.8	0.26	97.7
Ammonia Production	CO2	321.5	0.24	97.9
Limestone & Dolomite Use	CO2	297.0	0.22	98.2
Manure management	N2O	294.1	0.22	98.4
Aluminium Production	CO2	257.3	0.19	98.6
Iron and Steel Production	CO2	229.7	0.17	98.7
Road Transportation	N2O	227.0	0.17	98.9
Stationary Combustion Solid fuels	N2O	173.1	0.13	99.0
Solvent and other product use	CO2	160.3	0.12	99.2
Oil, Natural Gas and Other sources	CH4	158.2	0.12	99.3
Forest Land remaining Forest Land	CH4	134.9	0.10	99.4
Railways	CO2	118.0	0.09	99.5
Solid fuels – Other	CO2	106.8	0.08	99.5
Rice Production	CH4	105.0	0.08	99.6
Road Transportation	CH4	100.2	0.07	99.7
Stationary Combustion Biomass	CH4	74.6	0.05	99.7
Ferroalloys	CO2	61.9	0.05	99.8
Aluminium Production	PFCs	58.7	0.04	99.8
Stationary Combustion Biomass	N2O	40.1	0.03	99.9
Field burning of agr.residues	CH4	26.9	0.02	99.9
Stationary Combustion Liquid fuels	CH4	24.7	0.02	99.9
Other Mineral (Glass)	CO2	17.4	0.01	99.9
Navigation	N2O	16.6	0.01	99.9
Civil Aviation	N2O	14.5	0.01	99.9
Railways	N2O	14.2	0.01	99.9
Forest Land remaining Forest Land	N2O	13.7	0.01	100.0
Field burning of agr.residues	N2O	10.4	0.01	100.0
SF6 from electrical equipment	SF6	9.9	0.01	100.0

IPCC source categories	GHG	Current year (Gg CO₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Stationary Combustion Solid fuels	CH4	8.0	0.01	100.0
Grassland remaining Grassland	CH4	7.8	0.01	100.0
Other transportation	CO2	7.4	0.01	100.0
Oil, Natural Gas and Other sources	CO2	7.0	0.01	100.0
Stationary Combustion Gaseous fuels	N2O	6.5	0.00	100.0
Waste incineration	CO2	3.1	0.00	100.0
Stationary Combustion Gaseous fuels	CH4	2.8	0.00	100.0
Railways	CH4	1.4	0.00	100.0
Grassland remaining Grassland	N2O	0.8	0.00	100.0
Navigation	CH4	0.7	0.00	100.0
Civil Aviation	CH4	0.5	0.00	100.0
Other transportation	N2O	0.1	0.00	100.0
Oil, Natural Gas and Other sources	N2O	0.0	0.00	100.0
Other transportation	CH4	0.0	0.00	100.0
Other Chemicals	CH4	0.0	0.00	100.0
HFC-23 Emissions from HCFC-22 Manufacture	HFC	0.0	0.00	100.0
		135,819.59		

Table I.3   *Key categories analysis without LULUCF – Level assessment for Base year*

IPCC source categories	GHG	Base year (Gg CO₂ eq)	Level Assessment (Base Year)	Cumulative total
Stationary Combustion Solid fuels	CO2	39,873.31	37.02	37.02
Stationary Combustion Liquid fuels	CO2	21,484.24	19.95	56.97
Road Transportation	CO2	11,761.40	10.92	67.89
Cement Production	CO2	5,640.90	5.24	73.12
Indirect N2O from nitrogen used in agr.	N2O	3,591.25	3.33	76.46
Animal Production	N2O	3,383.45	3.14	79.60
HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	3.02	82.62
Enteric fermentation	CH4	2,877.43	2.67	85.29
Direct N2O from agr. Soils	N2O	2,740.61	2.54	87.84
Wastewater handling	CH4	2,318.94	2.15	89.99
Navigation	CO2	1,824.81	1.69	91.68
Solid waste disposal on land	CH4	1,806.88	1.68	93.36
Nitric Acid Production	N2O	1,109.04	1.03	94.39
Coal Mining (surface)	CH4	1,095.27	1.02	95.41
Civil Aviation	CO2	716.84	0.67	96.07
Manure management	CH4	496.76	0.46	96.53
Lime Production	CO2	431.97	0.40	96.94
Stationary Combustion Liquid fuels	N2O	385.19	0.36	97.29
Wastewater handling	N2O	325.05	0.30	97.59
Manure management	N2O	301.45	0.28	97.87
Stationary Combustion Gaseous fuels	CO2	295.94	0.27	98.15
Limestone & Dolomite Use	CO2	285.60	0.27	98.41
Aluminium Production	CO2	231.96	0.22	98.63
Railways	CO2	202.69	0.19	98.82
Solvent and other product use	CO2	169.71	0.16	98.98
Stationary Combustion Solid fuels	N2O	155.33	0.14	99.12
Road Transportation	N2O	122.76	0.11	99.23
Road Transportation	CH4	108.19	0.10	99.33
Iron and Steel Production	CO2	92.70	0.09	99.42
Oil, Natural Gas and Other sources	CH4	91.59	0.09	99.51
Aluminium Production	PFCs	82.97	0.08	99.58
Stationary Combustion Biomass	CH4	81.62	0.08	99.66
Oil, Natural Gas and Other sources	CO2	70.23	0.07	99.72
Rice Production	CH4	69.10	0.06	99.79
Ferroalloys	CO2	47.36	0.04	99.83
Stationary Combustion Biomass	N2O	41.71	0.04	99.87
Field burning of agr.residues	CH4	27.06	0.03	99.90
Railways	N2O	24.22	0.02	99.92
Other Mineral (Glass)	CO2	20.20	0.02	99.94
Stationary Combustion Liquid fuels	CH4	17.03	0.02	99.95
Navigation	N2O	14.21	0.01	99.97
Field burning of agr.residues	N2O	10.05	0.01	99.97
Civil Aviation	N2O	7.71	0.01	99.98
Stationary Combustion Solid fuels	CH4	7.02	0.01	99.99
Navigation	CH4	3.61	0.00	99.99
SF6 from electrical equipment	SF6	3.59	0.00	100.00
Railways	CH4	2.38	0.00	100.00
ODS substitutes	HFC	1.15	0.00	100.00
Other Chemicals	CH4	0.52	0.00	100.00

IPCC source categories	GHG	Base year (Gg CO₂ eq)	Level Assessment (Base Year)	Cumulative total
Stationary Combustion Gaseous fuels	N2O	0.51	0.00	100.00
Civil Aviation	CH4	0.26	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.00	100.00
Waste incineration	CO2	0.15	0.00	100.00
Stationary Combustion Gaseous fuels	CH4	0.10	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
Solid fuels – Other	CO2	0.00	0.00	100.00
Ammonia Production	CO2	0.00	0.00	100.00
107,707.25				

Table I.4   *Key categories analysis with LULUCF – Level assessment for Base year*

IPCC source categories	GHG	Base year (Gg CO₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
Stationary Combustion Solid fuels	CO2	39,873.31	35.92	35.92
Stationary Combustion Liquid fuels	CO2	21,484.24	19.35	55.27
Road Transportation	CO2	11,761.40	10.59	65.87
Cement Production	CO2	5,640.90	5.08	70.95
Indirect N2O from nitrogen used in agr.	N2O	3,591.25	3.24	74.18
Animal Production	N2O	3,383.45	3.05	77.23
HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	2.93	80.16
Enteric fermentation	CH4	2,877.43	2.59	82.75
Direct N2O from agr. Soils	N2O	2,740.61	2.47	85.22
Wastewater handling	CH4	2,318.94	2.09	87.31
Forest Land remaining Forest Land	CO2	2,042.79	1.84	89.15
Navigation	CO2	1,824.81	1.64	90.80
Solid waste disposal on land	CH4	1,806.88	1.63	92.42
Cropland remaining Cropland	CO2	1,205.41	1.09	93.51
Nitric Acid Production	N2O	1,109.04	1.00	94.51
Coal Mining (surface)	CH4	1,095.27	0.99	95.49
Civil Aviation	CO2	716.84	0.65	96.14
Manure management	CH4	496.76	0.45	96.59
Lime Production	CO2	431.97	0.39	96.98
Stationary Combustion Liquid fuels	N2O	385.19	0.35	97.32
Wastewater handling	N2O	325.05	0.29	97.62
Manure management	N2O	301.45	0.27	97.89
Stationary Combustion Gaseous fuels	CO2	295.94	0.27	98.15
Limestone & Dolomite Use	CO2	285.60	0.26	98.41
Aluminium Production	CO2	231.96	0.21	98.62
Railways	CO2	202.69	0.18	98.80
Solvent and other product use	CO2	169.71	0.15	98.96
Stationary Combustion Solid fuels	N2O	155.33	0.14	99.10
Road Transportation	N2O	122.76	0.11	99.21
Road Transportation	CH4	108.19	0.10	99.30
Iron and Steel Production	CO2	92.70	0.08	99.39
Oil, Natural Gas and Other sources	CH4	91.59	0.08	99.47
Aluminium Production	PFCs	82.97	0.07	99.55
Stationary Combustion Biomass	CH4	81.62	0.07	99.62
Oil, Natural Gas and Other sources	CO2	70.23	0.06	99.68
Rice Production	CH4	69.10	0.06	99.74
Forest Land remaining Forest Land	CH4	48.08	0.04	99.79
Ferroalloys	CO2	47.36	0.04	99.83
Stationary Combustion Biomass	N2O	41.71	0.04	99.87
Field burning of agr.residues	CH4	27.06	0.02	99.89
Railways	N2O	24.22	0.02	99.91
Other Mineral (Glass)	CO2	20.20	0.02	99.93
Stationary Combustion Liquid fuels	CH4	17.03	0.02	99.95
Navigation	N2O	14.21	0.01	99.96
Field burning of agr.residues	N2O	10.05	0.01	99.97
Civil Aviation	N2O	7.71	0.01	99.98
Stationary Combustion Solid fuels	CH4	7.02	0.01	99.98
Forest Land remaining Forest Land	N2O	4.88	0.00	99.99
Navigation	CH4	3.61	0.00	99.99

IPCC source categories	GHG	Base year (Gg CO₂ eq) (absolute values)	Level Assessment with LULUCF	Cumulative total
SF6 from electrical equipment	SF6	3.59	0.00	99.99
Railways	CH4	2.38	0.00	100.00
Grassland remaining Grassland	CH4	1.80	0.00	100.00
ODS substitutes	HFC	1.15	0.00	100.00
Other Chemicals	CH4	0.52	0.00	100.00
Stationary Combustion Gaseous fuels	N2O	0.51	0.00	100.00
Civil Aviation	CH4	0.26	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.00	100.00
Grassland remaining Grassland	N2O	0.18	0.00	100.00
Waste incineration	CO2	0.15	0.00	100.00
Stationary Combustion Gaseous fuels	CH4	0.10	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
Solid fuels – Other	CO2	0.00	0.00	100.00
Ammonia Production	CO2	0.00	0.00	100.00
Conversion to Forest Land	CO2	0.00	0.00	100.00
		135,819.59		

