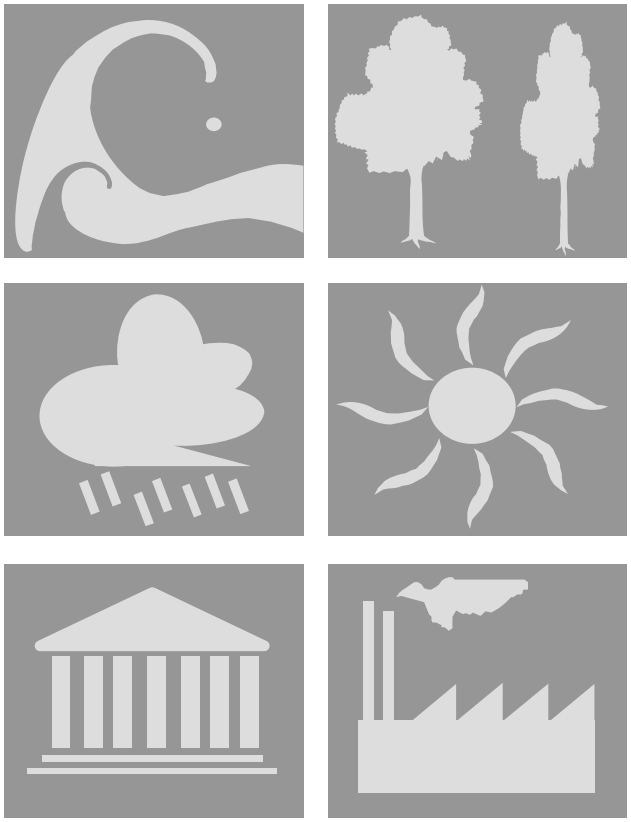
MINISTRY FOR THE ENVIRONMENT, PHYSICAL PLANNING AND PUBLIC WORKS

CLIMATE CHANGE



EMISSIONS INVENTORY

ANNUAL INVENTORY SUBMISSION UNDER THE CONVENTION AND THE KYOTO PROTOCOL FOR GREENHOUSE AND OTHER GASES FOR THE YEARS 1990-2006

APRIL 2008

ANNUAL INVENTORY SUBMISSION
UNDER THE CONVENTION AND
THE KYOTO PROTOCOL
FOR GREENHOUSE AND OTHER GASES
FOR YEARS 1990-2006

EXECUTIVE SUMMARY

ES.1 Greenhouse gas inventories and climate change

The present report, prepared by Greece (Ministry for Environment, Physical Planning and Public Works (climate team) in co-operation with National Technical University of Athens, NTUA – School of Chemical Engineering (inventory team)), contains estimates of GHG emissions for the period 1990-2006. **It constitutes Greece 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. It should be noted that the issues raised during in-country review of the initial report of Greece held from 23 to 28 of April 2007 by the Expert Review Team (ERT) are addressed in chapters 1 (concerning the maintenance of the institutional and procedural arrangements, the arrangements for the technical competence of the staff, and the capacity for the timely performance of Greece's national system) and chapter 3 (concerning the adjustments of the energy sector proposed). All other recommendations suggested by ERT have also been taken into account.

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 Associated Countries agreed to a -8% reduction, US to -7%, Japan to -6% while other countries such as Russia and Australia had to stabilize their emissions at 1990 levels.

Detailed rules for the implementation of the Protocol were set out at the 7th Conference of the Parties (in Marrakech) and are described in the Marrakech 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/MOP) held in Canada (December 2005) the rules for the implementation of the Protocol agreed at COP7 were adopted. In addition, a new working group was established to discuss future commitments for developed countries for the period after 2012.

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 3/CP.5, 18/CP.8 and 13/CP/9). 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 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, 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 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 and more specifically the Division of Air Pollution and Noise Control has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission.. (National UNFCCC Focal point : Elpida Politi, Address: 147, Patission Street, 11251, Athens, Greece , e-mail: epoliti@minenv.gr, tel.: +30210 8677012, fax: +30210 8646939).

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** designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays a more active role in the inventory planning, preparation and management.
- The **National Technical University of Athens (NTUA) / School of Chemical Engineering**, which has the technical and scientific responsibility for the compilation of the annual inventory.
- **Governmental agencies and ministries, international associations, along with individual private industrial companies**. The involvement of these entities is not limited to data providing but also concerns 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 (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 (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 and then the NIR is submitted, by the Ministry for Environment, to the European Commission and to the UNFCCC Secretariat.

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/e4100.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 - 2006 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 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 106.83 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 2006, GHG emissions (without *LULUCF*) amounted to 133.11 Mt CO_2 eq showing an increase of 24.6 % compared to base year emissions and of 27.3% compared to 1990 levels. If emissions / removals from *LULUCF* were included then the increase would be 26.2% (from 101.38 Mt CO_2 eq in 1990 to 127.91 Mt CO_2 eq in 2006).

Carbon dioxide emissions accounted for 82% of total GHG emissions in 2006 (without *LULUCF*) and increased by approximately 32% from 1990. Nitrous oxide emissions accounted for 7.8% of total GHG emissions in 2006 and decreased by 14% from 1990, while methane emissions accounted for 6.3 % of the total GHG emissions in 2006 and decreased by 6.8% from 1990. Finally, F-gases emissions that accounted for 3.6% of total GHG emissions in 2006, increased by 38% from 1995 (base year for F-gases).

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2006 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 2006 accounted for 81.8% of total GHG emissions (without LULUCF) and increased by approximately 35% compared to 1990 levels.

  The living standards improvement, due to the economic growth of the period 1990 – 2006, 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 living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), of passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO_2 emissions per electricity produced from fossil fuels have decreased about 7% mainly as a result of the introduction of the natural gas into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends (see also Chapter 3). For instance, the significant increase of electricity demand in 1999 was not followed by a similar

increase of emissions because of the penetration of natural gas and the high availability of hydropower (the highest of the period 1990 – 2006).

The last years a slight decrease in GHG emissions Though the increase of energy consumption in the domestic and tertiary sector, the last years a slight decrease in GHG emissions is observed due to the penetrationof natural gas, energy conservation measures and RES technologies.

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 2006 accounted for 10.2% of the total emissions (without *LULUCF*) and increased by 48% compared to 1990 levels due to the increasing production of mineral products (mainly cement) as well as the gradual substitution of ozone depleting substances from halocarbons. However, the annual rate of increase has been moderate in the recent years (the average rate of increase is 0.7% for the period 1990-2006) and emissions in 2006 seem to be decreased in relation to 2005 (with the exception of the production of halocarbons and SF6 category).
- The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.1% of the total emissions) and increased slightly since 1990.
- Emissions from *Agriculture* that accounted for 9.1% of total emissions in 2006 (without *LULUCF*), decreased by approximately 14% 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* (2.8% of the total emissions, without *LULUCF*), decreased by approximately 20% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions. Moreover, the increase of the number of managed solid waste disposal sites, without a systematic exploitation of the biogas produced, and the limited application of alternative management practices resulted in the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

Table ES.1 Total GHG emissions in Greece (in kt CO_2 eq) for the period 1990-2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
A. GHG emissions per gas (without LULUCF)																	
CO_2	82,422.17	82,909.08	84,655.37	84,482.80	86,600.58	87,017.41	89,271.43	94,113.43	98,776.10	98,224.37	103,659.42	106,005.96	105,663.52	109,889.49	110,201.85	110,499.54	109,666.12
CH_4	8,981.74	8,973.78	9,017.23	8,983.92	9,062.79	9,063.46	9,211.82	9,170.98	9,214.97	9,010.25	8,842.43	8,445.70	8,416.04	8,338.97	8,283.50	8,262.34	8,403.21
N_2O	12,002.95	11,849.25	11,689.67	11,024.19	11,242.65	10,988.11	11,449.36	11,134.26	10,954.60	11,025.10	11,091.21	10,871.16	10,864.03	10,904.14	10,790.90	10,413.20	10,320.01
HFC	935.06	1,106.82	908.39	1,606.64	2,143.91	3,336.67	3,928.61	4,246.67	4,741.49	5,564.02	4,486.01	4,150.09	4,368.94	4,285.96	4,373.27	4,579.97	4,648.01
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72	148.38	91.38	88.33	77.30	71.71	71.71	70.53
SF_6	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06	4.25	4.25	4.47	4.47	4.47
Total	**104,602.62**	**105,099.66**	**106,526.22**	**106,253.49**	**109,147.00**	**110,492.21**	**113,936.64**	**118,834.41**	**123,894.69**	**123,959.33**	**128,231.43**	**129,568.33**	**129,405.11**	**133,500.11**	**133,725.70**	**133,831.23**	**133,112.35**
B. GHG emissions / removals from LULUCF																	
CO_2	-3,268.86	-3,616.69	-3,095.64	-3,900.40	-3,574.07	-4,427.62	-4,013.88	-3,977.65	-3,611.47	-4,457.08	-3,162.55	-5,344.28	-5,480.39	-5,554.12	-5,435.17	-5,244.32	-5,217.12
CH_4	49.87	25.48	75.40	66.35	62.25	34.76	21.75	46.65	125.11	9.71	166.10	22.88	3.20	4.48	11.08	8.29	16.73
N_2O	5.06	2.59	7.65	6.73	6.32	3.53	2.21	4.73	12.70	0.99	16.86	2.32	0.33	0.45	1.12	0.84	1.70
Total	**-3,213.92**	**-3,588.63**	**-3,012.59**	**-3,827.31**	**-3,505.51**	**-4,389.34**	**-3,989.92**	**-3,926.27**	**-3,473.67**	**-4,446.39**	**-2,979.59**	**-5,319.08**	**-5,476.86**	**-5,549.19**	**-5,422.97**	**-5,235.18**	**-5,198.69**
C. GHG emissions from International Transport																	
CO_2	10475.30	9478.60	10665.71	12212.33	13251.52	13862.55	12399.31	12343.16	13595.02	12685.32	13857.13	13351.48	12214.71	13150.47	13327.28	11465.99	12663.40
CH_4	16.73	15.37	17.67	20.55	21.83	23.39	20.62	20.76	23.14	20.72	23.83	23.17	20.80	21.34	21.53	19.07	20.59
N_2O	90.21	81.50	91.52	104.26	113.64	118.06	106.04	105.86	116.41	109.99	118.83	114.49	105.12	114.16	115.76	92.76	101.43
Total	**10582.24**	**9575.47**	**10774.91**	**12337.14**	**13387.00**	**14004.00**	**12525.96**	**12469.78**	**13734.57**	**12816.03**	**13999.80**	**13489.14**	**12340.63**	**13285.97**	**13464.57**	**11577.82**	**12785.42**

Table ES.2 Total GHG emissions (in kt CO_2 eq) by sector for the period 1990-2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy	77,623.15	78,323.69	80,052.72	79,740.79	81,952.17	81,952.40	84,434.29	89,044.46	93,977.58	93,374.58	98,779.76	101,125.13	101,043.52	105,310.11	105,564.54	105,430.34	104,681.13
Industrial processes	8,845.58	8,849.96	8,742.23	9,409.90	9,825.28	11,465.53	12,118.43	12,719.47	13,008.22	13,863.66	13,005.57	12,662.08	12,735.91	12,669.59	12,806.75	13,181.79	13,087.51
Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33	154.67	155.12	155.50	155.87	157.70	159.64
Agriculture	13,519.23	13,306.17	13,101.49	12,503.16	12,736.05	12,486.24	12,776.15	12,486.82	12,342.24	12,364.27	12,357.76	12,144.28	12,079.00	11,998.61	11,936.71	11,733.98	11,644.91
Waste	4,444.95	4,444.06	4,456.94	4,429.52	4,470.27	4,433.39	4,455.62	4,430.60	4,414.25	4,196.86	3,931.01	3,482.17	3,391.56	3,366.30	3,261.83	3,327.43	3,539.15
Total [1]	**104,602.62**	**105,099.66**	**106,526.22**	**106,253.49**	**109,147.00**	**110,492.21**	**113,936.64**	**118,834.41**	**123,894.69**	**123,959.33**	**128,231.43**	**129,568.33**	**129,405.11**	**133,500.11**	**133,725.70**	**133,831.23**	**133,112.35**
LULUCF	**-3,213.92**	**-3,588.63**	**-3,012.59**	**-3,827.31**	**-3,505.51**	**-4,389.34**	**-3,989.92**	**-3,926.27**	**-3,473.67**	**-4,446.39**	**-2,979.59**	**-5,319.08**	**-5,476.86**	**-5,549.19**	**-5,422.97**	**-5,235.18**	**-5,198.69**
Index per sector																	
Energy	100.0	100.90	103.13	102.73	105.58	105.58	108.77	114.71	121.07	120.29	127.26	130.28	130.17	135.67	136.00	135.82	134.86
Industrial processes	100.0	100.05	98.83	106.38	111.08	129.62	137.00	143.79	147.06	156.73	147.03	143.15	143.98	143.23	144.78	149.02	147.96
Solvents	100.0	100.05	98.83	106.38	111.08	129.62	137.00	143.79	147.06	156.73	147.03	143.15	143.98	143.23	144.78	149.02	147.96
Agriculture	100.0	98.42	96.87	95.35	93.84	92.36	90.91	89.48	88.07	86.68	85.31	83.97	82.64	81.34	80.06	78.80	77.56
Waste	100.0	99.98	100.27	99.65	100.57	99.74	100.24	99.68	99.31	94.42	88.44	78.34	76.30	75.73	73.38	74.86	79.62
Total [2]	**100.0**	**100.12**	**102.10**	**101.02**	**104.19**	**104.65**	**108.44**	**113.33**	**118.77**	**117.88**	**123.54**	**122.55**	**122.23**	**126.20**	**126.55**	**126.83**	**126.16**

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 1990-2006.

The key features of emissions trends for indirect greenhouse gases and SO_2 are the following:

- NOx emissions increased by 12.6% from 1990 to 2006. Energy sector accounts for the high majority of emissions (99%), while the increase is due to the increased energy consumption in the residential sector. 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 32.7% of the NOx emissions in 2006). Emissions from *Industrial processes* decreased by 10% 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 32.4% from 1990 to 2006 and as a result total CO emissions in 2006 decreased by 26%. Emissions from industrial processes in 2006 increased by 5% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires.
- NMVOC emissions decreased by 5.3% from 1990 to 2006. Emissions from transport, which is the main source of NMVOC emissions in Greece, in 2006 decreased by 21% compared to 1990 levels, while emissions from *Energy* decreased by 13% from 1990 to 2006. The significant increase of NMVOC emissions from *Industrial processes* (approximately 44% from 1990 to 2006) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 5.2% compared to 1990 levels.
- SO_2 emissions increased by 13.6% from 1990 to 2006. Emissions from electricity generation, which is the main source of SO_2 emissions in Greece (66.8 % of total SO_2 emissions for 2006), increased with a mean annual rate of increase of 1.8% for the period 1990 – 2006. 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 34.5%, 8% and 17% respectively for the period 1990 – 2006. Emissions from *Industrial processes* increased by 2% from 1990 due to increase of sulphuric acid industrial production.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

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 on the need for an effective instrument to provide confidence in addressing the climate change challenge, the parties at 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 Associated Countries agreed to a -8% reduction, US to -7%, Japan to -6% while other countries such as Russia and Australia had to stabilize their emissions at 1990 levels.

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 a joint implementation,
- 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 Marrakech) and are described in the Marrakech 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/MOP) held in Canada (December 2005) the rules for the implementation of the Protocol agreed at COP7 were adopted. In addition, a new working group was established to discuss future commitments for developed countries for the period after 2012.

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 to 15% ± 3% by 2000 compared to 1990 levels. The measures to be 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 gases emissions (MEPPPW / 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 a National Programme (MEPPPW / NOA 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.

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.

Greece, as an Annex I signatory Party to the Convention, has to comply with the above-mentioned reporting requirements. Parallel commitments also exist under the European Council Decision 280/2004/EC concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.

With the present report, prepared by the National Technical University of Athens / School of Chemical Engineering for the Ministry for Environment, Physical Planning and Public Works, which contains estimates of GHG emissions for Greece for the years 1990-2006, the above obligations are addressed.

1.1.3 Structure of the report

The present NIR consists of 9 chapters and 5 annexes. **Chapter 1** continues with (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 – 2002 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 2005 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.

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 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, 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 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 and more specifically the Division of Air Pollution and Noise Control has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission.. (National UNFCCC Focal point : Elpida Politi, Address: 147, Patission Street, 11251, Athens, Greece , e-mail: epoliti@minenv.gr, tel.: +30210 8677012, fax: +30210 8646939).

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 designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays a more active role in the inventory planning, preparation and management.
- The National Technical University of Athens (NTUA) / School of Chemical Engineering, which has the technical and scientific responsibility for the compilation of the annual inventory.
- Governmental agencies and ministries, international associations, along with individual private industrial companies. The involvement of these entities is not limited to data providing but also concerns methodological issues as appropriate.

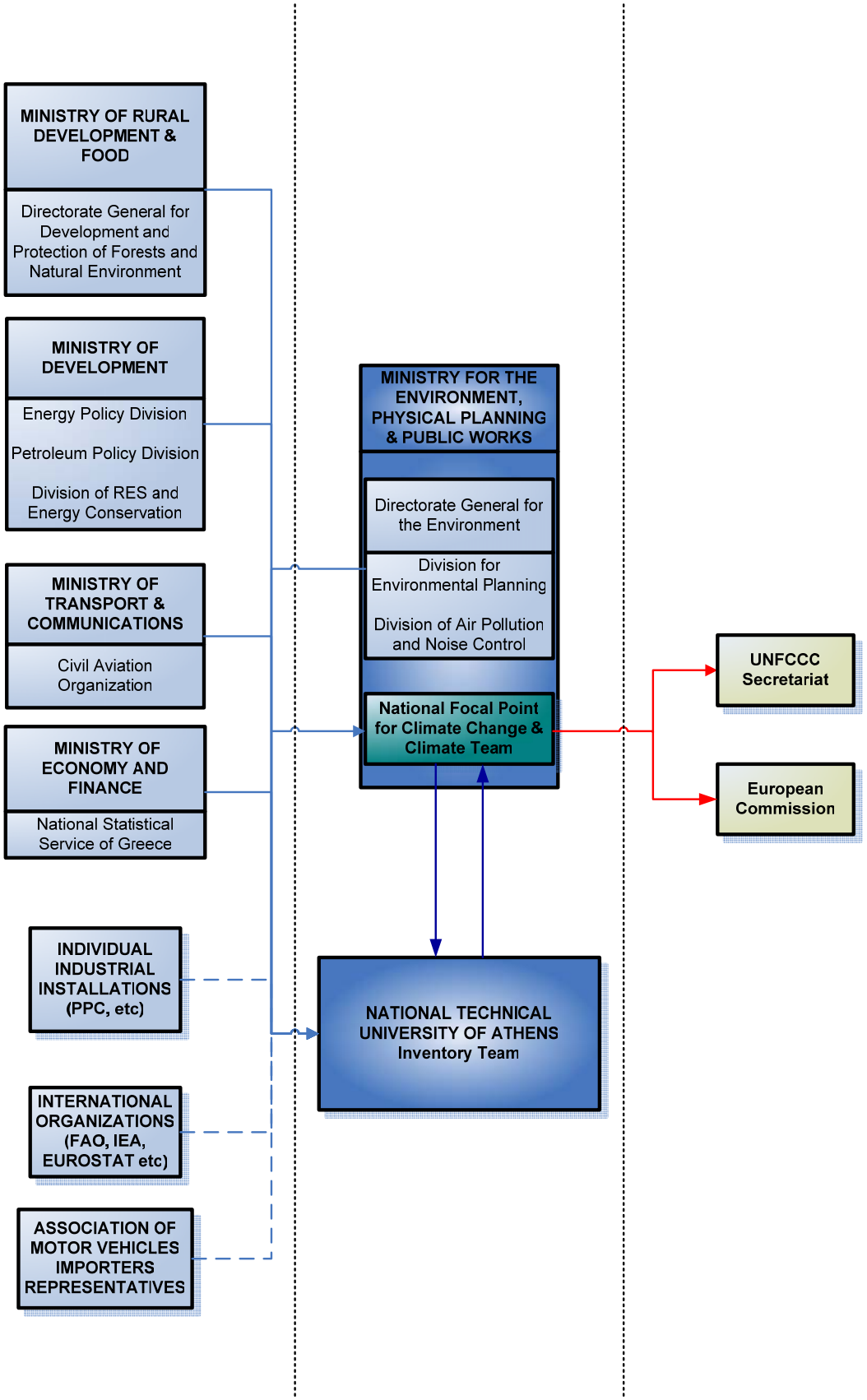


Figure 1.1 Organizational Structure of the National Inventory System

1.2.2 Roles and Responsibilities

1.2.2.1 Ministry for the Environment, Physical Planning & Public Works

The Ministry for the Environment, as previously stated, designated 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/MOP.
- The official consideration and approval of the inventory prior to its submission.
- The response to any issues raised by the inventory review process under Article 8 of the Kyoto Protocol, in co-operation with the NTUA Inventory Team.
- 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 technical responsible for the inventory institution (currently NTUA) at the beginning of each inventory cycle. Thus, the continuity of the inventory preparation process and knowledge transfer between the bodies which undertake the technical responsibility of the GHG inventory preparation is ensured.
- The administration of the National Registry. Greece cooperates with the Member states of the European Union and with the supplementary transaction log and the registry of the European Community by maintaining the national registries in a consolidated system. The administration of the registry is assigned to the National Center for the Environment and Sustainable Development, which reports to the Ministry of Environment and operates under the authority of the latter.

The role of the Ministry for the Environment 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 participating in the inventory process through continuous communication and frequent scheduled and / or ad-hoc meetings with the Inventory Team of NTUA and the competent ministries involved.

For that reason, a five (5) member team (task force) was established, named the MINENV Climate Team, within the Ministry for the Environment, comprising high level professionals with adequate technical and scientific background and experience. The scope of this team is the fulfillment of the above-mentioned roles and responsibilities. The team is comprised of the following experts, personnel of the Division of Air Pollution and Noise Control of the Ministry:

1. Elpida Politi, National UNFCCC focal point
2. Sotiria Koloutsou
3. Moraiti Christina,
4. Balas Dionisios
5. Lytras Euthimios

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

The Ministry for the Environment 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 compilation of the annual national inventory (Inventory Team). In this framework, NTUA 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 Forest, 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.
4. Data processing and archiving.
5. Assessment of the consistency of the methodologies applied.
6. Reliability check of results.
7. Key categories analysis.
8. Inventory improvement – recalculations.
9. Uncertainty assessment.
10. Preparation of Common Reporting Format (CRF) tables.
11. Preparation of National Inventory Report (NIR).
12. Reporting of the required information according to Article 3 of the Decision 280/2004/EC of the European Parliament and of the Council.

13. Preparation and keeping of Centralised Inventory File which is delivered to the Ministry for the Environment / Climate Team at the end of each inventory cycle.
14. Development of QA/QC procedures.
15. Monitoring the implementation of QA/QC procedures.
16. Internal audit of GHG inventory preparation.
17. Training of 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 sections). It should be mentioned that this co-operation is not restricted to data collection but it also concerns methodological issues as appropriate

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 agencies and ministries, international associations, individual private or public industrial companies

The following government agencies and ministries, international associations, individual private or public industrial companies develop and maintain, within their terms of operation, data sets and emission methodology information necessary for the estimation of GHG emissions / removals.

- The Ministry for the Environment provides information and data for Large Combustion Plants (fuel consumption, NOx and SO2 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 person: 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 for 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 6965809, fax: +30210 6965845, 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 forestry. Furthermore, the Ministry of Rural Development and Food is the responsible entity for establishing a system for the identification and measurement of areas of land subject to LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol. These 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
- 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.

It should be stated that a new significant institutional source of data is the National Center for the Environment and Sustainable Development (NCESD), supervised by the Ministry for the Environment. This entity is also responsible for the operation of the National Registry. (Contact person: Alexandros Karavanas, tel: +30210 8089271, Fax: +30210 8084707).

Moreover, 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.

The co-operation between the NTUA Inventory Team and the MINENV Climate Team and the other entities described, is taking its final official form which is based on written agreements between MINENV, NTUA and the other entities involved. These agreements include a description

of each entity's responsibilities, concerning the inventory preparation, in providing data or other relative information. This formal framework is expected to improve the collaboration between the entities involved, to assure the timely collection and the quality of the activity data required and to solve data access restriction problems raised due to confidentiality issues. The appointment of specific contact persons are responsible to collaborate with the NTUA Inventory Team and the MINENV Climate Team will further facilitate the inventory preparation process. Furthermore, it should be stated that the Ministry for the Environment intends to include the above agreements in a legislative adjustment.

Moreover, another supporting action for the improvement of the inventory system, is the planning and execution of training seminars of all representatives of the entities involved in the inventory system. The managing of this action is a responsibility of NTUA Inventory Team. Becoming familiar with the activity data and information required and their impact on the quality, completeness and timely performance of the inventory, data providers will contribute to the minimization of time delays and the improvement of the quality of the data needed.

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 (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 and then the NIR is submitted, by the Ministry for Environment, to the European Commission and to the UNFCCC Secretariat.