Table I.5   *Key categories analysis without LULUCF – Trend assessment for 2007*

IPCC source categories	GHG	Base year (Gg CO₂ eq)	Current year (Gg CO₂eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
Stationary Combustion Liquid fuels	CO2	21,484.24	29,887.31	34.80	22.29	22.29
Road Transportation	CO2	11,761.40	19,785.00	33.23	21.28	43.57
Stationary Combustion Gaseous fuels	CO2	295.94	7,336.03	29.16	18.67	62.25
Stationary Combustion Solid fuels	CO2	39,873.31	44,767.97	20.27	12.98	75.23
Wastewater handling	CH4	2,318.94	357.81	8.12	5.20	80.43
Direct N2O from agr. soils	N2O	2,740.61	1,451.72	5.34	3.42	83.85
Indirect N2O from nitrogen used in agr.	N2O	3,591.25	2,612.99	4.05	2.59	86.45
Nitric Acid Production	N2O	1,109.04	439.53	2.77	1.78	88.22
ODS substitutes	HFC	1.15	665.57	2.75	1.76	89.99
Solid waste disposal on land	CH4	1,806.88	2,443.87	2.64	1.69	91.68
Cement Production	CO2	5,640.90	6,272.31	2.61	1.67	93.35
Civil Aviation	CO2	716.84	1,347.83	2.61	1.67	95.02
Ammonia Production	CO2	0.00	321.45	1.33	0.85	95.88
Coal Mining (surface)	CH4	1,095.27	1,402.72	1.27	0.82	96.69
Navigation	CO2	1,824.81	2,113.06	1.19	0.76	97.46
Iron and Steel Production	CO2	92.70	229.71	0.57	0.36	97.82
Solid fuels - Other	CO2	0.00	106.79	0.44	0.28	98.10
Road Transportation	N2O	122.76	226.98	0.43	0.28	98.38
Railways	CO2	202.69	118.00	0.35	0.22	98.61
Oil, Natural Gas and Other sources	CH4	91.59	158.21	0.28	0.18	98.78
Oil, Natural Gas and Other sources	CO2	70.23	6.96	0.26	0.17	98.95
Enteric fermentation	CH4	2,877.43	2,930.48	0.22	0.14	99.09
Wastewater handling	N2O	325.05	376.94	0.21	0.14	99.23
Lime Production	CO2	431.97	468.98	0.15	0.10	99.33
Rice Production	CH4	69.10	105.00	0.15	0.10	99.42
Aluminium Production	CO2	231.96	257.32	0.11	0.07	99.49
Aluminium Production	PFCs	82.97	58.66	0.10	0.06	99.55
Stationary Combustion Solid fuels	N2O	155.33	173.11	0.07	0.05	99.60
Stationary Combustion Liquid fuels	N2O	385.19	368.75	0.07	0.04	99.64
Ferroalloys	CO2	47.36	61.91	0.06	0.04	99.68
Limestone & Dolomite Use	CO2	285.60	296.97	0.05	0.03	99.71
Railways	N2O	24.22	14.22	0.04	0.03	99.74
Manure management	CH4	496.76	486.91	0.04	0.03	99.77
Solvent and other product use	CO2	169.71	160.34	0.04	0.02	99.79
Road Transportation	CH4	108.19	100.19	0.03	0.02	99.81
Stationary Combustion Liquid fuels	CH4	17.03	24.68	0.03	0.02	99.83
Other transportation	CO2	0.00	7.44	0.03	0.02	99.85
Manure management	N2O	301.45	294.11	0.03	0.02	99.87
Stationary Combustion Biomass	CH4	81.62	74.55	0.03	0.02	99.89
Civil Aviation	N2O	7.71	14.46	0.03	0.02	99.91
SF6 from electrical equipment	SF6	3.59	9.92	0.03	0.02	99.92
Stationary Combustion Gaseous fuels	N2O	0.51	6.51	0.02	0.02	99.94
Animal Production	N2O	3,383.45	3,379.25	0.02	0.01	99.95
Waste incineration	CO2	0.15	3.06	0.01	0.01	99.96
Navigation	CH4	3.61	0.70	0.01	0.01	99.97
Other Mineral (Glass)	CO2	20.20	17.38	0.01	0.01	99.97
Stationary Combustion Gaseous fuels	CH4	0.10	2.79	0.01	0.01	99.98
Navigation	N2O	14.21	16.62	0.01	0.01	99.99
Stationary Combustion Biomass	N2O	41.71	40.14	0.01	0.00	99.99

IPCC source categories	GHG	Base year (Gg CO₂ eq)	Current year (Gg CO₂eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
Railways	CH4	2.38	1.40	0.00	0.00	100.00
Stationary Combustion Solid fuels	CH4	7.02	7.97	0.00	0.00	100.00
Field burning of agr.residues	N2O	10.05	10.35	0.00	0.00	100.00
Civil Aviation	CH4	0.26	0.47	0.00	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.02	0.00	0.00	100.00
Field burning of agr.residues	CH4	27.06	26.94	0.00	0.00	100.00
Other transportation	N2O	0.00	0.06	0.00	0.00	100.00
Other transportation	CH4	0.00	0.00	0.00	0.00	100.00
Other Chemicals	CH4	0.52	0.00	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	0.00	0.00	0.00	100.00
		107,707.20	131,850.45	0.18	100.0	

Table I.6   *Key categories analysis with LULUCF – Trend assessment for 2007*

IPCC source / sink categories	GHG	Base year (Gg CO₂ eq)	Current year (Gg CO₂eq)	Trend Assessment (Absolute)	Contribution to trend (%)	Cumulative total
Stationary Combustion Gaseous fuels	CO2	295.94	7,336.03	0.05	22.13	22.13
Road Transportation	CO2	11,761.40	19,785.00	0.04	19.44	41.57
Stationary Combustion Liquid fuels	CO2	21,484.24	29,887.31	0.04	15.73	57.30
Stationary Combustion Solid fuels	CO2	39,873.31	44,767.97	0.01	4.66	61.97
Wastewater handling	CH4	2,318.94	357.81	0.02	7.38	69.34
Direct N2O from agr. soils	N2O	2,740.61	1,451.72	0.01	5.46	74.81
Indirect N2O from nitrogen used in agr.	N2O	3,591.25	2,612.99	0.01	4.91	79.72
Nitric Acid Production	N2O	1,109.04	439.53	0.01	2.68	82.40
ODS substitutes	HFC	1.15	665.57	0.00	2.10	84.50
Animal Production	N2O	3,383.45	3,379.25	0.00	1.72	86.22
Cropland remaining Cropland	CO2	-1,205.41	-832.57	0.00	1.79	88.01
Conversion to Forest Land	CO2	0.00	-523.57	0.00	1.66	89.67
Civil Aviation	CO2	716.84	1,347.83	0.00	1.63	91.30
Enteric fermentation	CH4	2,877.43	2,930.48	0.00	1.29	92.59
Cement Production	CO2	5,640.90	6,272.31	0.00	0.85	93.44
Ammonia Production	CO2	0.00	321.45	0.00	1.02	94.46
Solid waste disposal on land	CH4	1,806.88	2,443.87	0.00	1.10	95.56
Railways	CO2	202.69	118.00	0.00	0.37	95.93
Iron and Steel Production	CO2	92.70	229.71	0.00	0.39	96.32
Solid fuels - Other	CO2	0.00	106.79	0.00	0.34	96.66
Coal Mining (surface)	CH4	1,095.27	1,402.72	0.00	0.42	97.08
Manure management	CH4	496.76	486.91	0.00	0.28	97.36
Stationary Combustion Liquid fuels	N2O	385.19	368.75	0.00	0.25	97.61
Road Transportation	N2O	122.76	226.98	0.00	0.27	97.87
Forest Land remaining Forest Land	CH4	48.08	134.94	0.00	0.25	98.12

IPCC source / sink categories	GHG	Base year (Gg CO₂ eq)	Current year (Gg CO₂eq)	Trend Assessment (Absolute)	Contribution to trend (%)	Cumulative total
Oil, Natural Gas and Other sources	CO2	70.23	6.96	0.00	0.24	98.36
Manure management	N2O	301.45	294.11	0.00	0.18	98.53
Oil, Natural Gas and Other sources	CH4	91.59	158.21	0.00	0.16	98.70
Navigation	CO2	1,824.81	2,113.06	0.00	0.01	98.71
Lime Production	CO2	431.97	468.98	0.00	0.10	98.81
Limestone & Dolomite Use	CO2	285.60	296.97	0.00	0.11	98.92
Solvent and other product use	CO2	169.71	160.34	0.00	0.12	99.03
Aluminium Production	PFCs	82.97	58.66	0.00	0.12	99.15
Forest Land remaining Forest Land	CO2	-2,042.79	-2,451.82	0.00	0.26	99.42
Road Transportation	CH4	108.19	100.19	0.00	0.08	99.50
Rice Production	CH4	69.10	105.00	0.00	0.08	99.57
Stationary Combustion Biomass	CH4	81.62	74.55	0.00	0.06	99.64
Aluminium Production	CO2	231.96	257.32	0.00	0.04	99.67
Railways	N2O	24.22	14.22	0.00	0.04	99.72
Stationary Combustion Solid fuels	N2O	155.33	173.11	0.00	0.02	99.74
Stationary Combustion Biomass	N2O	41.71	40.14	0.00	0.03	99.77
Wastewater handling	N2O	325.05	376.94	0.00	0.00	99.77
Forest Land remaining Forest Land	N2O	4.88	13.69	0.00	0.03	99.79
Other transportation	CO2	0.00	7.44	0.00	0.02	99.82
Other Mineral (Glass)	CO2	20.20	17.38	0.00	0.02	99.83
Stationary Combustion Gaseous fuels	N2O	0.51	6.51	0.00	0.02	99.85
Ferroalloys	CO2	47.36	61.91	0.00	0.02	99.88
SF6 from electrical equipment	SF6	3.59	9.92	0.00	0.02	99.89
Grassland remaining Grassland	CH4	1.80	7.76	0.00	0.02	99.91
Civil Aviation	N2O	7.71	14.46	0.00	0.02	99.93
Field burning of agr.residues	CH4	27.06	26.94	0.00	0.01	99.94
Stationary Combustion Liquid fuels	CH4	17.03	24.68	0.00	0.02	99.96

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
Navigation	CH4	3.61	0.70	0.00	0.01	99.97
Waste incineration	CO2	0.15	3.06	0.00	0.01	99.98
Stationary Combustion Gaseous fuels	CH4	0.10	2.79	0.00	0.01	99.99
Field burning of agr.residues	N2O	10.05	10.35	0.00	0.00	99.99
Railways	CH4	2.38	1.40	0.00	0.00	100.00
Grassland remaining Grassland	N2O	0.18	0.79	0.00	0.00	100.00
Stationary Combustion Solid fuels	CH4	7.02	7.97	0.00	0.00	100.00
Oil, Natural Gas and Other sources	N2O	0.20	0.02	0.00	0.00	100.00
Navigation	N2O	14.21	16.62	0.00	0.00	100.00
Civil Aviation	CH4	0.26	0.47	0.00	0.00	100.00
Other transportation	N2O	0.00	0.06	0.00	0.00	100.00
Other transportation	CH4	0.00	0.00	0.00	0.00	100.00
Other Chemicals	CH4	0.52	0.00	0.00	0.00	100.00
HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	0.00	0.00	0.00	100.00
		104,513.93	128,203.06	0.23	100.0	

Annex II: CO$_2$ emissions from Energy – Sectoral approach

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 in order to calculate plant specific CO$_2$ emission factors per sector (IPCC source category) and fuel. We also capitalize on them to estimate CH$_4$ and N$_2$O 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 3.6 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 Ministry for Development 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.