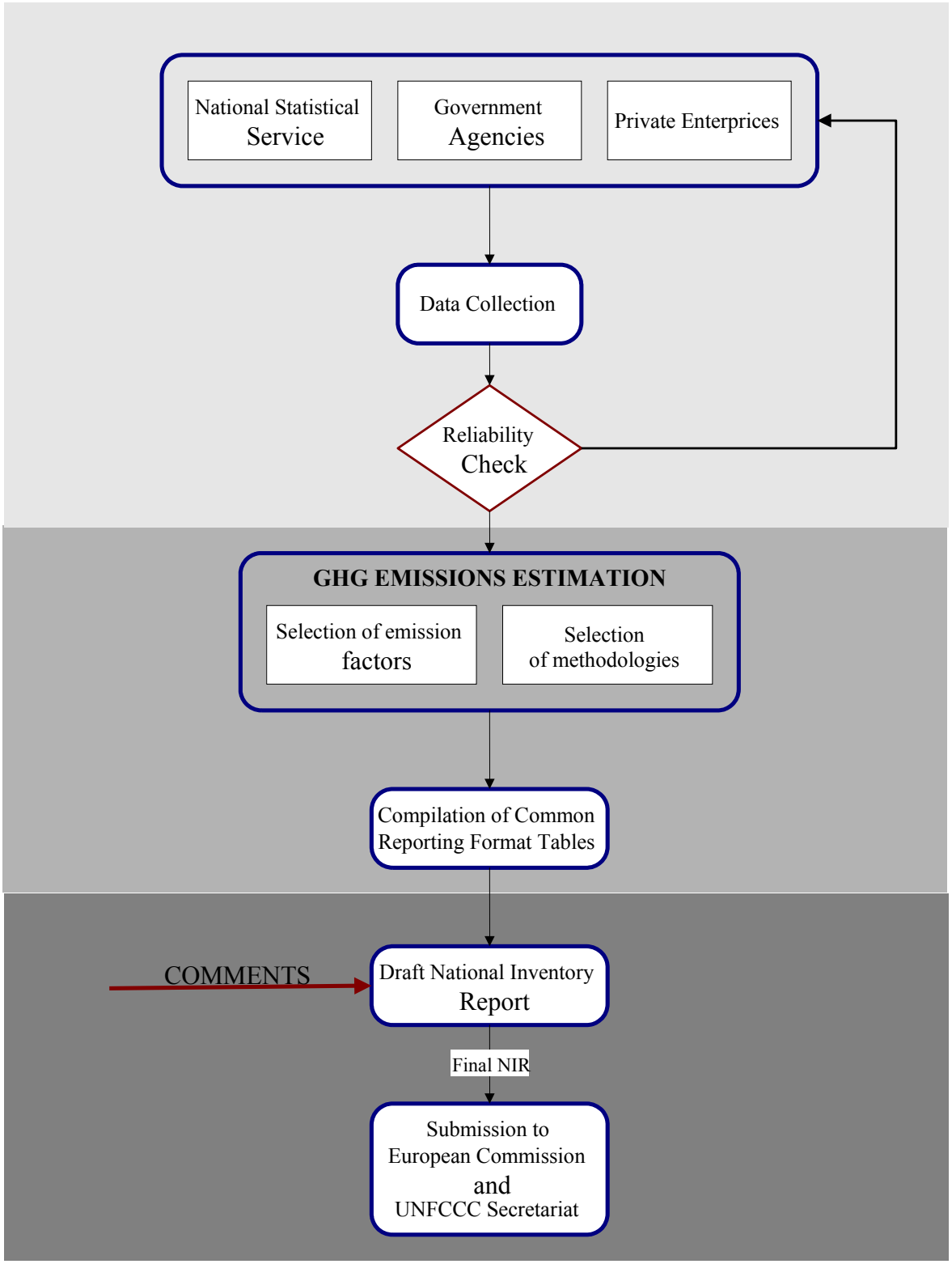


Figure 1.2 GHG emissions inventory preparation process in Greece

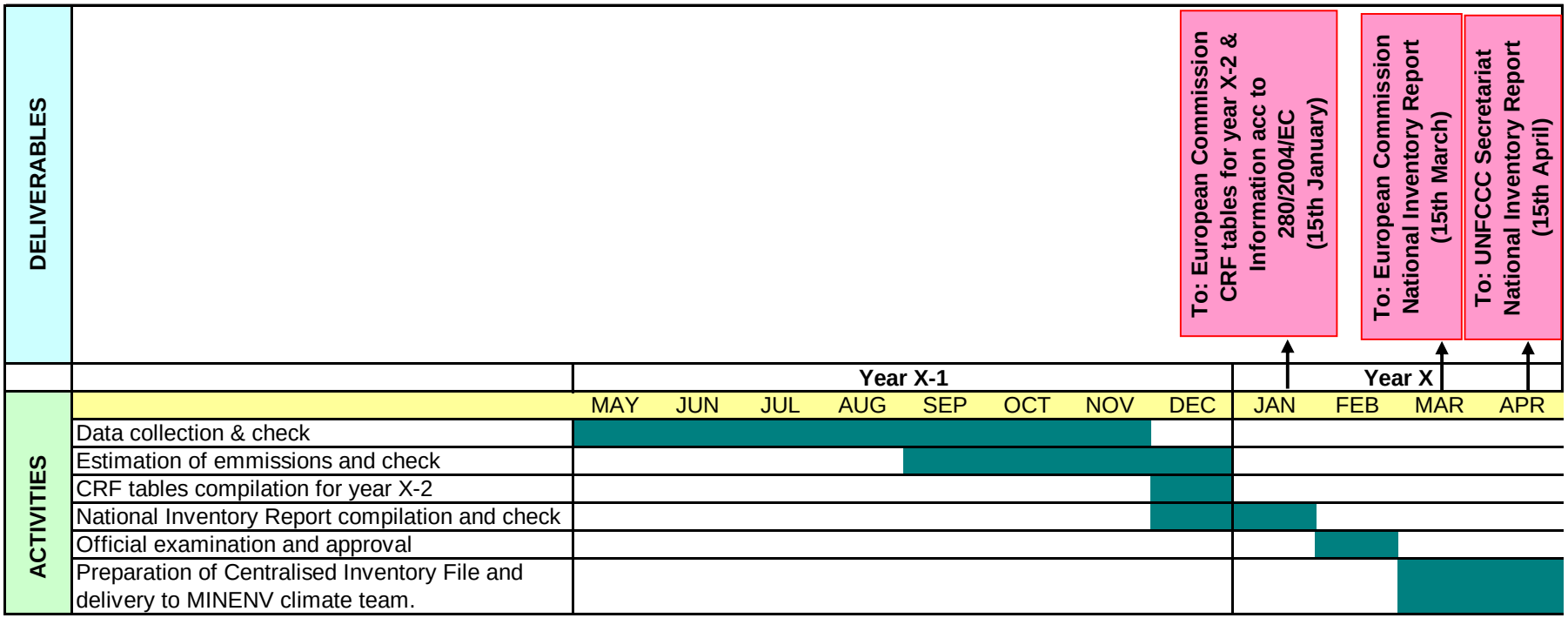


Figure 1.3 Timetable for the preparation and submission of GHG emissions/removals inventory in Greece

As shown in the timetable, the government agencies and ministries and the individual private or public industrial companies referred prviously should have collected and delivered the respective activity data needed for the inventory (for year X-2). These data should be compiled and maintained, within their terms of operation and 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.

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 stage of the inventory preparation, all inventory related information is handled to the person responsible for keeping the Centralised Inventory File (member of the Climate Team), who in turn gives 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 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.
- Calculation files, including the uncertainty estimation files.
- Expert review reports.
- Any comments from the public review of the inventory.
- A list of permissions given for the modification of elements stored in the Centralised Inventory File.

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 resources and special attention was paid in selecting the emission factors that better describe practices in Greece. In a limited number of sources, with significant however contribution to total emissions, emission factors arising from plant specific measurements or information and are used. 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.

[1] Emissions estimates from road transport presented in this inventory derive from the implementation of the COPERT III 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,T2	D,M	CR,M,T2	CR,D,M	CR,M,T2	CR,D,M		
4. Other sectors	T2	D	T2	D	T2	D		
B. Fugitive emissions from fuels								
1. Solid fuels	CS	CS	T1	D	NA	NA		
2. Oil and Natural gas	T1	D	T1	D	T1	D		
2. Industrial processes								
A. Mineral products	T3	PS	NA	NA	NA	NA		
B. Chemical industry	NA	NA	T1	D	D	D		
C. Metal production	CR,T3	CR,PS	NA	NA	NA	NA	T3b	CS
E. Production of halocarbons and SF_6							T1	D
F. Consumption of halocarbons and SF_6							T2a	D
3. Solvents and other products use	CR	CR			NA	NA		
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		

CR = CORINAIR, CS = Country Specific, NE = Not Estimated,

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

D = Default IPCC methodology ad emission factor

IE = Included Elsewhere

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.

With the exception of the United Nations Food and Agricultural Organization (FAO) from which data on the annual consumption of fertilizers are collected, 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 (MD 2004) along with the data from the verified reports from installations under the EU ETS for years 2005 & 2006 constituted a significant source of information and an additional quality control check. Data collected, cover the period 2000 – 2006 and in some cases the whole period 1990 – 2006. 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 for Development
1.A2	Manufacturing industries and construction	Fuel consumption	• Ministry for Development
1.A3	Transport	Number of vehicles	• Ministry for Transport • National Statistical Service of Greece • *Association of Greek Auto Importers*
		Aircraft landing and take off cycles	• Civil Aviation Organisation
1.A4	Residential / Tertiary sector / Agriculture	Fuel consumption	• Ministry for Development
1.B	Fugitive emissions from fuels	Amount of fuels Transmission/distribution pipelines length	• Ministry for Development
2	Industrial processes	Industrial production	• National Statistical Service of Greece. • Industrial units
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	• National Statistical Service of Greece • Ministry for Agriculture
		Fertilizer use	• UN Food and Agricultural Organisation
5	Land Use, Land Use Change and Forestry	Forest area Forest fires	• Ministry for Agriculture • General Directorate for the Forests and the Natural Environment
6	Waste	Quantities - composition of solid waste generated Recycling Population Industrial production	• Ministry for Environment • 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.

- Steel production (CO_2 emissions) is added to the key categories as a result of the trend assessment.
- Limestone and dolomite use (CO_2 emissions) is not included in the key categories identified in the present analysis.
- CO_2 emissions from solid waste disposal on land (biogas flaring) are not included in the key categories as the relevant emissions are not included in national totals due to the biogenic origin of the emissions.

Ten key sources are found in the energy sector, being responsible for 77.5% of total GHG emissions in 2006 (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 – Solid fuels	N_2O	Level
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	N_2O	Level
Stationary combustion – Gaseous fuels	CO_2	Level, Trend
Transport – Road transport	CO_2	Level, Trend
Transport – Road transport	N_2O	Trend
Transport – Navigation	CO_2	Level
Transport - Aviation	CO_2	Trend
Coal mining and handling	CH_4	Level
Industrial processes		
Cement production	CO_2	Level, Trend
Nitric acid production	N_2O	Trend
Iron & steel production	CO2	Trend
HCFC-22 production	HFC-23	Level, Trend
Ozone depleting substances substitutes	F-gases	Level, 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
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 – Solid fuels	N_2O	Level
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	N_2O	Level
Stationary combustion – Gaseous fuels	CO_2	Level, Trend
Transport – Road transport	CO_2	Level, Trend
Transport – Road transport	N_2O	Trend
Transport – Navigation	CO_2	Level
Transport - Aviation	CO_2	Trend
Coal mining and handling	CH_4	Level
Industrial processes		
Cement production	CO_2	Level, Trend
Nitric acid production	N_2O	Trend
Iron & steel production	CO2	Trend
HCFC-22 production	HFC-23	Level, Trend
Ozone depleting substances substitutes	F-gases	Level, 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, Trend
Cropland remaining Cropland	CO_2	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. 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.

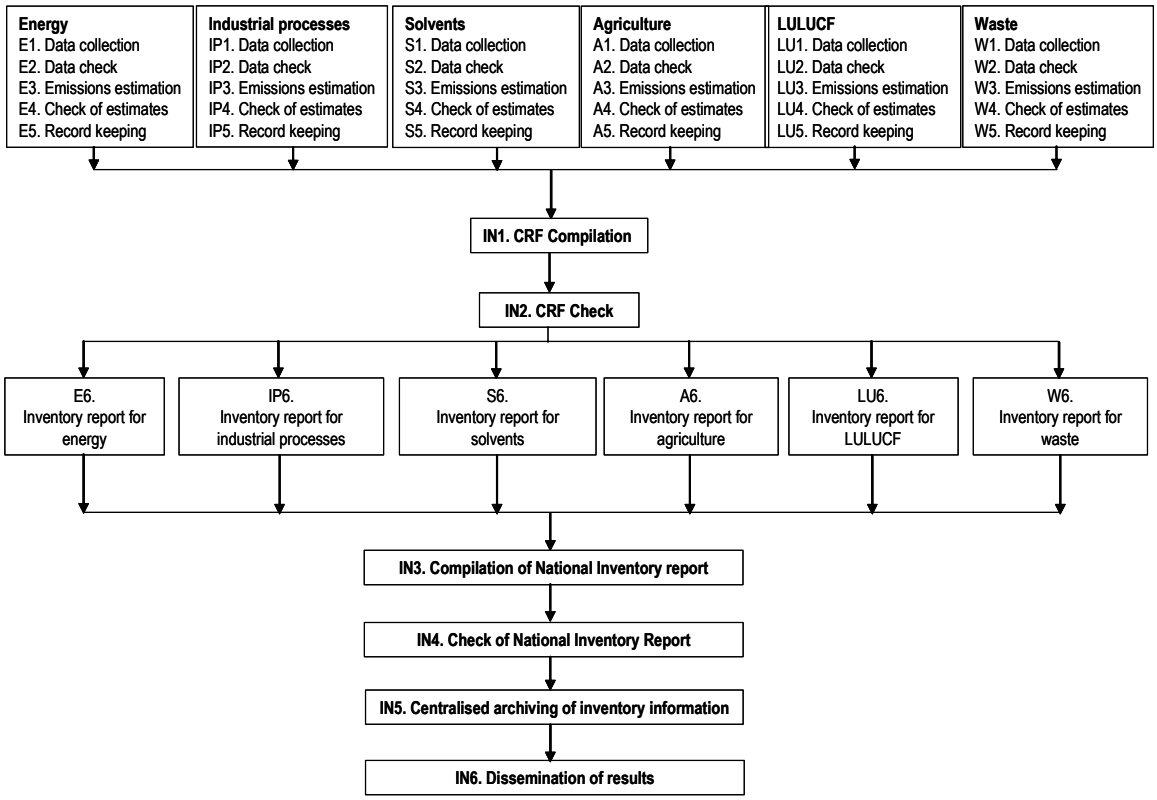


Figure 1.4 Flow chart activities concerning the GHG emissions inventory

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.

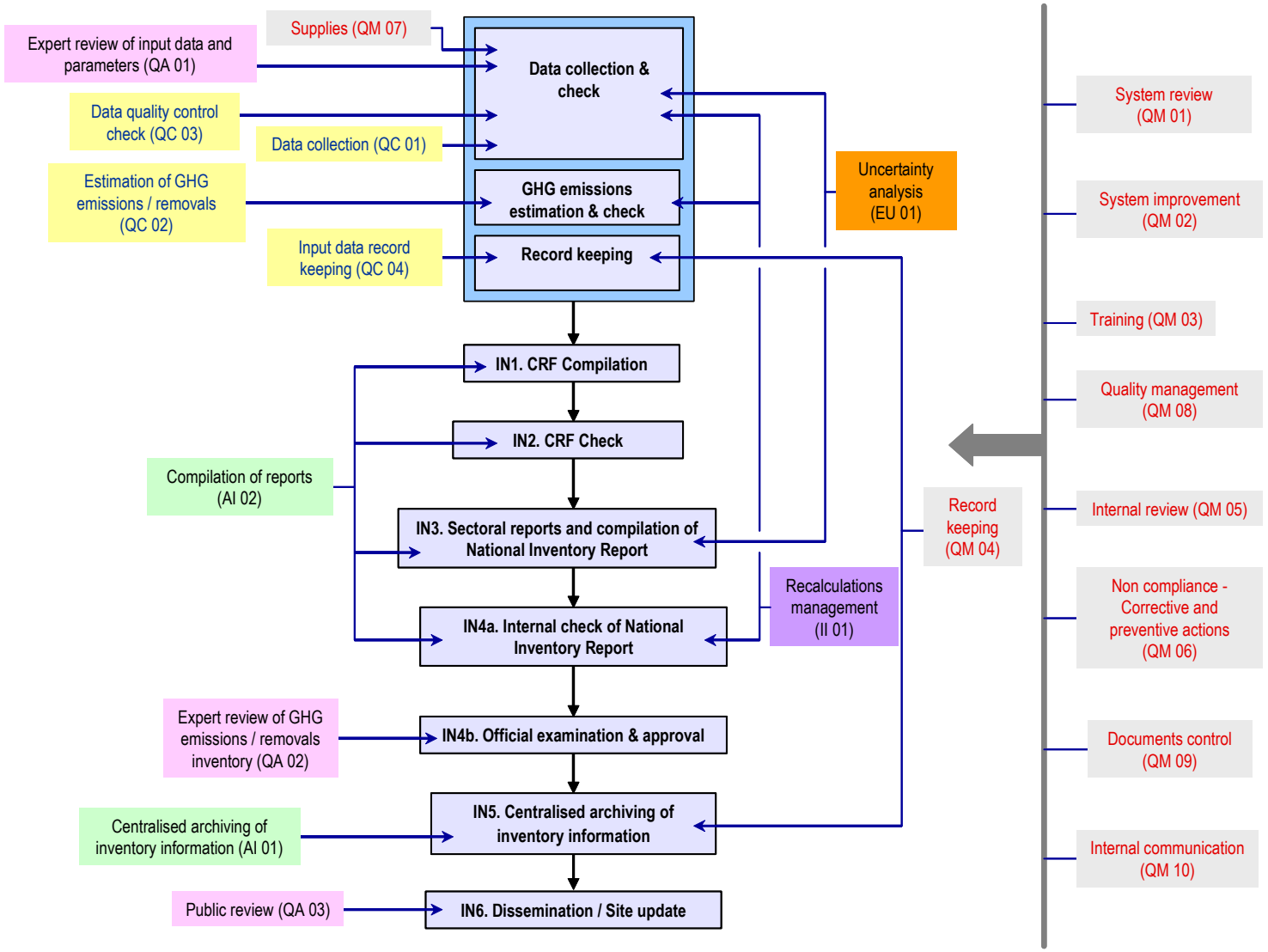


Figure 1.5 QA/QC processes and procedures and inventory related activities

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.

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 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 2006 (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 2006, were estimated at:

3.50% for CO_2 emissions

37.9% for CH_4 emissions

81.8% for N_2O emissions and

127.2% 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	CO_2	7.1
Stationary combustion – Liquid fuels		7.1
Stationary combustion – Gaseous fuels		7.1
Mobile combustion – Road transport		5.0
Mobile combustion – Navigation		7.1
Mobile combustion – Aviation		7.1
Pipeline transport		7.1
Fugitive – Oil and Natural gas		300.0
Cement production		2.8
Lime production		29.2
Iron & steel production		7.1
Waste incineration		100.1
Total CO_2		**3.50**
Fuel combustion	CH_4	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		200.0
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		**37.9**
Fuel combustion	N_2O	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		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		**81.8**
HFC-23 emissions from production of HCFC-22	F-gases	70.7
Ozone depleting substances substitutes		200.1
PFC from Aluminium production		1.4
Total F-gases		**127.2**
Total uncertainty (%)		**9.32**

In general, the uncertainties associated with CO_2 are very low, while the least accurate estimations are those for N_2O. 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 9.315% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 10.98%. These results are slightly higher compared to results of the analysis performed in previous submissions. The increase is mainly attributed to estimation of emissions from "new" sources (compared to previous submissions) with significant uncertainty (F-gases emissions from commercial refrigeration). As a result, the relative contribution of those gases to total emissions increased affecting the estimated overall uncertainty.

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	79,4
Conversion to forest land	CO_2	112,8
Cropland remaining cropland	CO_2	67,3
Forest land remaining forest land	CH_4	70,9
Cropland remaining cropland	CH_4	100,5
Forest land remaining forest land	N_2O	70,9
Cropland remaining cropland	N_2O	100,5

The uncertainty estimates for GHG emissions per gas, with LULUCF, in 2006, were estimated at (the detailed calculations are presented in Annex IV):

- 4.8% for CO_2 emissions,
- 31.9% for CH_4 emissions,
- 81.8% for N_2O emissions and
- 127.2% for the F-gases emissions.

Total uncertainty is 10.1%, while the uncertainty that carried over into the GHG emissions trend is 11.6%. 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 1990-2006 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:

- CH_4 and N_2O emissions from the use of natural gas in road transport due to the lack of appropriate emission factors. However, it should be mentioned that the effect of this gap is minor as the contribution of natural gas to total consumption in road transport is, at the moment, negligible (0.19% of total energy consumption in road transport for 2006).
- CO_2 emissions from lignite mining.
- Emissions from a number of minor sources (Soda ash production and use, Asphalt roofing, Road paving with asphalt and Food & Drink) included in *Industrial processes* are not estimated due to the lack of the necessary activity data.
- CO_2 emissions from ammonia and 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.
- In previous submissions F-gases emissions were estimated only for the sub-source *Refrigerating and air conditioning equipment* due to data availability problems. In this submission an effort has been done to include emissions from aerosol (meter dose inhalers) and transport refrigeration for 2006.
- Potential emissions are not estimated, as, for the time being, imports/exports of the relative chemical compounds are not recorded separately.
- N_2O emissions from *Solvents and other products use*.
- CH_4 emissions from Agricultural soils.
- N_2O emissions from wastewater handling.

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 - 2006 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 106.83 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 2006, GHG emissions (without *LULUCF*) amounted to 133.11 Mt CO_2 eq showing an increase of 24.6 % compared to base year emissions and of 27.3% compared to 1990 levels. If emissions / removals from *LULUCF* were included then the increase would be 26.2% (from 101.38 Mt CO_2 eq in 1990 to 127.91 Mt CO_2 eq in 2006).

Carbon dioxide emissions accounted for 82% of total GHG emissions in 2006 (without *LULUCF*) and increased by approximately 32% from 1990. Nitrous oxide emissions accounted for 7.8% of total GHG emissions in 2006 and decreased by 14% from 1990, while methane emissions accounted for 6.3 % of the total GHG emissions in 2006 and decreased by 6.8% from 1990. Finally, F-gases emissions that accounted for 3.6% of total GHG emissions in 2006, increased by 38% from 1995 (base year for F-gases).

Table 2.1 Total GHG emissions in Greece (in kt CO_2 eq) for the period 1990-2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
A. GHG emissions per gas (without LULUCF)																	
CO_2	82,422.17	82,909.08	84,655.37	84,482.80	86,600.58	87,017.41	89,271.43	94,113.43	98,776.10	98,224.37	103,659.42	106,005.96	105,663.52	109,889.49	110,201.85	110,499.54	109,666.12
CH_4	8,981.74	8,973.78	9,017.23	8,983.92	9,062.79	9,063.46	9,211.82	9,170.98	9,214.97	9,010.25	8,842.43	8,445.70	8,416.04	8,338.97	8,283.50	8,262.34	8,403.21
N_2O	12,002.95	11,849.25	11,689.67	11,024.19	11,242.65	10,988.11	11,449.36	11,134.26	10,954.60	11,025.10	11,091.21	10,871.16	10,864.03	10,904.14	10,790.90	10,413.20	10,320.01
HFC	935.06	1,106.82	908.39	1,606.64	2,143.91	3,336.67	3,928.61	4,246.67	4,741.49	5,564.02	4,486.01	4,150.09	4,368.94	4,285.96	4,373.27	4,579.97	4,648.01
PFC	257.62	257.56	252.30	152.59	93.62	82.97	71.74	165.34	203.75	131.72	148.38	91.38	88.33	77.30	71.71	71.71	70.53
SF_6	3.07	3.16	3.26	3.35	3.45	3.59	3.68	3.73	3.78	3.87	3.99	4.06	4.25	4.25	4.47	4.47	4.47
Total	**104,602.62**	**105,099.66**	**106,526.22**	**106,253.49**	**109,147.00**	**110,492.21**	**113,936.64**	**118,834.41**	**123,894.69**	**123,959.33**	**128,231.43**	**129,568.33**	**129,405.11**	**133,500.11**	**133,725.70**	**133,831.23**	**133,112.35**
B. GHG emissions / removals from LULUCF																	
CO_2	-3,268.86	-3,616.69	-3,095.64	-3,900.40	-3,574.07	-4,427.62	-4,013.88	-3,977.65	-3,611.47	-4,457.08	-3,162.55	-5,344.28	-5,480.39	-5,554.12	-5,435.17	-5,244.32	-5,217.12
CH_4	49.87	25.48	75.40	66.35	62.25	34.76	21.75	46.65	125.11	9.71	166.10	22.88	3.20	4.48	11.08	8.29	16.73
N_2O	5.06	2.59	7.65	6.73	6.32	3.53	2.21	4.73	12.70	0.99	16.86	2.32	0.33	0.45	1.12	0.84	1.70
Total	**-3,213.92**	**-3,588.63**	**-3,012.59**	**-3,827.31**	**-3,505.51**	**-4,389.34**	**-3,989.92**	**-3,926.27**	**-3,473.67**	**-4,446.39**	**-2,979.59**	**-5,319.08**	**-5,476.86**	**-5,549.19**	**-5,422.97**	**-5,235.18**	**-5,198.69**
C. GHG emissions from International Transport																	
CO_2	10475.30	9478.60	10665.71	12212.33	13251.52	13862.55	12399.31	12343.16	13595.02	12685.32	13857.13	13351.48	12214.71	13150.47	13327.28	11465.99	12663.40
CH_4	16.73	15.37	17.67	20.55	21.83	23.39	20.62	20.76	23.14	20.72	23.83	23.17	20.80	21.34	21.53	19.07	20.59
N_2O	90.21	81.50	91.52	104.26	113.64	118.06	106.04	105.86	116.41	109.99	118.83	114.49	105.12	114.16	115.76	92.76	101.43
Total	**10582.24**	**9575.47**	**10774.91**	**12337.14**	**13387.00**	**14004.00**	**12525.96**	**12469.78**	**13734.57**	**12816.03**	**13999.80**	**13489.14**	**12340.63**	**13285.97**	**13464.57**	**11577.82**	**12785.42**

2.2 Emissions trends per sector

GHG emissions trends by sector for the period 1990 - 2006 are presented in ***Table 2.2***.

- Emissions from *Energy* in 2006 ***(Figure 2.1)*** accounted for 81.8% of total GHG emissions (without LULUCF) and increased by approximately 35% compared to 1990 levels.