Table II.1   *Correspondence between IPCC source categories, energy balance sectors and*
                     CORINAIR activities

Energy balance sectors	IPCC source categories	CORINAIR activities
Production	Reference approach	
Imports	Reference approach	
Exports	Reference approach	
International marine bunkers	Reference approach /Bunkers	080404 – International marine bunkers
Stock changes	Reference approach	
TRANSFORMATION		
Electricity plants	1.A.1a	0101 – Public power / steam turbines, gas turbines, stationary engines
CHP plants	1.A.2a – 1.A.2f	
Heat plants	1.A.1a	
ENERGY SECTOR		
Petroleum refineries	1.A.1b	0103 – Petroleum refining plants
Oil and gas extraction	1.A.1c	010504 – Coal mining. oil/gas extraction, pipeline compressors / gas turbines
		010503 – Coal mining. oil/gas extraction, pipeline compressors / boilers
INDUSTRY		
Iron and steel	1.A.2a	030302 – Reheating furnaces
		030303 – Grey iron foundries
Chemical industry	1.A.2c	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
of which: Feedstocks	Non-energy uses	
Non-ferrous metals	1.A.2b	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
		030322 – Alumina production
Non-metallic minerals	1.A.2f	030311 – Cement
		030312 – Lime
		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 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Primary production	51896	52695	55051	54817	56672	57662	59781	58844	60884	62051	63887	66344	70468	68299	70041	69398	64521	66496
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exports	0	0	14	0	0	0	0	22	6	21	21	0	0	0	0	0	0	0
Stock changes	157	-1144	-544	366	1301	-700	-1629	-197	-254	-1083	698	911	-1746	1770	827	698	-189	59
DOMESTIC SUPPLY	**52053**	**51551**	**54493**	**55183**	**57973**	**56962**	**58152**	**58625**	**60624**	**60947**	**64564**	**67255**	**68722**	**70069**	**70868**	**70096**	**64332**	**66561**
Transfers	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	14	0	0	0
TRANSFORMATION	**50881**	**50616**	**53993**	**54501**	**57463**	**56431**	**57511**	**58098**	**60160**	**60637**	**64100**	**67005**	**68566**	**69874**	**70655**	**69840**	**63956**	**66056**
Electricity plants	50531	50265	53790	54323	57249	56240	57354	57929	60027	60513	63864	66740	68221	69455	70233	55953	50267	52715
CHP plants[17]	0	0	0	0	0	0	0	0	0	0	0	0	0	6670	9631	13476	13423	13153
BKB plants	350	351	203	178	214	191	157	169	133	124	236	265	345	419	422	411	266	188
FINAL CONSUMPTION	**1172**	**935**	**500**	**682**	**510**	**531**	**641**	**527**	**464**	**310**	**464**	**250**	**156**	**195**	**199**	**256**	**376**	**317**
INDUSTRY	*515*	*432*	*379*	*552*	*406*	*408*	*503*	*418*	*362*	*235*	*381*	*172*	*156*	*195*	*195*	*224*	*345*	*313*
Iron and steel	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
Non-ferrous metals	299	318	359	445	333	342	439	359	355	233	379	170	156	195	195	224	345	313
Non-metallic minerals	17	20	13	22	15	4	4	2	2	2	2	2	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*
OTHER SECTORS	*78*	*125*	*121*	*130*	*104*	*123*	*138*	*109*	*102*	*75*	*83*	*78*	*0*	*0*	*4*	*32*	*31*	*4*
Agriculture	19	25	33	40	30	40	45	30	30	48	53	50	0	0	0	20	30	0
Commercial and public	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	4	12	1	4
Non-specified	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*

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[17] Fuel consumption in CHP plants is included in electricity plants

Table II.3   *Energy balance of natural gas in TJ (GCV) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Primary production	5783	5713	5279	3893	1992	1837	1939	1879	1687	105	1771	1683	1776	1298	1203	851	1209	1026
Imports	0	0	0	0	0	0	321	5415	28900	50918	70696	69912	73460	83824	91013	108495	126604	155138
Stock changes	0	0	0	0	0	0	-196	-135	-214	-29	-1102	-1130	173	-287	1098	141	-11	-336
DOMESTIC SUPPLY	**5783**	**5713**	**5279**	**3893**	**1992**	**1837**	**2064**	**7160**	**30372**	**50994**	**71366**	**70466**	**75408**	**84835**	**93314**	**109487**	**127802**	**155828**
Transfers	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	-58	17	0	0	16	-198	38	81	760
TRANSFORMATION	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1913**	**14267**	**35735**	**52324**	**51865**	**55058**	**61214**	**66404**	**74529**	**87877**	**114104**
Electricity plants	0	0	0	0	0	0	0	1913	14267	35735	52324	51865	55058	61214	66404	73621	87060	113520
CHP plants[18]	756	743	653	636	622	584	689	1027	491	545	1274	1098	1372	902	564	908	817	584
ENERGY SECTOR	**1737**	**1847**	**1603**	**1524**	**1756**	**1679**	**1769**	**1964**	**1460**	**138**	**2282**	**2102**	**1800**	**1595**	**1881**	**1768**	**1894**	**1659**
Oil and gas extraction	1737	1847	1603	1524	1756	1679	1769	1879	1424	105	1771	1683	1776	1537	1670	1437	1501	1354
Distribution losses	0	0	0	0	0	0	0	85	36	32	511	419	24	58	212	331	393	305
FINAL CONSUMPTION	**4046**	**3866**	**3677**	**2370**	**236**	**158**	**295**	**3283**	**14646**	**15180**	**16742**	**16498**	**18551**	**22010**	**25227**	**33190**	**38031**	**39305**
INDUSTRY SECTOR	*4046*	*3866*	*3677*	*2370*	*236*	*158*	*295*	*3283*	*14090*	*14707*	*16178*	*15476*	*16931*	*19559*	*21471*	*19801*	*20690*	*25391*
Iron and steel	0	0	0	0	0	0	0	104	1193	2072	2315	2697	2879	2476	2751	3252	3166	3639
Chemical industry	4046	3866	3677	2370	236	158	150	1681	8563	6591	5385	2843	3732	6076	6694	8421	8036	8217
Of which: Feedstocks	4046	3866	3677	2370	236	158	150	1681	8430	6256	5072	2479	3032	5175	5495	5959	6030	6379
Non-ferrous metals	0	0	0	0	0	0	0	0	234	1094	1647	1495	1785	2280	2316	2946	2372	2649
Non-metallic minerals	0	0	0	0	0	0	0	89	1095	1187	1638	2697	2927	2535	2793	3198	4316	3887
Transport equipment	0	0	0	0	0	0	0	8	67	56	41	73	50	59	61	75	87	352
Food and tobacco	0	0	0	0	0	0	145	1269	1893	2721	3517	2807	2903	3350	3731	5074	5840	3425
Paper. pulp	0	0	0	0	0	0	0	60	381	267	505	802	1036	1160	1301	1245	1557	1393
Wood and wood products	0	0	0	0	0	0	0	0	0	0	0	0	0	1	23	35	28	41
Construction	0	0	0	0	0	0	0	0	0	0	0	0	82	363	0	0	0	0
Textile and leather	0	0	0	0	0	0	0	72	660	720	914	1276	1128	1259	1244	896	817	1027
Non-specified	0	0	0	0	0	0	0	0	5	0	217	713	410	0	534	618	501	761
TRANSPORT	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*293*	*501*	*510*	*483*	*552*	*670*	*815*
Road transport	0	0	0	0	0	0	0	0	0	0	0	256	404	446	444	475	582	667
Pipeline transport	0	0	0	0	0	0	0	0	0	0	0	37	97	65	40	77	88	148
OTHER SECTOR	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*556*	*473*	*563*	*729*	*1119*	*1941*	*3272*	*6840*	*10648*	*13099*
Commercial and public	0	0	0	0	0	0	0	0	365	311	360	510	761	1158	1822	3434	4168	4883
Residential	0	0	0	0	0	0	0	0	191	163	203	219	358	783	1451	3406	6480	8216
NON-ENERGY USE	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

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[18] Fuel consumption in CHP plants is added to the respective industrial sectors

Table II.4   *Energy balance of heavy fuel oil (in kt) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production	5596	5374	5284	4419	5308	6061	7424	7149	6959	6326	7510	7361	7328	7543	7095	6956	6953	7116
Imports	2233	1806	2040	1955	1342	733	151	435	411	298	174	169	36	184	171	264	389	677
Exports	2026	1217	1710	654	832	616	1032	696	196	280	220	255	564	649	748	604	835	979
International marine bunkers	2063	1846	2052	2444	2557	2641	2399	2413	2798	2452	2898	2933	2624	2757	2809	2542	2761	2860
Stock changes	-80	-223	121	196	204	81	-72	7	-41	45	-32	25	-66	-36	159	-47	16	-261
DOMESTIC SUPPLY	**3660**	**3894**	**3683**	**3472**	**3465**	**3618**	**4072**	**4482**	**4335**	**3937**	**4534**	**4367**	**4110**	**4285**	**3868**	**4027**	**3762**	**3227**
Transfers	-733	-404	-287	-445	-453	-579	-653	-1135	-1125	-716	-1392	-1324	-1050	-1360	-955	-1006	-465	-629
Statistical differences	-245	186	143	-14	-17	-178	139	60	-117	-89	-37	-72	-38	-68	-128	-62	-26	-163
TRANSFORMATION	**1421**	**1559**	**1506**	**1598**	**1561**	**1697**	**1590**	**1541**	**1483**	**1585**	**1634**	**1539**	**1516**	**1513**	**1398**	**1601**	**1631**	**1581**
Electricity plants	1421	1559	1506	1598	1561	1697	1590	1541	1483	1585	1634	1539	1516	1513	1398	1595	1624	1576
CHP plants [19]	34	49	58	67	58	58	55	39	32	24	27	19	0	0	7	6	7	5
ENERGY SECTOR	**266**	**279**	**260**	**210**	**273**	**274**	**295**	**294**	**318**	**313**	**372**	**358**	**397**	**351**	**416**	**442**	**482**	**465**
Petroleum refineries	266	279	260	210	273	274	295	294	318	313	372	358	397	351	416	442	482	465
FINAL CONSUMPTION	**1485**	**1466**	**1487**	**1233**	**1195**	**1246**	**1395**	**1452**	**1526**	**1412**	**1173**	**1218**	**1185**	**1129**	**1227**	**1040**	**1184**	**1181**
INDUSTRY	*1186*	*1156*	*1154*	*977*	*899*	*957*	*1122*	*1084*	*960*	*793*	*909*	*849*	*867*	*787*	*808*	*667*	*791*	*772*
Iron and steel	101	96	97	86	78	47	21	16	18	8	18	19	20	17	13	4	5	5
Chemical industry	92	45	43	26	24	29	106	124	159	81	87	82	82	74	110	106	123	120
Of which: Feedstock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-ferrous metals	185	157	161	157	144	142	162	185	151	211	214	216	232	230	240	177	198	193
Non-metallic minerals	159	174	188	177	165	179	178	182	94	67	89	86	86	78	132	138	157	153
Transport equipment	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	4	4
Machinery	0	0	0	0	0	0	13	13	13	12	15	15	15	10	7	6	7	7
Mining	22	21	23	21	20	50	67	52	42	42	43	43	45	3	3	3	4	4
Food and tobacco	241	250	255	257	240	235	249	224	236	181	208	187	203	208	166	104	125	122
Paper. pulp	84	81	80	71	65	59	77	85	66	66	81	66	67	64	47	42	47	46
Wood and wood products	0	3	2	2	2	4	3	1	2	2	2	2	2	2	2	2	3	3
Construction	0	27	26	22	21	50	20	17	21	18	30	36	35	30	25	28	32	31
Textile and leather	111	93	108	91	82	88	140	137	101	79	92	75	77	68	60	54	46	42
Non-specified	191	209	171	67	58	74	84	46	55	24	27	19	0	0	0	0	40	42
TRANSPORT	*237*	*231*	*255*	*201*	*256*	*268*	*245*	*340*	*538*	*591*	*236*	*335*	*283*	*306*	*375*	*326*	*359*	*350*
Internal navigation	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359	350
OTHER SECTORS	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Agriculture	*62*	*79*	*78*	*55*	*40*	*21*	*28*	*28*	*28*	*28*	*28*	*34*	*35*	*36*	*44*	*23*	*31*	*30*
Commercial and public	13	24	21	15	15	10	15	15	15	15	15	18	18	19	21	47	29	29
Residential	13	20	19	15	10	11	13	13	13	13	13	16	17	17	23	0	0	0
Non-specified	36	35	38	25	15	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*

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[19] Fuel consumption in CHP plants is added to the respective industrial sectors

Table II.5   *Energy balance of diesel (in kt) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production	3663	3289	3786	3259	3723	3987	4760	5144	5544	4866	5647	5452	5624	6053	5369	5653	6452	6656
Imports	2303	2474	2042	2370	2198	2293	2788	2292	2539	2738	2013	2435	2993	3003	3672	3757	3591	2629
Exports	556	496	509	201	267	342	493	185	284	586	576	794	891	1102	1164	1480	2311	2307
International marine bunkers	510	514	657	718	801	966	776	771	758	706	750	612	549	497	472	384	398	365
Stock changes	-169	162	99	-51	-32	67	-166	-133	-468	419	108	35	-251	129	-327	-271	-204	178
DOMESTIC SUPPLY	**4731**	**4915**	**4761**	**4659**	**4821**	**5039**	**6113**	**6347**	**6573**	**6731**	**6442**	**6516**	**6926**	**7586**	**7078**	**7275**	**7130**	**7276**
Transfers	0	0	0	-25	0	-171	-554	-667	-592	-646	-208	89	36	1	141	140	-20	32
Statistical differences	7	-23	-47	-150	-2	-176	-177	-158	-244	-83	-98	-61	-16	-214	133	-37	-503	-453
TRANSFORMATION	**314**	**312**	**338**	**287**	**272**	**305**	**381**	**367**	**371**	**336**	**382**	**376**	**465**	**499**	**452**	**429**	**438**	**514**
Electricity plants	314	312	338	287	272	305	381	367	371	336	382	376	465	499	452	424	438	507
CHP plants	1	7	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	7
ENERGY SECTOR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**33**	**27**
FINAL CONSUMPTION	**4410**	**4626**	**4470**	**4497**	**4551**	**4739**	**5355**	**5471**	**5854**	**5832**	**5950**	**6290**	**6513**	**7302**	**6634**	**7023**	**7142**	**6735**
INDUSTRY SECTOR	*355*	*326*	*291*	*296*	*320*	*457*	*490*	*500*	*525*	*560*	*504*	*500*	*500*	*550*	*227*	*439*	*486*	*435*
Iron and steel	41	20	20	26	28	18	5	11	12	20	13	13	15	17	1	1	1	1
Chemical industry	15	12	11	11	12	8	5	3	9	10	9	9	9	9	9	10	10	9
Of which: Feedstock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-ferrous metals	0	25	24	25	27	38	28	13	21	23	23	23	20	23	1	2	2	2
Non-metallic minerals	49	30	31	31	34	48	36	40	49	53	49	48	42	48	3	4	4	4
Transport equipment	0	2	2	2	2	12	12	7	15	17	16	15	15	16	15	17	18	18
Mining	43	32	31	32	35	49	43	45	41	42	41	40	40	45	38	40	41	37
Food and tobacco	33	35	33	39	42	59	45	37	49	53	51	51	50	52	22	23	23	21
Paper. pulp	12	11	10	14	15	8	5	10	9	10	10	10	10	14	2	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
Construction	0	1	1	1	1	1	75	94	118	126	130	130	135	140	131	140	142	127
Textile and leather	17	16	15	20	22	18	10	3	5	8	10	10	7	8	5	5	4	3
Non-specified	145	142	113	95	102	198	224	235	195	195	150	150	156	177	0	194	238	210
TRANSPORT	*1761*	*1955*	*1952*	*1986*	*1978*	*1988*	*1985*	*2010*	*2245*	*2217*	*2193*	*2280*	*2295*	*2441*	*2406*	*2423*	*2598*	*2666*
Road	1362	1549	1557	1588	1601	1660	1711	1732	1851	1888	1890	1895	1925	2100	2058	2055	2199	2309
Rail	63	49	47	48	52	43	45	42	42	40	40	40	40	40	40	40	41	37
Internal navigation	336	357	348	350	325	285	229	236	352	289	263	345	330	301	308	328	358	320
OTHER SECTORS	*2294*	*2345*	*2227*	*2215*	*2253*	*2294*	*2880*	*2961*	*3084*	*3055*	*3253*	*3510*	*3718*	*4311*	*4001*	*4161*	*4058*	*3634*
Agriculture	857	888	822	802	808	750	761	760	760	760	760	770	850	929	786	806	845	757
Commercial and public	145	167	155	150	160	165	200	192	195	195	203	270	278	300	285	365	371	332
Residential	1292	1290	1250	1263	1285	1379	1919	2009	2129	2100	2290	2470	2590	3082	2930	2990	2842	2545
Non-specified	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*

Table II.6   *Energy balance of gasoline (in kt) for the period 1990 – 2007*

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production	3379	3128	3581	3445	3543	3545	3383	3607	3671	3205	3758	3770	3802	3653	3629	4058	4327	4318
Imports	213	162	345	242	98	217	180	45	152	477	415	116	514	749	1059	1023	1002	609
Exports	1097	884	1238	1077	1094	881	780	556	645	653	1011	678	809	942	1216	1261	1351	1373
Stock changes	-45	59	-171	11	141	34	-4	-115	-69	169	-27	3	-122	53	11	2	-259	56
DOMESTIC SUPPLY	**2450**	**2465**	**2517**	**2621**	**2688**	**2915**	**2779**	**2981**	**3109**	**3198**	**3135**	**3211**	**3385**	**3513**	**3483**	**3822**	**3719**	**3613**
Transfers	0	0	0	0	0	0	42	4	28	17	22	167	153	166	121	99	140	76
Statistical differences	27	-34	-65	-23	-7	141	-119	-50	-19	0	-123	-7	-5	-6	-159	3	-100	-448
TRANSFORMATION	**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**
FINAL CONSUMPTION	**2423**	**2499**	**2582**	**2644**	**2695**	**2774**	**2940**	**3035**	**3156**	**3215**	**3280**	**3385**	**3543**	**3685**	**3763**	**3918**	**3959**	**4137**
INDUSTRY	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
TRANSPORT	*2373*	*2447*	*2532*	*2594*	*2645*	*2724*	*2890*	*2985*	*3106*	*3165*	*3230*	*3336*	*3493*	*3650*	*3730*	*3888*	*3931*	*4108*
Road transport	2373	2447	2532	2594	2645	2724	2890	2985	3106	3165	3230	3336	3493	3650	3730	3888	3931	4108
OTHER SECTORS	*50*	*52*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*49*	*50*	*35*	*33*	*30*	*28*	*29*
Agriculture	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28	29
Non specified	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*

Annex III: CO_2 emissions from fuel combustion – Reference approach

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:

Apparent consumption = Primary production + Imports - Exports – International bunkers + Stock change

The apparent consumption of secondary fuels is estimated by the following equation:

Apparent consumption = Imports - Exports - International bunkers + 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 CO_2.

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 CO_2 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 3.6***). It is assumed that the carbon that remains unoxidised is stored indefinitely.

Step 6: Estimation of CO_2 emissions.

Carbon emissions from all fuels are multiplied by 44/12 to be converted to CO_2 emissions. and are summed. giving the total amount of CO_2 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***.

Table III.1   ***Net calorific value of lignite (in TJ / kt) for the period 1990 - 2007***

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

The application of the reference approach for each year is presented hereafter (Tables 1.A(b) of the Common Reporting Format).

Table III.2 Reference approach for 2007

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	74,00	20.330,00	1.056,00		-207,00	19.141,00	42,75	NCV	818.277,75	20,00	16.365,56		16.365,56	0,99	59.406,96
		Orimulsion									NCV							
		Natural Gas Liquids		7,00					7,00	41,56	NCV	290,89	17,20	5,00		5,00	0,99	18,16
	Secondary Fuels	Gasoline	kt		609,00	1.373,00		59,00	-705,00	43,96	NCV	-30.991,80	18,90	-585,75		-585,75	0,99	-2.126,25
		Jet Kerosene	kt		401,00	793,00	928,00	-3,00	-395,00	44,59	NCV	-17.613,05	19,50	-343,45		-343,45	0,99	-1.246,74
		Other Kerosene	kt			17,00		-1,00	-18,00	44,75	NCV	-805,50	19,60	-15,79		-15,79	0,99	-57,31
		Shale Oil									NCV							
		Gas / Diesel Oil	kt		2.629,00	2.307,00	365,00	178,00	135,00	43,00	NCV	5.805,00	20,20	117,26	NO	117,26	0,99	425,66
		Residual Fuel Oil	kt		677,00	979,00	2.860,00	-261,00	-3.423,00	40,19	NCV	-137.570,37	21,10	-2.902,73		-2.902,73	0,99	-10.536,93
		Liquefied Petroleum Gas (LPG)	kt		22,00	251,00		-2,00	-231,00	47,31	NCV	-10.928,61	17,20	-187,97	NO	-187,97	0,99	-682,34
		Ethane									NCV				NO			NO
		Naphtha	kt		0,00	321,00		15,00	-306,00	45,01	NCV	-13.773,06	20,00	-275,46	99,45	-374,91	0,99	-1.360,91
		Bitumen	kt			144,00		-10,00	-154,00	40,19	NCV	-6.189,26	20,00	-123,79	243,55	-367,34	0,99	-1.333,43
		Lubricants	kt		7,00	113,00	33,00	1,00	-195,44	40,19	NCV	-7.854,91	20,00	-157,10	3,22	-160,31	0,99	-581,94
		Petroleum Coke	kt		956,00			-62,00	824,00	31,93	NCV	26.309,87	27,50	723,52		723,52	0,99	2.626,38
		Refinery Feedstocks	kt		2.357,00			-26,00	2.331,00	42,50	NCV	99.067,50	20,00	1.981,35		1.981,35	0,99	7.192,30
		Other Oil						1,00	1,00	40,19	NCV	40,19	20,00	0,80	46,22	-45,41	0,99	-164,86
Other Liquid Fossil																		
Other non-specified											NCV							
Liquid Fossil Totals												724.064,64		14.601,46	392,43	14.209,03		51.578,76
Solid Fossil	Primary Fuels	Anthracite (2)									NCV							
		Coking Coal									NCV				NO	NO		NO
		Other Bituminous Coal	kt		605,00	16,00		122,00	711,00	25,74	NCV	18.303,27	26,44	484,02		484,02	0,98	1.739,24
		Sub-bituminous Coal									NCV							
		Lignite	kt	66.496,00	6,00			59,00	66.561,00	5,30	NCV	353.577,72	33,95	12.004,59		12.004,59	0,98	43.136,48
		Oil Shale									NCV							
		Peat									NCV							
	Secondary Fuels	BKB(3) and Patent Fuel						1,00	1,00	14,20	NCV	14,20	25,80	0,37		0,37	0,98	1,32
		Coke Oven/Gas Coke	kt						0,00	29,31	NCV	0,00	29,50	0,00		0,00	0,98	0,00
Other Solid Fossil																		
Other non-specified											NCV							
Solid Fossil Totals												371.895,20		12.488,97	NO	12.488,97		44.877,03
Gaseous Fossil		Natural Gas (Dry)	TJ	923,40	139.624,20			-302,40	134.515,23	1,00	NCV	134.515,23	15,30	2.058,08	0,06	2.058,03	1,00	7.508,37
Other Gaseous Fossil																		
		Other non-specified									NCV							
Gaseous Fossil Totals												134.515,23		2.058,08	0,06	2.058,03		7.508,37
Total												1.230.475,07		29.148,51	392,49	28.756,02		103.964,16
Biomass total												21.252,69		611,73		611,73		2.220,59
		Solid Biomass		19.566,69	62,00				19.628,69	1,00	NCV	19.628,69	29,90	586,90		586,90	0,99	2.130,44
		Liquid Biomass		92,00	3,00				95,00	1,00	NCV	95,00	20,00	1,90		1,90	0,99	6,90
		Gas Biomass		1.529,00					1.529,00	1,00	NCV	1.529,00	15,00	22,94		22,94	0,99	83,25