  The living standards improvement, due to the economic growth of the period 1990 – 2006, 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 living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), of passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO_2 emissions per electricity produced from fossil fuels have decreased about 7% mainly as a result of the introduction of the natural gas into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends (see also Chapter 3). For instance, the significant increase of electricity demand in 1999 was not followed by a similar increase of emissions because of the penetration of natural gas and the high availability of hydropower (the highest of the period 1990 – 2006).

  The last years a slight decrease in GHG emissions Though the increase of energy consumption in the domestic and tertiary sector, the last years a slight decrease in GHG emissions is observed due to the penetrationof natural gas, energy conservation measures and RES technologies.

  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 2006 accounted for 10.2% of the total emissions (without *LULUCF*) and increased by 48% compared to 1990 levels due to the increasing production of mineral products (mainly cement) as well as the gradual substitution of ozone depleting substances from halocarbons. However, the annual rate of increase has been moderate in the recent years (the average rate of increase is 0.7% for the period 1990-2006) and emissions in 2006 seem to be decreased in relation to 2005 (with the exception of the production of halocarbons and SF6 category).

- The contribution of the *Solvents and other products use* sector to total GHG emissions is minor (0.1% of the total emissions) and increased slightly since 1990.

- Emissions from *Agriculture* that accounted for 9.1% of total emissions in 2006 (without *LULUCF*), decreased by approximately 14% 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* (2.8% of the total emissions, without *LULUCF*), decreased by approximately 20% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions. Moreover, the increase of the number of managed solid waste disposal sites, without a systematic exploitation of the biogas produced, and the limited application of alternative management practices resulted in the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

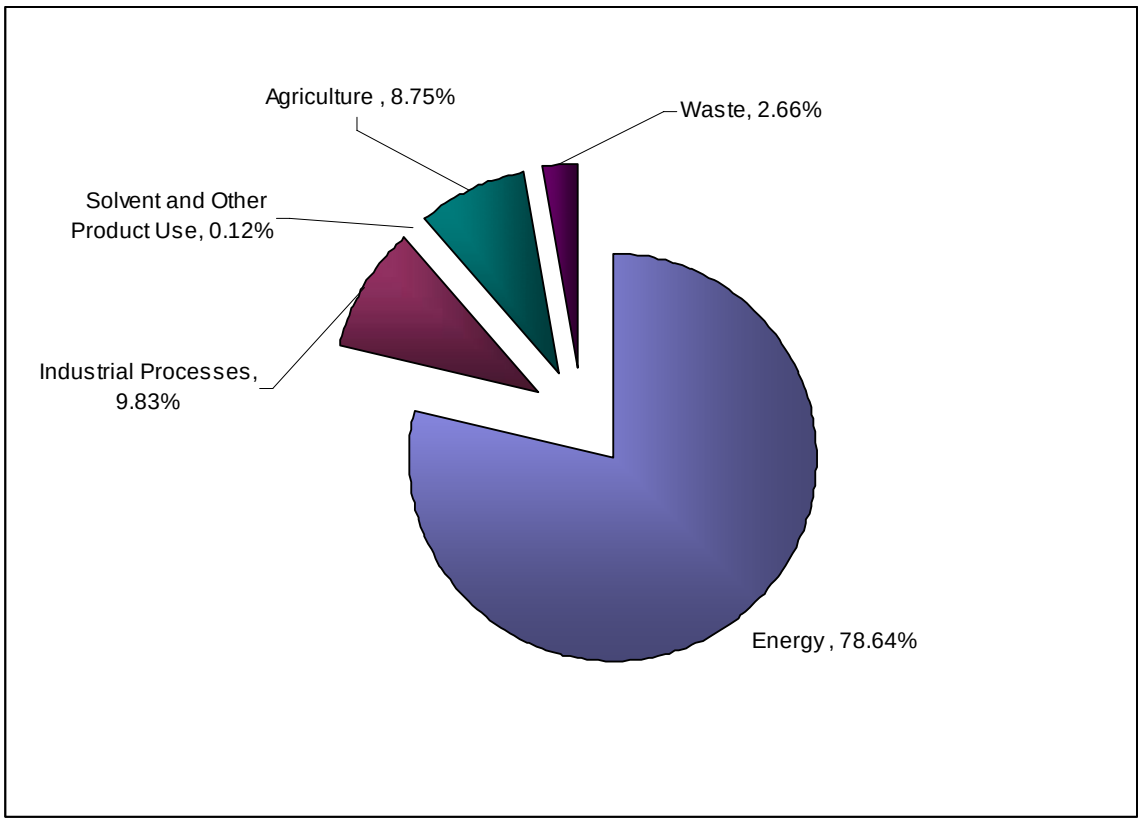


Figure 2.1 Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2006

Table 2.2 Total GHG emissions (in kt CO_2 eq) by sector for the period 1990-2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy	77,623.15	78,323.69	80,052.72	79,740.79	81,952.17	81,952.40	84,434.29	89,044.46	93,977.58	93,374.58	98,779.76	101,125.13	101,043.52	105,310.11	105,564.54	105,430.34	104,681.13
Industrial processes	8,845.58	8,849.96	8,742.23	9,409.90	9,825.28	11,465.53	12,118.43	12,719.47	13,008.22	13,863.66	13,005.57	12,662.08	12,735.91	12,669.59	12,806.75	13,181.79	13,087.51
Solvents	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	157.33	154.67	155.12	155.50	155.87	157.70	159.64
Agriculture	13,519.23	13,306.17	13,101.49	12,503.16	12,736.05	12,486.24	12,776.15	12,486.82	12,342.24	12,364.27	12,357.76	12,144.28	12,079.00	11,998.61	11,936.71	11,733.98	11,644.91
Waste	4,444.95	4,444.06	4,456.94	4,429.52	4,470.27	4,433.39	4,455.62	4,430.60	4,414.25	4,196.86	3,931.01	3,482.17	3,391.56	3,366.30	3,261.83	3,327.43	3,539.15
Total [1)]	**104,602.62**	**105,099.66**	**106,526.22**	**106,253.49**	**109,147.00**	**110,492.21**	**113,936.64**	**118,834.41**	**123,894.69**	**123,959.33**	**128,231.43**	**129,568.33**	**129,405.11**	**133,500.11**	**133,725.70**	**133,831.23**	**133,112.35**
LULUCF	**-3,213.92**	**-3,588.63**	**-3,012.59**	**-3,827.31**	**-3,505.51**	**-4,389.34**	**-3,989.92**	**-3,926.27**	**-3,473.67**	**-4,446.39**	**-2,979.59**	**-5,319.08**	**-5,476.86**	**-5,549.19**	**-5,422.97**	**-5,235.18**	**-5,198.69**
Index per sector																	
Energy	100.0	100.90	103.13	102.73	105.58	105.58	108.77	114.71	121.07	120.29	127.26	130.28	130.17	135.67	136.00	135.82	134.86
Industrial processes	100.0	100.05	98.83	106.38	111.08	129.62	137.00	143.79	147.06	156.73	147.03	143.15	143.98	143.23	144.78	149.02	147.96
Solvents	100.0	100.05	98.83	106.38	111.08	129.62	137.00	143.79	147.06	156.73	147.03	143.15	143.98	143.23	144.78	149.02	147.96
Agriculture	100.0	98.42	96.87	95.35	93.84	92.36	90.91	89.48	88.07	86.68	85.31	83.97	82.64	81.34	80.06	78.80	77.56
Waste	100.0	99.98	100.27	99.65	100.57	99.74	100.24	99.68	99.31	94.42	88.44	78.34	76.30	75.73	73.38	74.86	79.62
Total [2)]	**100.0**	**100.12**	**102.10**	**101.02**	**104.19**	**104.65**	**108.44**	**113.33**	**118.77**	**117.88**	**123.54**	**122.55**	**122.23**	**126.20**	**126.55**	**126.83**	**126.16**

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 2006 by source category is presented in ***Table 2.3***. Total CO_2 emissions increased from 82.42 Mt in 1990 to 109.67 Mt in 2006 (without LULUCF). This upward trend (increase of 33% from 1990 to 2006) 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 75.3 Mt in 1990 to 101.78 Mt in 2006, presenting a total increase of 35% from 1990 to 2006. Carbon dioxide emissions from *Industrial processes* in 2006 increased by 11.44% compared to 1990 levels. On the contrary, emissions from *Solvents and other products use* decreased by 6% compared to 1990 levels. Finally, emissions from *Waste* in 2006 show a continuous increase from 2004. (***Figure 2.2)***.

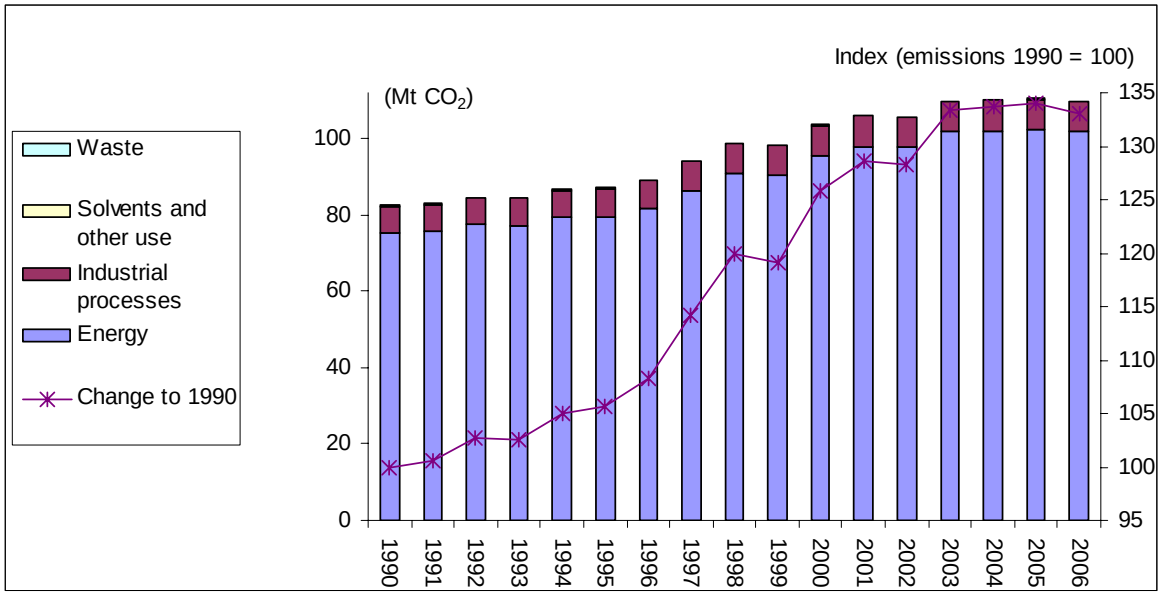


Figure 2.2 CO_2 emissions by sector (in Mt) for the years 1990 – 2006 (without LULUCF)

Table 2.3 CO_2 emissions / removals by sector for the period 1990-2006 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total (with LULUCF)	**79,153.32**	**79,292.39**	**81,559.73**	**80,582.39**	**83,026.50**	**82,589.78**	**85,257.56**	**90,135.78**	**95,164.62**	**93,767.29**	**100,496.87**	**100,661.68**	**100,183.13**	**104,335.37**	**104,766.68**	**105,255.22**	**104,449.00**
Total (without LULUCF)	**82,422.17**	**82,909.08**	**84,655.37**	**84,482.80**	**86,600.58**	**87,017.41**	**89,271.43**	**94,113.43**	**98,776.10**	**98,224.37**	**103,659.42**	**106,005.96**	**105,663.52**	**109,889.49**	**110,201.85**	**110,499.54**	**109,666.12**
1. Energy	**75,316.10**	**75,839.26**	**77,519.47**	**77,249.66**	**79,421.20**	**79,385.82**	**81,650.41**	**86,223.69**	**91,031.27**	**90,385.07**	**95,631.25**	**97,852.02**	**97,635.80**	**101,802.85**	**102,040.42**	**102,449.62**	**101,775.39**
A. Fuel combustion	75,316.08	75,839.25	77,519.46	77,249.64	79,421.19	79,385.81	81,650.39	86,223.66	91,031.24	90,385.05	95,567.81	97,762.60	97,569.92	101,714.92	101,921.87	102,332.82	101,664.99
1. Energy industries	42,445.06	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	55,408.34	54,838.01	56,082.31	57,402.02	57,651.29	54,743.56
2. Man. industry and Construction	10,370.31	10,160.94	9,525.25	9,275.65	9,096.12	9,855.78	10,546.98	10,649.91	10,833.78	9,639.64	10,614.29	10,633.19	10,252.63	10,102.97	9,405.91	8,277.20	9,549.45
3. Transport	14,374.81	15,243.03	15,647.73	15,856.16	16,168.20	16,530.17	17,005.40	17,764.76	19,524.42	19,943.59	19,068.91	19,876.41	20,092.31	21,243.62	21,624.14	22,286.61	23,351.75
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	10,555.10	10,391.74	10,997.42	11,844.66	12,386.97	14,286.02	13,489.81	14,117.72	14,020.23
B. Fugitive emissions	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.02	63.43	89.42	65.88	87.92	118.55	116.80	110.39
2. Industrial processes	**6,936.36**	**6,894.04**	**6,963.06**	**7,063.02**	**7,016.16**	**7,476.94**	**7,468.87**	**7,736.67**	**7,592.44**	**7,679.34**	**7,870.84**	**7,999.26**	**7,872.59**	**7,931.14**	**8,004.58**	**7,891.22**	**7,730.08**
A. Mineral products	6,454.21	6,407.56	6,486.63	6,588.73	6,565.24	7,008.64	7,036.66	7,256.48	7,064.93	7,166.91	7,303.83	7,357.73	7,102.65	7,201.46	7,197.47	7,342.09	7,199.55
C. Metal production	482.15	486.48	476.44	474.29	450.92	468.30	432.21	480.19	527.51	512.43	567.01	641.52	769.94	729.69	807.11	549.14	530.54
3. Solvents	**169.71**	**175.78**	**172.84**	**170.12**	**163.22**	**154.65**	**152.16**	**153.07**	**152.39**	**159.96**	**157.33**	**154.67**	**155.12**	**155.50**	**155.87**	**157.70**	**159.64**
5. LULUCF	**-3,268.86**	**-3,616.69**	**-3,095.64**	**-3,900.40**	**-3,574.07**	**-4,427.62**	**-4,013.88**	**-3,977.65**	**-3,611.47**	**-4,457.08**	**-3,162.55**	**-5,344.28**	**-5,480.39**	**-5,554.12**	**-5,435.17**	**-5,244.32**	**-5,217.12**
6. Waste	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.41**	**0.79**	**0.98**	**1.00**	**1.00**
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**	**13,351.48**	**12,214.71**	**13,150.47**	**13,327.28**	**11,465.99**	**12,663.40**
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	2,321.55	2,321.55	3,021.87	3,106.36	2,387.08	2,862.92
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	11,029.93	9,893.16	10,128.61	10,220.92	9,078.91	9,800.48