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

$$u_{i,g} = \sqrt{u_{AD,i}^2 + u_{EF,i,g}^2}$$

$$U_{i,g} = \frac{u_{i,g} \cdot E_{i,g}}{\sum\limits_{i,g} E_{i,g}}$$

$$U_{tot} = \sqrt{\sum\limits_{i,g} U_{i,g}^2}$$

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 CO_2, CH_4 and N_2O emissions and with 1995 as base year for 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 classification of source / sink categories does not coincide completely with the one used for the identification of key categories because it was curried out at levels dictated by the availability of existing appropriate information. Emissions from sources not included in the uncertainty analysis represent less than 1% of total emissions in 2007 (without *LULUCF*).

✢ 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, with and without the sector of *LULUCF* respectively.

Table IV.1   Reasoning for activity data and emission factor uncertainty value

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Stationary Combustion - solid fuels	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	Default carbon content per fuel has been used acc to IPCC guidelines with 95% confidence intervals. The % uncertainty is estimated < 5%. For conservative reasons we select 5%.
Stationary Combustion - liquid fuels	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	Default carbon content per fuel has been used acc to IPCC guidelines with 95% confidence intervals. The % uncertainty is estimated < 5%. For conservative reasons we select 5%.
Stationary Combustion - gaseous fuels	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	Default carbon content per fuel has been used acc to IPCC guidelines with 95% confidence intervals. The % uncertainty is estimated < 5%. For conservative reasons we select 5%.
Road transport	CO_2	Default IPCC uncertainty is 5%.	Uncertainty of emissions of CO2 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.
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.
Iron and Steel Production	CO_2	Plant specific data (IPCC GPG)	Uncertianty of EF for reducing agent
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	Uncertainty given by data provider (1st NFI)	The respective EF uncertainty was combined.
Conversion to Forest Land	CO_2	Uncertainty given by data provider (Activity data were reported to EU according to respective guidelines).	The respective EF uncertainty was combined.
Cropland remaining Cropland	CO_2	Uncertainty of the following activity data were combined: Aplanted 10%. Bm 15% and λ 10%.	The respective EF uncertainty was combined.
Stationary Combustion - all fuels	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	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
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.
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	20 % Rev. 1996. P. 4.12. Ta 4-5. We use the uncertainty from IPCC 2006. P10.50 ("For countries where there is a wide variety of management systems used usage data can be in the range of 25% to 50%") because we select EF according to managed systems without to be absolute clear the situation in Greece
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$_4$	According to Good Practice Guidance for poor quality data	Estimated value according to Good Practice Guidance Page 5.12. Table 5.2
Unmanaged solid waste disposal	CH$_4$	According to Good Practice Guidance for poor quality data	Estimated value according to Good Practice Guidance . Page 5.12. Table 5.2
Wastewater handling	CH$_4$	According to Good Practice Guidance . Page 5.12 Table 5.2	Estimated value according to Good Practice Guidance. Page 5.19 Table 5.3
Forest Land remaining Forest Land	CH$_4$	Uncertainty given by data provider. Increased to include disaggregation of data based on flammability factor (10% uncertainty of total area burned and 5 % of dissagregation based on statistics).	Suggested default value by LULUCF IPCC GPG (p 3.50)
Stationary Combustion - all fuels	N$_2$O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	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.
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)	N2O may be generated as by product and the Nox abatement may or may note reduce N2O (IPCC GPG).
Manure management	N$_2$O	According to IPCC 2006 Guidance. P10.50. For countries where there is a wide variety of management systems used usage data can be in the range of 25% to 50%	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	Estimated value according to IPCC 2006 Guidance . Page11.11. Table 11.1
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	IPCC 2006. P10.50. For countries where there is a wide variety of management systems used usage data can be in the range of 25% to 50% IPCC. P. 10.66	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
Forest Land remaining Forest Land	N$_2$O	Uncertainty given by data provider. Increased to include disaggregation of data based on flammability factor (10% uncertainty of total area burned and 5 % of dissagregation based on statistics).	Uncertainty given by data provider. Increased to include disaggregation of data based on flammability factor (10% uncertainty of total area burned and 5 % of dissagregation based on statistics).
Grassland remaining Grassland	N$_2$O	Uncertainty given by data provider.	Uncertainty given by data provider.
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).
Substitutes for ODS	HFC	Market surveys performed by ICAP. Include information from total manufacturer/importers	"Estimation from National Association of Refrigerating and Cooling Technicians
PFC from Aluminium	PFC	Plant specific data. measurements by plant.	give an overall guidance but are not updated each year."

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	39873.31	44767.97	5	5	7.1	2.4	-0.0384	0.4208	-0.19	2.98	2.98
1A 1.2.4	Stationary Combustion - liquid fuels	CO_2	21484.24	29887.31	5	5	7.1	1.6	0.0334	0.2809	0.17	1.99	1.99
1A 1.2.4	Stationary Combustion - gaseous fuels	CO_2	295.94	7336.03	5	5	7.1	0.4	0.0655	0.0690	0.33	0.49	0.59
1A3	Road transport	CO_2	11761.40	19785.00	5	5	7.1	1.1	0.0504	0.1860	0.25	1.31	1.34
1A3	Navigation	CO_2	1824.81	2113.06	5	5	7.1	0.1	-0.0012	0.0199	-0.01	0.14	0.14
1A3	Civil Aviation	CO_2	716.84	1347.83	5	5	7.1	0.1	0.0044	0.0127	0.02	0.09	0.09
1A3	Other transportation	CO_2	0.00	7.44	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	6.96	5	300	300.0	0.0	-0.0007	0.0001	-0.22	0.00	0.22
2A1	Cement Production	CO_2	5640.90	6272.31	2	2	2.8	0.1	-0.0060	0.0590	-0.01	0.17	0.17
2A2	Lime Production	CO_2	431.97	468.98	25	15	29.2	0.1	-0.0006	0.0044	-0.01	0.16	0.16
2A2	Lime Production		0.00	321.45	2	2	2.8	0.0	0.0030	0.0030	0.01	0.01	0.01
2C1	Iron and Steel Production	CO_2	92.70	229.71	5	5	7.1	0.0	0.0011	0.0022	0.01	0.02	0.02
6C	Waste incineration	CO_2	0.15	3.06	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
	Total CO_2		82192.48	112547.12									
1A 1.2.4	Stationary Combustion - all fuels	CH_4	105.77	107.87	5	100	100.1	0.1	-0.0002	0.0010	-0.02	0.01	0.02
1A3	Road transport	CH_4	108.19	100.19	4	40	40.2	0.0	-0.0003	0.0009	-0.01	0.01	0.01
1A3	Navigation	CH_4	3.61	0.70	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH_4	0.26	0.47	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	158.21	5	300	300.0	0.4	0.0004	0.0015	0.13	0.01	0.13
1B	Coal Mining	CH_4	1095.27	1402.72	2	300	300.0	3.2	0.0006	0.0132	0.17	0.04	0.17

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO$_2$ eq	Gg CO$_2$ eq	%	%	%	%	%	%	%	%	%
4A	Enteric fermentation	CH$_4$	2877.43	2930.48	5	30	30.4	0.7	-0.0056	0.0275	-0.17	0.19	0.26
4B	Manure management	CH$_4$	496.76	486.91	5	50	50.2	0.2	-0.0011	0.0046	-0.06	0.03	0.07
4C	Rice cultivation	CH$_4$	69.10	105.00	2	40	40.0	0.0	0.0002	0.0010	0.01	0.00	0.01
4F	Field burning of agr. residues	CH$_4$	27.06	26.94	20	20	28.3	0.0	-0.0001	0.0003	0.00	0.01	0.01
6A1	Managed solid waste disposal	CH$_4$	83.23	753.41	12	40	41.8	0.2	0.0061	0.0071	0.24	0.12	0.27
6A2	Unmanaged solid waste disposal	CH$_4$	1720.02	1645.39	12	72	73.0	0.9	-0.0043	0.0155	-0.31	0.26	0.41
6B	Wastewater handling	CH$_4$	2318.94	357.81	30	30	42.4	0.1	-0.0233	0.0034	-0.70	0.14	0.71
		Total CH$_4$	8997.21	8076.11									
1A 1.2.4	Stationary Combustion - all fuels	N$_2$O	582.74	588.51	5	300	300.0	1.4	-0.0012	0.0055	-0.35	0.04	0.36
1A3	Road transport	N$_2$O	122.76	226.98	5	50	50.2	0.1	0.0007	0.0021	0.04	0.02	0.04
1A3	Navigation	N$_2$O	14.21	16.62	5	300	300.0	0.0	0.0000	0.0002	0.00	0.00	0.00
1A3	Civil Aviation	N$_2$O	7.71	14.46	5	300	300.0	0.0	0.0000	0.0001	0.01	0.00	0.01
1A3	Other transportation		0.00	0.06	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N$_2$O	1109.04	439.53	5	100	100.1	0.3	-0.0086	0.0041	-0.86	0.03	0.86
4B	Manure management	N$_2$O	301.45	294.11	50	100	111.8	0.3	-0.0007	0.0028	-0.07	0.20	0.21
4D	Agricultural soils - direct emissions	N$_2$O	2740.61	1451.72	20	400	400.5	4.5	-0.0179	0.0136	-7.17	0.39	7.18
4D	Agricultural soils - indirect emissions	N$_2$O	3591.25	2612.99	20	50	53.9	1.1	-0.0168	0.0246	-0.84	0.69	1.09
4D	Animal Production	N$_2$O	3383.45	3379.25	50	100	111.8	2.9	-0.0072	0.0318	-0.72	2.25	2.36
4F	Field burning of agr. residues	N$_2$O	10.05	10.35	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
		Total N$_2$O	11863.27	9034.58									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	3253.07	0.00	50	50	70.7	0.0	-0.0375	0.0000	-1.87	0.00	1.87
2F	Substitutes for ODS	HFC	1.15	665.57	5	200	200.1	1.0	0.0062	0.0063	1.25	0.04	1.25
		Total HFC	3254.21	665.57									

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO$_2$ eq	Gg CO$_2$ eq	%	%	%	%	%	%	%	%	%
2C	PFC from Aluminium	PFC	82.97	58.66	1	1	1.4	0.0	-0.0004	0.0006	0.00	0.00	0.00
	TOTAL		106390.15	130382.04				7.374					8.959

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$_2$	39873.31	44767.97	5	5	7.1	2.5	-0.0405	0.4338	-0.20	3.07	3.07
1A 1.2.4	Stationary Combustion - liquid fuels	CO$_2$	21484.24	29887.31	5	5	7.1	1.7	0.0339	0.2896	0.17	2.05	2.05
1A 1.2.4	Stationary Combustion - gaseous fuels	CO$_2$	295.94	7336.03	5	5	7.1	0.4	0.0676	0.0711	0.34	0.50	0.61
1A3	Road transport	CO$_2$	11761.40	19785.00	5	5	7.1	1.1	0.0517	0.1917	0.26	1.36	1.38
1A3	Navigation	CO$_2$	1824.81	2113.06	5	5	7.1	0.1	-0.0012	0.0205	-0.01	0.14	0.14
1A3	Civil Aviation	CO$_2$	716.84	1347.83	5	5	7.1	0.1	0.0045	0.0131	0.02	0.09	0.10
1A3	Other transportation	CO$_2$	0.00	7.44	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	6.96	5	300	300.0	0.0	-0.0008	0.0001	-0.23	0.00	0.23
2A1	Cement Production	CO$_2$	5640.90	6272.31	2	2	2.8	0.1	-0.0063	0.0608	-0.01	0.17	0.17
2A2	Lime Production	CO$_2$	431.97	468.98	25	15	29.2	0.1	-0.0006	0.0045	-0.01	0.16	0.16
2B1	Ammonia Production		0.00	321.45	2.00	2.00	2.8	0.0	0.0031	0.0031	0.01	0.01	0.01
2C1	Iron and Steel Production	CO$_2$	92.70	229.71	5	5	7.1	0.0	0.0011	0.0022	0.01	0.02	0.02
6C	Waste incineration	CO$_2$	0.15	3.06	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
5.A.1	Forest Land remaining Forest Land	CO$_2$	-2042.79	-2451.82	10	100	100.5	-1.9	0.0006	-0.0238	0.06	-0.34	0.34
5.A.2	Conversion to Forest Land	CO$_2$	0.00	-523.57	5	100	100.1	-0.4	-0.0051	-0.0051	-0.51	-0.04	0.51
5.B.1	Cropland remaining Cropland	CO$_2$	-1205.41	-832.57	20	70	72.8	-0.5	0.0063	-0.0081	0.44	-0.23	0.50
		Total CO$_2$	78944.28	108739.16									
1A 1.2.4	Stationary Combustion - all fuels	CH$_4$	105.77	107.87	5	100	100.1	0.1	-0.0002	0.0010	-0.02	0.01	0.02
1A3	Road transport	CH$_4$	108.19	100.19	4	40	40.2	0.0	-0.0003	0.0010	-0.01	0.01	0.01
1A3	Navigation	CH$_4$	3.61	0.70	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO$_2$ eq	Gg CO$_2$ eq	%	%	%	%	%	%	%	%	%
1A3	Civil Aviation	CH$_4$	0.26	0.47	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	158.21	5	300	300.0	0.4	0.0004	0.0015	0.13	0.01	0.13
1B	Coal Mining	CH$_4$	1095.27	1402.72	2	300	300.0	3.3	0.0006	0.0136	0.17	0.04	0.17
4A	Enteric fermentation	CH$_4$	2877.43	2930.48	5	30	30.4	0.7	-0.0058	0.0284	-0.18	0.20	0.27
4B	Manure management	CH$_4$	496.76	486.91	5	50	50.2	0.2	-0.0012	0.0047	-0.06	0.03	0.07
4C	Rice cultivation	CH$_4$	69.10	105.00	2	40	40.0	0.0	0.0002	0.0010	0.01	0.00	0.01
4F	Field burning of agr. residues	CH$_4$	27.06	26.94	20	20	28.3	0.0	-0.0001	0.0003	0.00	0.01	0.01
6A1	Managed solid waste disposal	CH$_4$	83.23	753.41	12	40	41.8	0.2	0.0063	0.0073	0.25	0.12	0.28
6A2	Unmanaged solid waste disposal	CH$_4$	1720.02	1645.39	12	72	73.0	0.9	-0.0045	0.0159	-0.33	0.27	0.42
6B	Wastewater handling	CH$_4$	2318.94	357.81	30	30	42.4	0.1	-0.0241	0.0035	-0.72	0.15	0.74
5.A.1	Forest Land remaining Forest Land	CH$_4$	48.08	134.94	15	70	71.6	0.1	0.0007	0.0013	0.05	0.03	0.06
5.C.1	Grassland remaining Grassland	CH$_4$	1.80	7.76	10	100	100.5	0.0	0.0001	0.0001	0.01	0.00	0.01
	Total CH$_4$		9047.09	8218.80									
1A 1.2.4	Stationary Combustion - all fuels	N$_2$O	582.74	588.51	5	300	300.0	1.4	-0.0012	0.0057	-0.37	0.04	0.37
1A3	Road transport	N$_2$O	122.76	226.98	5	50	50.2	0.1	0.0007	0.0022	0.04	0.02	0.04
1A3	Navigation	N$_2$O	14.21	16.62	5	300	300.0	0.0	0.0000	0.0002	0.00	0.00	0.00
1A3	Civil Aviation	N$_2$O	7.71	14.46	5	300	300.0	0.0	0.0000	0.0001	0.01	0.00	0.01
1A3	Other transportation	N$_2$O	0.00	0.06	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N$_2$O	1109.04	439.53	5	100	100.1	0.3	-0.0089	0.0043	-0.89	0.03	0.89
4B	Manure management	N$_2$O	301.45	294.11	50	100	111.8	0.3	-0.0007	0.0029	-0.07	0.20	0.21
4D	Agricultural soils - direct emissions	N$_2$O	2740.61	1451.72	20	400	400.5	4.6	-0.0185	0.0141	-7.42	0.40	7.43
4D	Agricultural soils - indirect emissions	N$_2$O	3591.25	2612.99	20	50	53.9	1.1	-0.0174	0.0253	-0.87	0.72	1.13
4D	Animal Production	N$_2$O	3383.45	3379.25	50	100	111.8	3.0	-0.0075	0.0327	-0.75	2.32	2.43

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO$_2$ eq	Gg CO$_2$ eq	%	%	%	%	%	%	%	%	%
4F	Field burning of agr. residues	N$_2$O	10.05	10.35	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	4.88	13.69	15	70	71.6	16.7	0.1234	0.1651	8.64	3.50	9.32
5.C.1	Grassland remaining Grassland	N$_2$O	0.18	0.79	10	100	100.5	1.3	0.0079	0.0095	0.79	0.13	0.81
	Total N$_2$O		11868.33	9049.07									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	3253.07	0.00	50	50	70.7	0.0	-0.0387	0.0000	-1.93	0.00	1.93
2F	Substitutes for ODS	HFC	1.15	665.57	5	200	200.1	1.1	0.0064	0.0064	1.29	0.05	1.29
	Total HFC		3254.21	665.57									
2C	PFC from Aluminium	PFC	82.97	58.66	1	1	1.4	0.0	-0.0004	0.0006	0.00	0.00	0.00
	TOTAL		103196.88	126731.26				18.516					13.187

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 2007 increased by 26.35% compared to 1990 levels, with an average annual rate of increase estimated at 1.45% for the period 1990 - 2007. Emissions of NO_x derive by 99.3% from the energy sector and especially from transport, which is responsible for the 39.78% of total NO_x emissions. In **Table V.1** NO_x emissions by source category for the period 1990 – 2007 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 NO_x emission factor for paper and pulp production, 1500 gr/t, derives from IPCC Guidelines, while the emissions factors for steel (200 kg/kt) and aluminium production (2150 kg/kt) derive from CORINAIR. NO_x emission factor for nitric acid production (2540 kg/kt) is calculated based on NO_x measurements taking place in the industrial plants.

✣ 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 2007 decreased by 37.88% approximately compared to 1990 levels, with an average annual rate of decrease estimated at 3.39% for the period 1990 – 2007. CO emissions derive by 93.94% from the energy sector and especially from transport, which is responsible for the 59.8% of total CO emissions. In **Table V.2** CO emissions by source category for the period 1990 – 2007 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 CO emission factors for paper and pulp and ammonia production. 5600 and 7900 gr/t of product respectively, come from the IPCC Guidelines, while the emission factors for glass and aluminium production (100 kg/kt and 135 kg/t respectively) derive from CORINAIR. CO emission factor for steel production (2.3 kg/kt) derives from the BREF report about Best Available Techniques in the sector of iron and steel production.

✣ 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 22.95% in 2007 compared to 1990, with an average annual rate of decrease estimated at 1.36%. NMVOC emissions derive by 69% from the energy sector and especially from transport, which is responsible for the 18.79% of total NMVOC emissions. In *Table V.3* NMVOC emissions by source category for the period 1990 – 2007 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), ammonia (4700 gr/t) paper and pulp (3700 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 steel production (90 kg/t) derives from CORINAIR.

✣ 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 2007 increased by 14.35% compared to 1990 levels, with an average annual rate of increase estimated at 0.88% for the period 1990 - 2007. SO_2 emissions derive by 98.59% from the energy sector and mainly from the energy industries, which are responsible for the 68.1% of total SO_2 emissions. In *Table V.4* SO_2 emissions by source category for the period 1990 – 2007 are presented.

✣ The calculation of SO_2 emissions from the energy sector (area sources) is based on the sulphur content of the fuel. For point sources, measurement data from the relative plants were used.