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

2.3.2 Methane

The trend of methane emissions from 1990 to 2006 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 41% of total methane emissions in 2006 (without *LULUCF*). Methane emissions from *Agriculture* in 2006 decreased by 0.5% compared to 1990 levels. Methane emissions from *Waste* in 2006 accounted for 37.7% of total methane emissions and decreased by 23.14% 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 21.36% of the total methane emissions and increased more than two times from 1990.

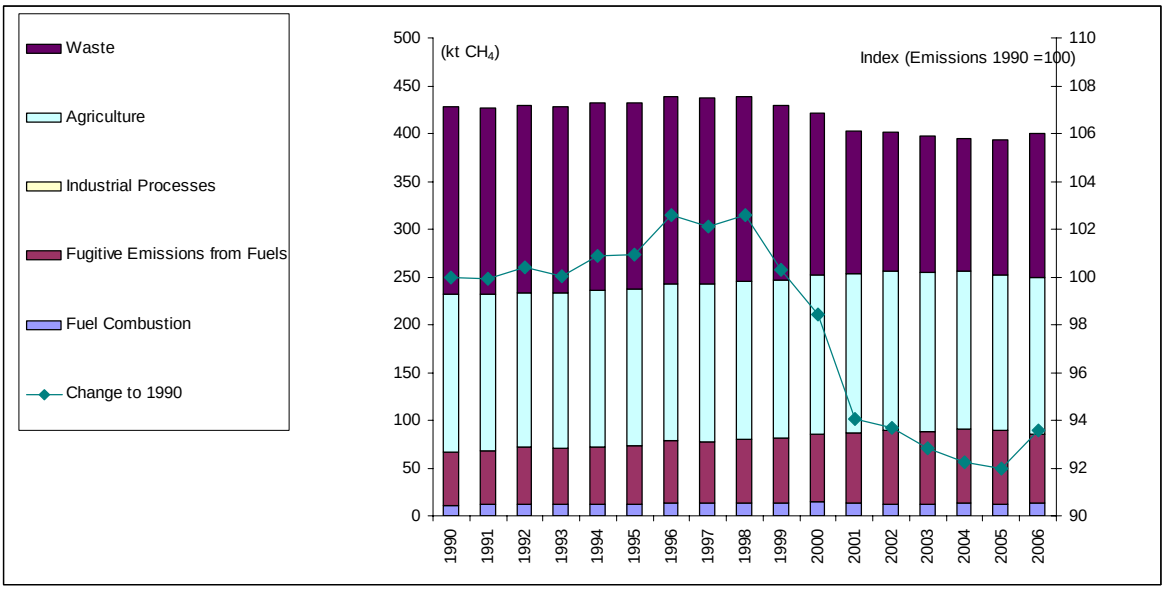


Figure 2.3 CH_4 emissions by sector (in kt) for the period 1990 – 2006 (without LULUCF)

Table 2.4 CH_4 emissions by source category for the period 1990-2006 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total (with LULUCF)	**430.08**	**428.54**	**432.98**	**430.97**	**434.53**	**433.25**	**439.69**	**438.93**	**444.77**	**429.52**	**428.98**	**403.27**	**400.92**	**397.31**	**394.98**	**393.84**	**400.95**
Total (without LULUCF)	**427.70**	**427.32**	**429.39**	**427.81**	**431.56**	**431.59**	**438.66**	**436.71**	**438.81**	**429.06**	**421.07**	**402.18**	**400.76**	**397.09**	**394.45**	**393.44**	**400.15**
1. Energy	**66.79**	**68.57**	**71.60**	**70.45**	**71.87**	**72.86**	**78.03**	**77.31**	**80.23**	**80.85**	**84.72**	**86.93**	**89.82**	**87.95**	**90.06**	**88.78**	**85.45**
A. Fuel combustion	10.41	11.53	12.64	12.44	12.18	12.34	12.88	12.81	12.96	13.37	14.02	13.68	12.47	12.46	12.76	12.44	13.84
1. Energy industries	0.34	0.33	0.35	0.35	0.36	0.36	0.37	0.38	0.39	0.40	0.44	0.44	0.43	0.44	0.46	0.83	0.84
2. Manufacturing industry and Construction	0.90	0.93	0.88	0.87	0.85	0.88	0.87	0.86	0.87	0.77	0.84	0.85	0.74	0.65	0.61	0.54	0.50
3. Transport	5.44	5.76	6.14	6.37	6.52	6.77	7.17	7.31	7.60	7.67	7.63	7.73	7.71	7.83	7.66	7.54	8.97
4. Other sectors	3.73	4.50	5.28	4.85	4.46	4.34	4.46	4.26	4.09	4.54	5.11	4.66	3.58	3.54	4.04	3.54	3.53
B. Fugitive emissions from fuels	56.38	57.05	58.95	58.00	59.68	60.52	65.15	64.50	67.27	67.48	70.70	73.24	77.35	75.48	77.29	76.33	71.61
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
2. Oil and natural gas	4.22	4.09	3.63	2.91	2.73	2.57	5.07	5.37	6.08	5.12	6.50	6.57	6.53	6.84	6.90	6.59	6.76
2. Industrial processes	**0.02**	**0.03**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.04**	**0.04**	**0.04**
4. Agriculture	**164.70**	**162.87**	**161.63**	**162.47**	**163.50**	**164.44**	**165.22**	**165.55**	**165.54**	**165.94**	**166.63**	**166.78**	**166.80**	**166.26**	**166.58**	**163.85**	**163.89**
A. Enteric fermentation	136.47	134.82	134.07	133.90	134.15	134.76	135.09	135.28	135.80	136.67	137.84	137.95	137.82	137.27	137.43	134.85	134.85
B. Manure management	23.66	23.30	23.15	23.11	23.07	23.01	23.00	23.03	23.15	23.29	23.42	23.18	23.12	23.20	23.19	22.95	23.26
C. Rice cultivation	3.29	2.95	2.94	4.05	4.74	5.22	5.72	5.82	5.25	4.67	3.98	4.22	4.48	4.52	4.55	4.62	4.46
F. Field burning of agricultural residues	1.29	1.81	1.47	1.41	1.53	1.44	1.41	1.43	1.34	1.32	1.39	1.42	1.38	1.27	1.42	1.43	1.32
5. LULUCF	**2.37**	**1.21**	**3.59**	**3.16**	**2.96**	**1.66**	**1.04**	**2.22**	**5.96**	**0.46**	**7.91**	**1.09**	**0.15**	**0.21**	**0.53**	**0.39**	**0.80**
6. Waste	**196.19**	**195.85**	**196.14**	**194.87**	**196.17**	**194.26**	**195.38**	**193.82**	**193.01**	**182.24**	**169.69**	**148.44**	**144.11**	**142.86**	**137.78**	**140.78**	**150.78**
A. Solid waste disposal on land	85.76	87.82	89.85	92.15	94.62	95.24	98.11	101.11	103.07	98.05	101.94	106.72	108.10	112.72	113.12	116.06	126.06
B. Wastewater handling	110.43	108.03	106.28	102.72	101.55	99.02	97.27	92.70	89.94	84.19	67.75	41.72	36.00	30.14	24.66	24.72	24.72
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**	**1.10**	**0.99**	**1.02**	**1.03**	**0.91**	**0.98**
Aviation	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
Marine	0.77	0.71	0.81	0.95	1.01	1.08	0.95	0.96	1.07	0.95	1.09	1.06	0.95	0.98	0.98	0.88	0.95

[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 2006 by source category is presented in ***Table 2.5*** and in ***Figure 2.4***.

Agriculture represents the largest anthropogenic source of nitrous oxide emissions in Greece (79% approximately of the total nitrous oxide emissions in 2006, without *LULUCF*). Emissions from this sector decreased by 18.5 % since 1990, mainly because of new agricultural practices applied, affecting the use of synthetic nitrogen fertilizers.

Nitrous oxide is also produced from the reaction between nitrogen and oxygen during fossil fuel combustion. Nitrous oxide emissions from fossil fuels combustion (accounting for 10.8% of total nitrous oxide emissions in 2006) increased by 22.9% from 1990. This increase is mainly attributed to the transport sector as a result of the increasing number of new technology, catalytic passenger cars. However, emissions from the *Energy* sector tend to decrease in recent years (2005-2006), due to penetration of natural gas in electricity production and decrease of solid fuel consumed.

Production of nitric acid is the major source of N_2O emissions from *Industrial processes* and accounts for 6.2% of total N_2O emissions in 2006. Nitrous oxide emissions from this source decreased by 11.12% from 1990, due to the reduction of nitric acid production in Greece.

N_2O emissions from *Waste* in 2006 (3.6% of total emissions without *LULUCF*) increased by 14.4% compared to 1990 levels.

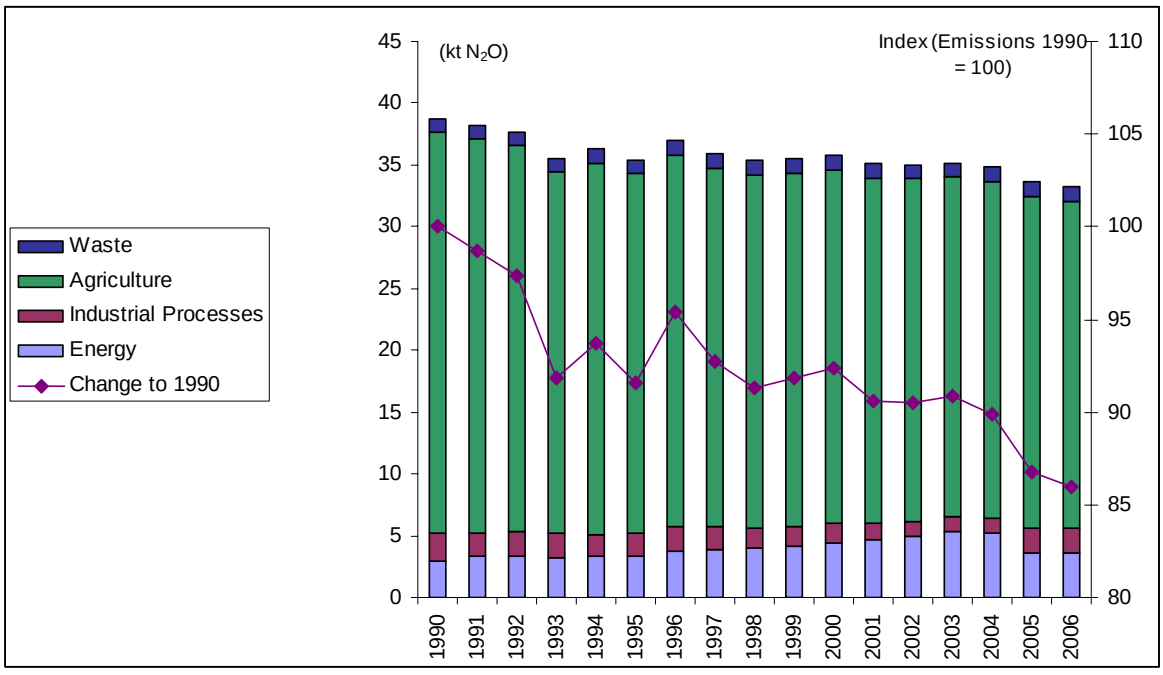


Figure 2.4 N_2O emissions by sector (in kt) for the period 1990 – 2004 (without LULUCF)