✣ In the sector *Industrial processes*, the SO_2 emission factors for the production of cement (300 gr/t), ammonia (30 gr/t) and paper pulp (7000 gr/t) are those suggested by the IPCC Guidelines, while emission factors for glass (1700 gr/t), aluminium (14.2 kg/t) and steel production (130 kg/t) derive from CORINAIR. Emission factor 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 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL	**296.1**	**312.8**	**322.6**	**319.8**	**327.6**	**314.6**	**319.5**	**329.2**	**352.8**	**343.9**	**336.5**	**350.7**	**350.4**	**361.2**	**359.4**	**385.8**	**361.1**	**375.4**
Energy	**292.5**	**309.3**	**318.7**	**316.2**	**324.0**	**311.4**	**316.4**	**325.8**	**348.7**	**341.1**	**331.8**	**347.8**	**347.7**	**358.6**	**356.6**	**383.0**	**358.3**	**371.1**
Fuel combustion	292.1	308.9	318.3	315.7	323.6	310.9	315.9	325.4	348.3	340.6	331.3	347.4	347.2	358.1	356.2	382.5	357.9	370.7
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	146.1	139.4	149.4
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	22.0	19.9	27.0
Transport	148.9	158.3	162.3	163.0	165.4	163.1	161.3	165.3	184.8	180.0	157.5	162.4	155.6	156.0	153.7	165.6	149.8	150.4
Other sectors	47.5	49.2	45.9	44.8	45.0	42.3	44.0	44.1	44.3	44.2	44.6	45.6	49.7	54.6	47.5	48.8	48.8	44.0
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	0.4	0.4	0.4
Industrial processes	**1.9**	**1.6**	**1.7**	**1.6**	**1.5**	**1.5**	**1.6**	**1.5**	**1.4**	**1.4**	**1.5**	**1.4**	**1.5**	**1.4**	**1.4**	**1.5**	**1.4**	**1.4**
Nitric acid production	1.3	1.1	1.1	1.1	1.0	1.0	1.2	1.0	0.8	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
Steel production	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.3	0.4	0.5	0.5	0.5
Aluminium production	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
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
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**
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
LULUCF	**0.6**	**0.3**	**0.9**	**0.8**	**0.7**	**0.4**	**0.3**	**0.6**	**1.5**	**0.1**	**2.0**	**0.3**	**0.0**	**0.1**	**0.1**	**0.1**	**0.2**	**1.7**
Forest and grassland conversion	0.6	0.3	0.9	0.8	0.7	0.4	0.3	0.6	1.5	0.1	2.0	0.3	0.0	0.1	0.1	0.1	0.2	1.7

Table V.2   *CO emissions (in kt) by source category. for the period 1990 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL	**1295.2**	**1307.5**	**1337.7**	**1337.8**	**1333.7**	**1328.4**	**1354.5**	**1354.9**	**1384.6**	**1310.6**	**1356.4**	**1265.9**	**1230.2**	**1192.6**	**1155.1**	**929.8**	**841.2**	**785.0**
Energy	**1224.5**	**1236.1**	**1253.2**	**1260.0**	**1256.8**	**1265.0**	**1297.1**	**1286.6**	**1282.7**	**1255.5**	**1234.8**	**1204.0**	**1177.1**	**1140.4**	**1096.8**	**873.2**	**783.1**	**674.9**
Fuel combustion	1224.3	1235.9	1253.0	1259.7	1256.5	1264.7	1296.9	1286.4	1282.5	1255.3	1234.6	1203.8	1176.8	1140.1	1096.6	872.9	782.8	674.6
Energy industries	36.4	34.8	36.8	37.0	38.8	37.2	36.2	39.7	42.3	42.5	46.0	46.8	46.2	47.0	48.7	48.8	45.9	48.8
Industry	9.5	9.5	9.4	9.4	9.1	9.7	10.1	10.2	10.0	9.7	10.9	11.4	11.3	9.4	9.4	11.1	11.5	12.1
Transport	913.2	921.6	941.3	948.4	943.4	953.9	984.8	970.1	964.5	938.6	912.2	881.5	854.8	838.3	797.6	712.1	616.9	499.8
Other sectors	265.2	269.9	265.4	265.0	265.3	264.0	265.7	266.3	265.6	264.4	265.5	264.1	264.5	245.3	240.9	101.0	108.6	113.9
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	0.2	0.2
Industrial processes	**22.9**	**22.8**	**22.2**	**20.6**	**18.7**	**18.6**	**18.7**	**18.9**	**21.7**	**23.5**	**23.1**	**22.4**	**22.9**	**23.7**	**23.8**	**23.5**	**23.6**	**23.7**
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
Ammonia production	2.5	2.0	1.3	0.6	NO	0.8	1.1	1.0	1.9	1.8	1.2	0.5	0.7	1.2	1.3	1.1	1.3	1.3
Steel 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
Aluminium production	20.2	20.6	20.7	19.9	18.6	17.7	17.7	17.9	19.7	21.6	21.9	21.9	22.1	22.5	22.5	22.3	22.3	22.4
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
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**
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
LULUCF	**20.8**	**10.6**	**31.4**	**27.6**	**25.9**	**14.5**	**9.1**	**19.4**	**52.1**	**4.0**	**69.2**	**9.5**	**1.3**	**1.9**	**4.7**	**3.0**	**7.0**	**59.5**
Forest and grassland conversion	20.8	10.6	31.4	27.6	25.9	14.5	9.1	19.4	52.1	4.0	69.2	9.5	1.3	1.9	4.7	3.0	7.0	59.5

Table V.3   *NMVOC emissions (in kt) by source category. for the period 1990 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL	**300.5**	**311.8**	**320.6**	**325.7**	**334.5**	**336.0**	**341.6**	**343.1**	**351.4**	**350.0**	**351.2**	**346.2**	**342.5**	**334.4**	**327.9**	**274.5**	**280.3**	**204.4**
Energy	**216.8**	**224.7**	**233.5**	**238.8**	**248.6**	**246.6**	**252.3**	**253.0**	**256.3**	**251.7**	**248.3**	**244.1**	**238.2**	**236.9**	**224.8**	**187.0**	**182.5**	**112.9**
Fuel combustion	194.6	203.1	210.7	216.8	225.2	221.3	226.5	226.5	228.9	225.2	219.7	215.8	209.0	206.9	195.9	155.3	149.9	79.4
Energy industries	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
Industry	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	4.9	4.5	4.7
Transport	160.3	168.1	176.5	182.9	191.1	187.5	192.2	191.8	194.5	190.8	184.3	180.4	173.5	172.4	162.3	131.8	126.3	55.5
Other sectors	24.3	24.8	24.2	24.0	24.0	23.6	23.8	23.8	23.7	23.6	23.7	23.7	24.1	23.7	22.6	12.0	12.7	12.6
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	31.6	32.6	33.5
Industrial processes	**27.0**	**28.8**	**29.6**	**30.7**	**31.6**	**37.7**	**38.2**	**38.8**	**43.7**	**44.6**	**49.8**	**49.8**	**51.8**	**44.8**	**50.4**	**34.4**	**44.1**	**37.6**
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
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
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
Ammonia production	1.5	1.2	0.8	0.3	NO	0.8	0.6	0.6	1.2	1.1	0.7	0.3	0.4	0.7	0.8	0.7	0.8	0.8
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
Steel production	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
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
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
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**
	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

Table V.4 *SO₂ emissions (in kt) by source category. for the period 1990 – 2007*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL	**471.6**	**512.8**	**528.9**	**524.6**	**516.3**	**539.2**	**529.1**	**522.5**	**530.0**	**548.4**	**499.5**	**504.5**	**515.7**	**554.1**	**548.3**	**549.2**	**533.6**	**543.1**
Energy	**462.0**	**503.7**	**520.6**	**516.8**	**508.3**	**530.4**	**520.5**	**513.6**	**520.9**	**539.0**	**491.0**	**496.1**	**507.2**	**545.5**	**539.6**	**539.1**	**525.9**	**535.4**
Fuel combustion	455.5	496.3	512.3	507.4	501.5	523.5	514.7	507.1	512.5	530.6	482.0	488.4	498.1	536.0	532.2	531.7	518.5	527.9
Energy industries	299.3	340.9	361.6	373.2	381.9	407.3	386.7	379.5	378.5	405.3	370.6	372.2	383.5	421.7	414.2	425.3	405.1	414.6
Industry	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	53.1	56.6	62.1
Transport	33.2	33.4	34.8	31.1	36.2	30.5	29.1	30.6	45.3	48.7	23.9	28.3	24.7	26.3	31.2	29.2	31.9	29.0
Other sectors	28.6	30.7	26.3	24.6	17.7	15.1	19.4	17.5	18.1	17.6	18.8	20.4	20.6	23.8	23.4	24.1	24.9	22.3
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	7.4	7.4	7.4
Industrial processes	**9.6**	**9.1**	**8.3**	**7.9**	**8.1**	**8.8**	**8.6**	**8.9**	**9.1**	**9.3**	**8.5**	**8.4**	**8.5**	**8.6**	**8.7**	**10.1**	**7.7**	**7.8**
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	3.8	3.7	3.6
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
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
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
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
Aluminium production	2.1	2.2	2.2	2.1	2.0	1.9	1.9	1.9	2.1	2.3	2.3	2.3	2.3	2.4	2.4	2.3	2.3	2.4
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

Annex VI: Assessment of Completeness

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.E.2.1 Forest Land converted to Settlements	By Law conversion of forest land is prohibited.	
Carbon	5 LULUCF	5.E.2.2 Cropland converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals	
Carbon	5 LULUCF	5.E.2.3 Grassland converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals	
Carbon	5 LULUCF	5.E.2.5 Other Land converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals	
Carbon	5 LULUCF	5.F.2.2 Cropland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals	
Carbon	5 LULUCF	5.F.2.3 Grassland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals	
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.2.1 Forest Land 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.2.2 Cropland 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.2.3 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	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.2.5 Other Land 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.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.2.1 Forest Land converted to Settlements	By Law conversion of forest land is prohibited.
Carbon	5 LULUCF	5.E.2.2 Cropland converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals
Carbon	5 LULUCF	5.E.2.3 Grassland converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals
Carbon	5 LULUCF	5.E.2.5 Other Land converted to Settlements	Some lands have been converted to Settlements, but activity data are not adequate to estimate GHG emissions/removals
Carbon	5 LULUCF	5.F.2.2 Cropland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals
Carbon	5 LULUCF	5.F.2.3 Grassland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals
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	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.2.2 Cropland 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.2.3 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	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.2.5 Other Land 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.E.2.1 Forest Land converted to Settlements	By Law conversion of forest land is prohibited.
Carbon	5 LULUCF	5.D.2.1 Forest Land 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.2.2 Cropland 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.2.3 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	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.2.5 Other Land 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.E.2.1 Forest Land converted to Settlements	By Law conversion of forest land is prohibited.
Carbon	5 LULUCF	5.F.2.2 Cropland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals
Carbon	5 LULUCF	5.F.2.3 Grassland converted to Other Land	Some lands have may been converted to Other Lands, but activity data are not adequate to estimate GHG emissions/removals
CH4	1 Energy	1.AA.3.B 1.AA.3.B Road Transportation	Lack of EF
CH4	1 Energy	1.AA.3.D 1.AA.3.D Navigation	Lack of EF
CH4	1 Energy	1.C1.B 1.C1.B Marine	There has not been an appropriate Emission Factor estimated
CH4	1 Energy	1.B.2.D Geothermal	Lack of background information and methodogical approach
CH4	2 Industrial Processes	2.B.1 Ammonia Production	No existing EF in the IPCC Guidelines.
CH4	2 Industrial Processes	2.C.1.1 Steel	Lack of EF
CH4	2 Industrial Processes	2.C.2 Ferroalloys Production	No existing EF in the IPCC Guidelines.
CH4	2 Industrial Processes	2.C.3 Aluminium Production	No existing EF in the IPCC Guidelines.
CH4	4 Agriculture	4.A 4.A Enteric Fermentation	There has not been an appropriate Emission Factor estimated
CH4	4 Agriculture	4.C.3.1 Water Depth 50-100 cm	Lack of activity data