Table 2.5 N2O emissions by source category for the period 1990-2006 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total (with LULUCF)	**38.74**	**38.23**	**37.73**	**35.58**	**36.29**	**35.46**	**36.94**	**35.93**	**35.38**	**35.57**	**35.83**	**35.08**	**35.05**	**35.18**	**34.81**	**33.59**	**33.30**
Total (without LULUCF)	**38.72**	**38.22**	**37.71**	**35.56**	**36.27**	**35.45**	**36.93**	**35.92**	**35.34**	**35.56**	**35.78**	**35.07**	**35.05**	**35.17**	**34.81**	**33.59**	**33.29**
1. Energy	**2.92**	**3.37**	**3.32**	**3.26**	**3.30**	**3.34**	**3.69**	**3.86**	**4.07**	**4.17**	**4.42**	**4.67**	**4.91**	**5.36**	**5.27**	**3.60**	**3.58**
A. Fuel combustion	2.92	3.37	3.32	3.26	3.30	3.34	3.69	3.86	4.07	4.17	4.42	4.67	4.91	5.36	5.27	3.60	3.58
1. Energy industries	0.34	0.48	0.51	0.51	0.53	0.52	0.51	0.55	0.59	0.61	0.68	0.68	0.68	0.70	0.72	0.63	0.59
2. Man. industry and Construction	0.18	0.39	0.39	0.38	0.38	0.43	0.47	0.48	0.48	0.47	0.52	0.53	0.54	0.51	0.49	0.40	0.40
3. Transport	0.54	0.56	0.57	0.58	0.60	0.66	0.74	0.82	0.96	1.05	1.09	1.22	1.34	1.50	1.60	1.89	1.89
4. Other sectors	1.86	1.93	1.85	1.79	1.79	1.73	1.98	2.00	2.04	2.04	2.13	2.23	2.35	2.65	2.45	0.68	0.70
B. Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Industrial processes	**2.30**	**1.90**	**1.98**	**1.88**	**1.83**	**1.82**	**2.08**	**1.83**	**1.50**	**1.56**	**1.60**	**1.34**	**1.29**	**1.19**	**1.14**	**2.04**	**2.04**
4. Agriculture	**32.45**	**31.89**	**31.31**	**29.33**	**30.01**	**29.14**	**30.02**	**29.07**	**28.60**	**28.64**	**28.58**	**27.88**	**27.66**	**27.44**	**27.22**	**26.75**	**26.46**
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	0.93	0.92	0.91	0.91	0.99	0.94
D. Agricultural soils	31.45	30.90	30.35	28.37	29.06	28.19	29.08	28.12	27.65	27.68	27.60	26.91	26.71	26.50	26.28	25.73	25.49
F. Field burning of agr. residues	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04	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**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**
6. Waste	**1.05**	**1.07**	**1.09**	**1.09**	**1.13**	**1.14**	**1.14**	**1.16**	**1.16**	**1.19**	**1.19**	**1.18**	**1.18**	**1.18**	**1.19**	**1.19**	**1.20**
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**	**0.37**	**0.34**	**0.37**	**0.37**	**0.30**	**0.33**
Aviation	0.09	0.07	0.08	0.08	0.10	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.11	0.11	0.07	0.07
Marine	0.21	0.19	0.22	0.25	0.27	0.29	0.25	0.25	0.28	0.25	0.29	0.28	0.25	0.26	0.26	0.23	0.25

[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).
- HFCs emissions from *Consumption of Halocarbons and SF6* accounts for half of the F-gases emissions in 2006, while emissions from Production of Halocarbons and SF6 is responsible for 48.5% of the rest.
- 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. It should be noted that estimation for the emissions from Transport Refrigeration are included for the first time in the current inventory.
- Use of F-Gases in metered dose inhalers. The estimation is performed for the first time in the current inventory.
- The use of SF_6 in the electricity transmissions / distribution system.

Table 2.6 Actual F-gases emissions for the period 1990-2006 (in kt CO_2 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**	**3,336.67**	**3,928.61**	**4,246.67**	**4,741.49**	**5,564.02**
HFC-23	935.06	1106.82	908.39	1606.64	2143.91	3253.07	3746.34	3960.22	4359.89	5023.04
HFC-32										
HFC-125										
HFC-134a						83,60	182,27	286,46	381,60	540,97
PFC	**257.62**	**257.56**	**252.30**	**152.59**	**93.62**	**82.97**	**71.74**	**165.34**	**203.75**	**131.72**
SF_6	**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**	**3,423.23**	**4,004.03**	**4,415.74**	**4,949.02**	**5,699.61**

	2000	2001	2002	2003	2004	2005	2006
HFC	**4,486.01**	**4,150.09**	**4,368.94**	**4,285.96**	**4,373.27**	**4,579.97**	**4,648.01**
HFC-23	3735.11	3181.46	3194.57	2661.05	2550.60	2550.60	2290.39
HFC-32	0.51	1.70	4.27	12.42	23.99	35.78	48.66
HFC-125	2.28	7.551	19.02	54.67	105.49	157.71	214.64
HFC-134a	750.90	968.62	1151.09	1557.82	1693.19	1835.87	2094.32
PFC	**148.38**	**91.38**	**88.33**	**77.30**	**71.71**	**71.71**	**70.53**
SF_6	**3.99**	**4.06**	**4.25**	**4.25**	**4.47**	**4.47**	**4.47**
Total	**4,638.38**	**4,245.52**	**4,461.53**	**4,367.51**	**4,449.45**	**4,656.15**	**4,723.01**

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

- NOx emissions increased by 12.6% from 1990 to 2006. Energy sector accounts for the high majority of emissions (99%), while the increase is due to the increased energy consumption in the residential sector. 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 32.7% of the NOx emissions in 2006). Emissions from *Industrial processes* decreased by 10% 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 32.4% from 1990 to 2006 and as a result total CO emissions in 2006 decreased by 26%. Emissions from industrial processes in 2006 increased by 5% compared to 1990 levels. The variation of CO emissions from *LULUCF* is related to the intensity and number of forest fires.
- NMVOC emissions decreased by 5.3% from 1990 to 2006. Emissions from transport, which is the main source of NMVOC emissions in Greece, in 2006 decreased by 21% compared to 1990 levels, while emissions from *Energy* decreased by 13% from 1990 to 2006. The significant increase of NMVOC emissions from *Industrial processes* (approximately 44% from 1990 to 2006) is attributed to the non-energy use of bitumen in the construction sector. Emissions from Solvents and other products use decreased by 5.2% compared to 1990 levels.
- SO_2 emissions increased by 13.6% from 1990 to 2006. Emissions from electricity generation, which is the main source of SO_2 emissions in Greece (66.8 % of total SO_2 emissions for 2006), increased with a mean annual rate of increase of 1.8% for the period 1990 – 2006. 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 34.5%, 8% and 17% respectively for the period 1990 – 2006. Emissions from *Industrial processes* increased by 2% from 1990 due to increase of sulphuric acid industrial production.

Table 2.7 Emissions trends for indirect greenhouse gases and SO_2 (in kt) for the period 1990-2006)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NOx	**280.27**	**290.25**	**294.84**	**294.67**	**301.48**	**298.29**	**302.40**	**308.82**	**324.48**	**313.76**	**305.48**	**317.35**	**319.83**	**320.47**	**316.85**	**328.65**	**315.62**
1. Energy	276.63	286.72	290.95	291.01	297.86	295.07	299.25	305.45	320.41	311.04	300.79	314.43	317.09	317.86	314.02	325.52	312.51
Transport	148.87	158.28	162.29	163.02	165.39	163.06	161.32	165.27	184.82	179.99	157.50	162.38	155.64	155.97	153.29	166.13	149.54
Other energy sectors	127.76	128.44	128.67	127.99	132.47	132.01	137.93	140.18	135.59	131.05	143.30	152.05	161.46	161.89	160.72	159.39	162.98
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	1.36	1.45	1.37	1.39	1.70	1.69
4. Agriculture	1.17	1.58	1.32	1.27	1.36	1.27	1.28	1.30	1.20	1.19	1.25	1.29	1.25	1.19	1.31	1.33	1.23
5. LULUCF	0.59	0.30	0.89	0.79	0.74	0.41	0.26	0.55	1.48	0.11	1.97	0.27	0.04	0.05	0.13	0.10	0.20
CO	**1295.20**	**1307.46**	**1337.67**	**1337.75**	**1334.11**	**1328.23**	**1354.35**	**1355.29**	**1384.42**	**1310.01**	**1356.38**	**1265.90**	**1230.21**	**1192.61**	**1154.91**	**1052.09**	**956.00**
1. Energy	1224.45	1236.14	1253.20	1259.96	1256.77	1265.02	1297.09	1286.61	1282.70	1255.53	1234.84	1204.02	1177.07	1140.40	1096.72	994.44	897.35
Transport	913.162	921.6107	941.3078	948.3513	943.3567	953.892	984.8079	970.1387	964.528	938.6335	912.2155	881.5448	854.7615	838.3387	797.5119	712.4152	616.5722
Other energy sectors	311.29	314.53	311.89	311.61	313.41	311.13	312.28	316.47	318.17	316.90	322.62	322.47	322.31	302.06	299.20	282.02	280.78
2. Industrial processes	22.91	22.78	22.19	20.60	19.18	18.47	18.55	19.28	21.46	22.82	23.13	22.44	22.89	23.66	23.78	24.11	24.05
4. Agriculture	27.06	37.93	30.86	29.54	32.23	30.26	29.65	29.97	28.13	27.62	29.21	29.91	28.91	26.69	29.80	30.09	27.63
5. LULUCF	20.78	10.62	31.42	27.65	25.94	14.48	9.06	19.44	52.13	4.05	69.21	9.53	1.33	1.87	4.62	3.46	6.97
NMVOC	**307.71**	**317.78**	**327.14**	**332.87**	**340.68**	**343.02**	**348.23**	**347.71**	**356.83**	**352.78**	**354.43**	**349.99**	**346.55**	**339.18**	**331.85**	**286.28**	**291.42**
1. Energy	216.84	224.74	233.52	238.83	248.60	246.61	252.33	252.95	256.30	251.66	248.26	244.09	238.19	236.95	224.81	193.38	188.31
Transport	160.30	168.13	176.47	182.90	191.14	187.54	192.23	191.85	194.53	190.80	184.25	180.40	173.47	172.36	162.32	132.33	126.56
Other energy sectors	56.54	56.61	57.05	55.93	57.47	59.08	60.10	61.10	61.77	60.85	64.01	63.69	64.72	64.59	62.49	61.05	61.75
2. Industrial processes	34.22	34.77	36.17	37.88	37.77	44.76	44.84	43.33	49.16	47.37	52.96	53.56	55.87	49.62	54.30	39.85	49.44
3. Solvents	56.65	58.27	57.45	56.16	54.31	51.64	51.05	51.43	51.36	53.75	53.20	52.35	52.49	52.61	52.73	53.05	53.68
SO_2	**471.60**	**512.79**	**528.87**	**524.64**	**516.29**	**539.17**	**529.11**	**522.45**	**529.92**	**548.30**	**499.39**	**504.49**	**515.74**	**554.08**	**548.31**	**544.79**	**535.62**
1. Energy	462.03	503.69	520.58	516.77	508.25	530.41	520.52	513.56	520.89	539.02	490.99	496.13	507.21	545.49	539.59	534.86	525.85
Transport	33.21	33.43	34.85	31.09	36.21	30.47	29.06	30.64	45.28	48.68	23.93	28.32	24.66	26.30	31.17	27.94	30.58
Other energy sectors	428.82	470.26	485.74	485.68	472.05	499.94	491.46	482.93	475.62	490.34	467.06	467.81	482.55	519.19	508.42	506.92	495.27
2. Industrial processes	9.57	9.10	8.29	7.87	8.04	8.77	8.59	8.88	9.03	9.28	8.40	8.35	8.54	8.60	8.72	9.94	9.77

3. Energy

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 2006 amounted to approximately 1300 PJ[3]. The consumption of solid fuels and oil products accounts for 88% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar and wind energy) are 1.5% and 1% respectively. Finally, the share of natural gas in gross inland consumption is more than 9% while the rest <1% of gross inland consumption is covered by electricity (net imports – exports). In 2006, gross inland consumption increased by approximately 43% 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.

[2] Emissions from off-road machinery should be reported under Stationary combustion according to the IPCC Guidelines
[3] Data for the year 2006 are provisional.