CH4	4 Agriculture	4.C.3.2 Water Depth > 100 cm	Lack of activity data
CH4	4 Agriculture	4.D.1 Direct Soil Emissions	There has not been any method for the estimation of CH4 emissions from this source.
CH4	4 Agriculture	4.D.3 Indirect Emissions	There has not been any method for the estimation of CH4 emissions from this source.
CH4	5 LULUCF	5 Forest Land converted to Other Land-Use Categories	Lack of activity data
CH4	5 LULUCF	5 Grassland converted to Other Land-Use Categories	Lack of activity data
CH4	6 Waste	6.B.1 6.B.1 Industrial Wastewater	Lack of activity data
CH4	6 Waste	6.B.1 6.B.1 Industrial Wastewater	Lack of activity data
CH4	6 Waste	6.B.1 6.B.1 Industrial Wastewater	Lack of activity data
CH4	6 Waste	6.B.2.1 6.B.2.1 Domestic and Commercial (w/o human sewage)	Lack of background data
CH4	6 Waste	6.B.2.1 6.B.2.1 Domestic and Commercial (w/o human sewage)	Lack of background data
CH4	6 Waste	6.C.2 Incineration of hospital wastes	Lack of Emission Factor. However CH4 emissions from clinical waste incineration are considered to be negligible (IPCC Good Practice Guidance 5.3.1)
CH4	6 Waste	6.C.2 Other non-specified	There are not sufficient data which would allow estimates for this source.
CO2	1 Energy	1.B.2.D Geothermal	Lack of background information and methodogical approach
CO2	2 Industrial Processes	2.A.5 Asphalt Roofing	Not available methodology in the IPCC guidelines.
CO2	2 Industrial Processes	2.A.6 Road Paving with Asphalt	Not available methodology in the IPCC guidelines.
CO2	2 Industrial Processes	2.B.5 Organic chemicals production	No method in the IPCC Guidelines
CO2	5 LULUCF	5 Forest Land converted to Other Land-Use Categories	Lack of activity data
CO2	5 LULUCF	5 Grassland converted to Other Land-Use Categories	Lack of activity data
CO2	6 Waste	6.C.2 Other non-specified	There are not sufficient data which would allow estimates for this source.
HFCs	2 Industrial Processes	2.F.1 Refrigeration and Air Conditioning Equipment	Lack of AD for potential emisisons.
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 emisisons.
HFCs	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD for potential emisisons.

HFCs	2 Industrial Processes	2.F.5 Solvents	Lack of AD for potential emissions.
N2O	1 Energy	1.AA.3.B 1.AA.3.B Road Transportation	Lack of EF
N2O	1 Energy	1.AA.3.D 1.AA.3.D Navigation	Lack of EF
N2O	1 Energy	1.C1.B 1.C1.B Marine	There has not been an appropriate Emission Factor estimated
N2O	1 Energy	1.B.2.D Geothermal	Lack of background information and methodogical approach
N2O	2 Industrial Processes	2.B.1 Ammonia Production	No existing EF in the IPCC Guidelines.
N2O	3 Solvent and Other Product Use	3.B Degreasing and Dry Cleaning	
N2O	3 Solvent and Other Product Use	3.D.1 Use of N2O for Anaesthesia	
N2O	3 Solvent and Other Product Use	3.D.2 Fire Extinguishers	
N2O	3 Solvent and Other Product Use	3.D.3 N2O from Aerosol Cans	
N2O	3 Solvent and Other Product Use	3.D.4 Other Use of N2O	
N2O	3 Solvent and Other Product Use	3.D.5 Wood Preservation	
N2O	3 Solvent and Other Product Use	3.D.5 Printing Industry	
N2O	3 Solvent and Other Product Use	3.D.5 Domestic solvent use	Lack of methodology and EF
N2O	3 Solvent and Other Product Use	3.D.5 Fat edible and non-edible oil extraction	
N2O	5 LULUCF	5 Forest Land converted to Other Land-Use Categories	Lack of activity data
N2O	5 LULUCF	5 Grassland converted to Other Land-Use Categories	Lack of activity data
N2O	6 Waste	6.B.1 6.B.1 Industrial Wastewater	Lack of methodological approach
N2O	6 Waste	6.B.1 6.B.1 Industrial Wastewater	Lack of activity data
N2O	6 Waste	6.B.2.1 6.B.2.1 Domestic and Commercial (w/o human sewage)	Lack of methodological approach
N2O	6 Waste	6.C.2 Incineration of hospital wastes	Lack of Emission Factor
N2O	6 Waste	6.C.2 Other non-specified	There are not sufficient data which would allow estimates for this source.
PFCs	2 Industrial Processes	2.F.1 Refrigeration and Air Conditioning Equipment	Lack of AD for potential emisisons.
PFCs	2 Industrial Processes	2.F.2 Foam Blowing	Lack of AD for potential emisisons.

PFCs	2 Industrial Processes	2.F.3 Fire Extinguishers	Lack of AD for potential emisisons.
PFCs	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD for potential emisisons.
PFCs	2 Industrial Processes	2.F.5 Solvents	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.1 Refrigeration and Air Conditioning Equipment	Lack of AD for potential emisisons.
SF6	2 Industrial Processes	2.F.2 Foam Blowing	Lack of AD for potential emisisons.
SF6	2 Industrial Processes	2.F.2 Foam Blowing	Lack of AD
SF6	2 Industrial Processes	2.F.3 Fire Extinguishers	Lack of AD for potential emisisons.
SF6	2 Industrial Processes	2.F.3 Fire Extinguishers	Lack of AD
SF6	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD for potential emisisons.
SF6	2 Industrial Processes	2.F.4 Aerosols/ Metered Dose Inhalers	Lack of AD
SF6	2 Industrial Processes	2.F.5 Solvents	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.5 Solvents	Lack of AD.
SF6	2 Industrial Processes	2.F.8 Electrical Equipment	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P1 Production	Lack of activity data
SF6	2 Industrial Processes	2.F.P2.1 In bulk	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P2.2 In products	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P3.1 In bulk	Lack of AD for potential emissions.
SF6	2 Industrial Processes	2.F.P3.2 In products	Lack of AD for potential emissions.
SF6	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**	**Explanation**
CH4	1.B.1.A.2.2 Post-Mining Activities	Post mining activities	Good Practice Guidance, p.2.75
CH4	1.B.1.B Solid Fuel Transformation		
CH4	1.B.2.B.5.1 at industrial plants and power stations		
CH4	1.B.2.B.5.2 in residential and commercial sectors		
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	
CH4	5.A.2 Land converted to Forest Land	5.A.2.Land converted to forest land/biomass burning/wildfires	Due to lack of disaggregated activity data
CH4	5.C.2 Land converted to Grassland	Land converted to Grassland/Biomass burning/Wildfires	Lack of disaggregated activity data
CO2	1.B.2.A.4 Refining / Storage		
CO2	1.B.2.B.5.1 at industrial plants and power stations		
CO2	1.B.2.B.5.2 in residential and commercial sectors		
CO2	2.A.4.2 Soda Ash Use	2 A 4 2 Soda ash use	Emissions from soda ash use are included in emissions from glass production.
CO2	5.A.1 Forest Land remaining Forest Land	Forest land remaining forest land/biomass burning/wildfires	
CO2	5.A.2 Land converted to Forest Land	5.A.2.Land converted to forest land/biomass burning/wildfires	Due to lack of disaggregated activity data
N2O	5.A.2 Land converted to Forest Land	5.A.2. Land converted to forest land/Direct N2O emissions from fertilization	Emissions from N fertilisation are reported in the Agriculture sector since there are not available disaggregated activity data on fertiliser applied to these lands from that applied to agriculture.
N2O	5.A.2 Land converted to Forest Land	5.A.2.Land converted to forest land/biomass burning/wildfires	Due to lack of disaggregated activity data
N2O	5.C.2 Land converted to Grassland	Land converted to Grassland/Biomass burning/Wildfires	Lack of disaggregated activity data

Annex VII: Supplementary Information under Article 7 paragraph 1 of the Kyoto Protocol

1. Information on Kyoto units (emission reduction units (ERUs), certified emission reductions (CERs), temporary certified emission reductions (tCERs), long-term certified emission reductions (lCERs), assigned amount units (AAUs) and removal units (RMUs)), as set out in section I.E of the annex to decision 15/CMP.1.

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 lCER 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, lCERs, 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.

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.

Tables with the Standard Electronic Format

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 2008 (X-1) the respective software application has been used (SEF_GR_2009_4_13-1-10 20-3-2009), which is included in this reporting submission.

2. Changes in national systems in accordance with Article 5, paragraph 1, and set out in section I.F of the annex to decision 15/CMP.1.

There are no changes in the structure and operation of the National Inventory system since the last year's submission, when the reorganised national system was already in place.. The ministerial circular No 918/21-4-08 released by MINENV entitled "Structure and operation of the National Greenhouse Gases Inventory System- Roles and Responsibilities" formalised the new institutional, legal and procedural arrangements within the national system. The circular defines the roles-responsibilities and the co-operation between the MINENV Climate team, the NTUA Inventory team and the designated focal persons of the competent Ministries and outlines procedures to ensure the continuity of the inventory compilation process.and the timely submission of the annual inventory.

Detailed information on the national system is provided in section 1.2. of this submission.

A review of the operation of the described national system took place in September 2008, together with the in –depth review of the inventories submitted in 2007 and 2008. The review concluded that the national system is performing its required functions, as set out in the annex to decision 19/CMP.1; that the institutional, legal and procedural arrangements established

and formalised by the ministerail circular are fully operational and that Greece has in place the institutional and procedural arrangements and the capacity, including the arrangements for the technical competence of the staff involved in the national system, to plan, prepare and manage inventories and their timely submission to the secretariat.

3. Changes in national registries as set out in section I.G of the annex to decision 15/CMP.1.

The GR registry concluded successfully the connection with ITL throught the "Go Live" process. Moreover, the registry software was upgraded by smart technologies GmbH (version 1.1.11.4).

4. Information on anthropogenic GHG emissions by sources and removals by sinks from land use, land-use change and forestry (LULUCF) activities under Article 3, paragraph 3, and, if any, elected activities under Article 3, paragraph 4, of the Kyoto Protocol, as set out in section I.D of the annex to decision 15/CMP.1.

The Ministry of Rural Development and Food has launched a project regarding the requirement for developing a methodology for estimation of emissions by sources and removals by sinks for activities under Article 3, paragraph 3, and activities elected under Article 3, paragraph 4, of the Kyoto Protocol, This project named "Planning and development of the national system for the estimation of emissions and removals from the LULUCF sector under the United Nations Framework Convention on Climate Change and its Kyoto Protocol" is carried out by the National Agricultural Research Foundation (NAGREF) which is overseen by the Ministry of Rural Development and Food. An intermediate progress report has already been submitted.

The information on anthropogenic GHG emissions by sources and removals by sinks of the above activities is mandatory from 2010 onwards and will be included in the next submission.

5.Minimization of adverse impacts in accordance with Article 3, paragraph 14, as set out in section I.H of the annex to decision 15/CMP.1.

This information is mandatory from 2010 onwards and will be included in the next submission.