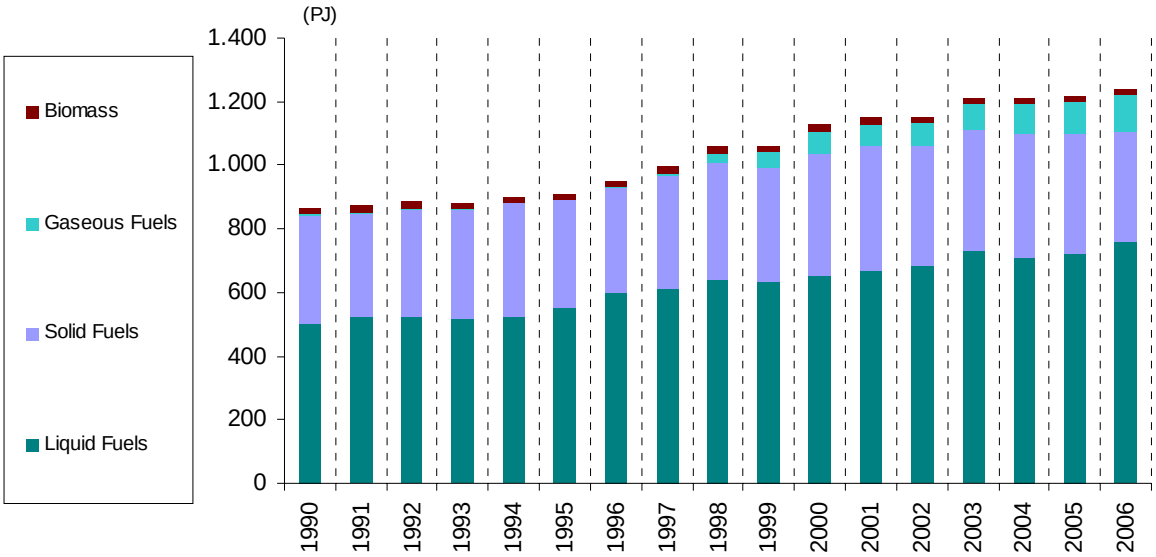


Figure 3.1 Gross inland consumption (in PJ) by energy type for the period 1990 - 2006

GHG emissions from *Energy* in 2006 increased by 35% compared to 1990 (***Figure 3.2***), while the average annual rate of increase for the period 1990 – 2006 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). The last two years an average annual rate decrease of 0.5% is observed.

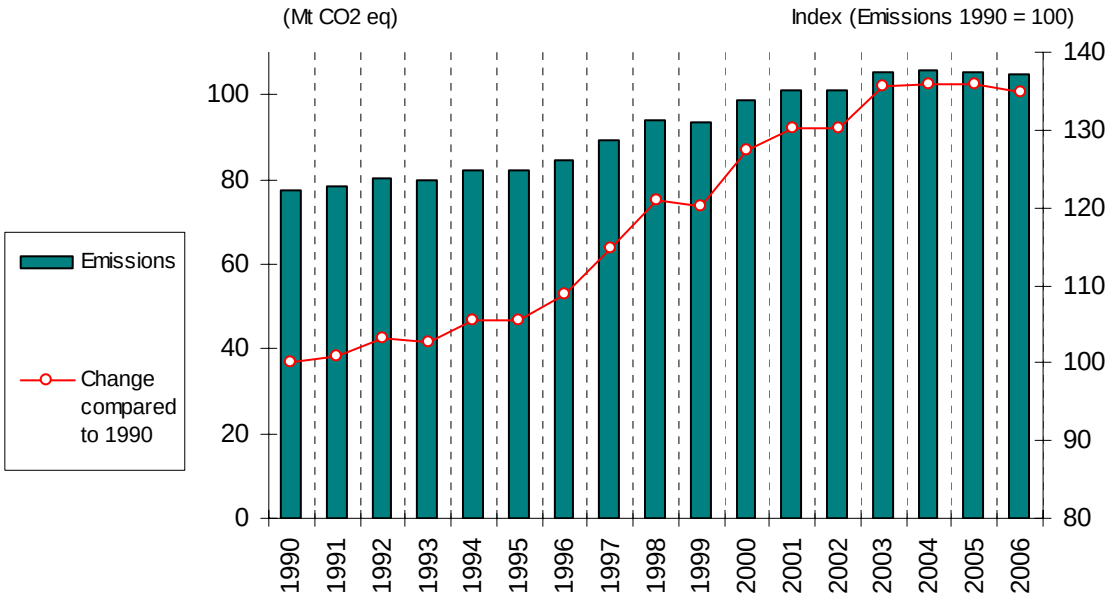


Figure 3.2 Total GHG emissions from Energy (in Mt CO_2 eq) for the period 1990 – 2006

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 1.1% 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 – 2006 decreased at 1% while GDP increased with higher rate (approximately 4%).

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 (52.5%) in 2006 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 23.1%, 9.3% and 13.7% 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 Other sectors (i.e. residential, tertiary and agriculture sectors), showing an average rate of increase of 3.3%, followed by transport with a 3.2% average annual rate of increase. Emissions from energy industries increased with an average annual rate of 1.7%, while emissions from manufacturing industries and construction emissions decreased with a mean annual rate of 0.2%. Finally, fugitive emissions from fuels increased with an average annual rate of 2% for the period 1990 – 2006.

Table 3.1 GHG emissions from Energy by source category and gas for the period 1990 – 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO2 emissions (in Mt)																	
A. Fuel Combustion																	
1. Energy Industries	42.45	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	57.65	54.74
2. Industry	10.37	10.16	9.53	9.28	9.10	9.86	10.55	10.65	10.83	9.64	10.61	10.63	10.25	10.10	9.41	8.28	9.55
3. Transport	14.37	15.24	15.65	15.86	16.17	16.53	17.01	17.76	19.52	19.94	19.07	19.88	20.09	21.24	21.62	22.29	23.35
4. Other Sectors	8.13	8.42	8.06	7.92	7.98	8.05	9.95	10.22	10.56	10.39	11.00	11.84	12.39	14.29	13.49	14.12	14.02
B. Fugitive Emissions from Fuels																	
1. Solid Fuels	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	NE. NO	0.06	0.09	0.07	0.09	0.11	0.11	0.10
2. Oil and Natural Gas	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	0.01	0.01	0.01
CH4 emissions (in kt)																	
A. Fuel Combustion																	
1. Energy Industries	0.34	0.33	0.35	0.35	0.36	0.36	0.37	0.38	0.39	0.40	0.44	0.44	0.43	0.44	0.46	0.83	0.84
2. Industry	0.90	0.93	0.88	0.87	0.85	0.88	0.87	0.86	0.87	0.77	0.84	0.85	0.74	0.65	0.61	0.54	0.50
3. Transport	5.44	5.76	6.14	6.37	6.52	6.77	7.17	7.31	7.60	7.67	7.63	7.73	7.71	7.83	7.66	7.54	8.97
4. Other Sectors	3.73	4.50	5.28	4.85	4.46	4.34	4.46	4.26	4.09	4.54	5.11	4.66	3.58	3.54	4.04	3.54	3.53
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
2. Oil and Natural Gas	4.22	4.09	3.63	2.91	2.73	2.57	5.07	5.37	6.08	5.12	6.50	6.57	6.53	6.84	6.90	6.59	6.76
N2O emissions																	
A. Fuel Combustion (in kt)																	
1. Energy Industries	0.34	0.48	0.51	0.51	0.53	0.52	0.51	0.55	0.59	0.61	0.68	0.68	0.68	0.70	0.72	0.63	0.59
2. Industry	0.18	0.39	0.39	0.38	0.38	0.43	0.47	0.48	0.48	0.47	0.52	0.53	0.54	0.51	0.49	0.40	0.40
3. Transport	0.54	0.56	0.57	0.58	0.60	0.66	0.74	0.82	0.96	1.05	1.09	1.22	1.34	1.50	1.60	1.89	1.89
4. Other Sectors	1.86	1.93	1.85	1.79	1.79	1.73	1.98	2.00	2.04	2.04	2.13	2.23	2.35	2.65	2.45	0.68	0.70
B. Fugitive Emissions from Fuels (in t)																	
1. Solid Fuels	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO	NA.NE NO
2. Oil and Natural Gas	0.64	0.65	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

NE: Not Estimated, NO: Not Occurring

3.1.2 Methodology

The calculation of GHG emissions from fuel combustion activities is based on 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	IPCC categories	CO_2		CH_4		N_2O	
1A	Fuel combustion	Method	Emission factor	Method	Emission factor	Method	Emission factor
1A1	Energy industries						
1A1a	Public electricity and heat production	T2	CS,PS	T2	D	T2	D
1A1b	Petroleum refining	T2	PS	T2	D	T2	D
1A1c	Solid fuel manufacturing and other energy industries	T2	PS	T2	D	T2	D
1A2	Manufacturing industries and Construction	T2	PS	T2	D	T2	D
1A3	Transport						
1A3a	Aviation	T2	D	T2	D	T2	D
1A3b	Road transport	M,T1	D,M	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	CS	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	CR	D	C	C	C	C

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

The energy data used for the calculation of emissions derived from the national energy balance compiled by the Ministry for Development. The Ministry for 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 Agency.

The main changes / improvements made in the present submission compared to the previous one concern:

- The use of the information from verified reports from installations under the EU ETS (Emission Trading System) for years 2005 and 2006.
- The use of Plant Specific emission factors derived from the processing of the data included in ETS reports.
- Taking into consideration the six adjustments recommended by the Expert Review Team (ERT) which performed the in-country review of the initial report of Greece from 23 to 28 of April 2007, the following recalculations of years 1990-2006 were performed:
    1. Public electricity and heat production (1.A.1(a)) - CO_2 emissions from the consumption of solid fuels (lignite).
    2. Energy industries (1.A.1) and manufacturing industries and construction (1.A.2) - N_2O emissions from the combustion of solid and liquid fuels. Moreover, CH_4 emissions from the same sources and CH_4 and N_2O from the combustion of fuels in other sectors (1.A.4) have been recalculated for year 2005.
    3. Chemicals (1.A.2(c)) - CO_2 emissions from the consumption of solid fuels (lignite) for ammonia production.
    4. Civil aviation (1,A.3(a)) - CO_2, CH_4 and N_2O emissions from the combustion of fuel (jet kerosene and aviation gasoline).
    5. Road transportation (1.A.3(b)) - CO_2 emissions from combustion of lubricants.
    6. Residential (1.A.4(b)) - CH_4 and N_2O emission from biomass consumption.

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 77.5% of total national GHG emissions in 2006 (without *LULUCF*).

Table 3.3 Key categories from Energy

IPCC source categories	Gas	Criteria
Stationary combustion – Solid fuels	CO_2	Level, Trend
Stationary combustion – Solid fuels	N_2O	Level
Stationary combustion – Liquid fuels	CO_2	Level, Trend
Stationary combustion – Liquid fuels	N_2O	Level
Stationary combustion – Gas	CO_2	Level, Trend
Mobile combustion – Road vehicles	CO_2	Level, Trend
Mobile combustion – Road vehicles	N_2O	Trend
Mobile combustion - Navigation	CO_2	Level
Mobile combustion – Aviation	CO_2	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.

3.1.3 Completeness

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

Table 3.4 Energy – Completeness of emissions inventory

ENERGY	Greenhouse gases						Other gases			
	CO_2	CH_4	N_2O	HFC	PFC	SF_6	NOx	CO	NMVOC	SO_2
Energy industries										
Public electricity and heat production	☒	☒	☒				☒	☒	☒	☒
Petroleum refining	☒	☒	☒				☒	☒	☒	☒
Manufacturing of solid fuels and other energy industries	☒	☒	☒				☒	NE	NE	NE
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	NE / ☒	☒	NE				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 70% - 75% of total fossil fuel consumption in Greece for the period 1990 – 2006 (***Figure 3.3***).

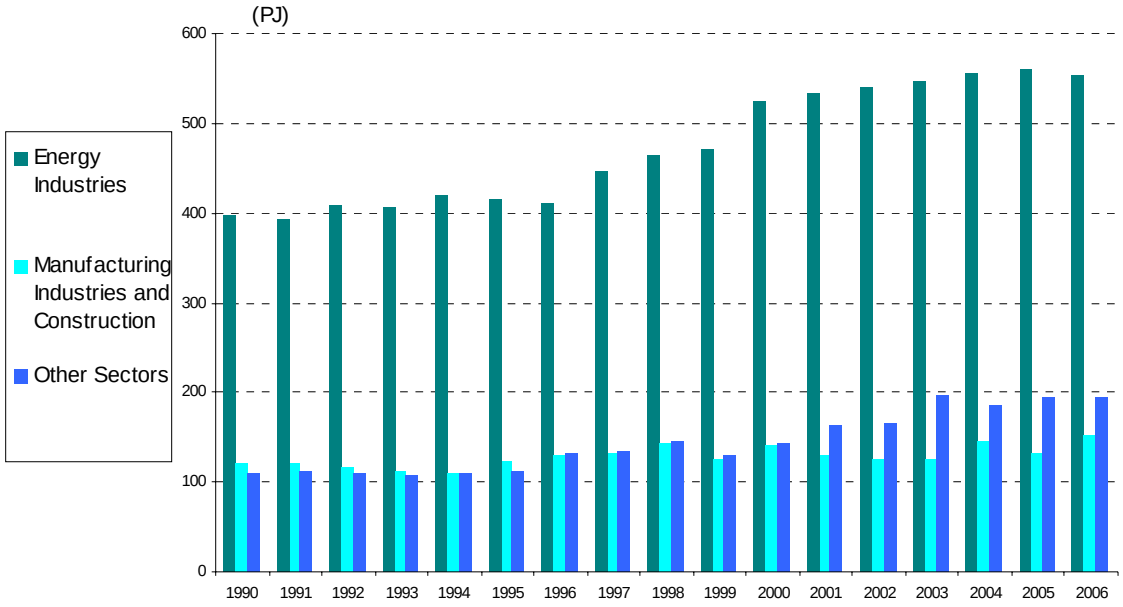


Figure 3.3 ***Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2006***

The consumption of fossil fuels in 2006 increased by approximately 37% compared to 1990, with an average annual rate of increase of 2.3% for the period 1990 – 2006.

- Fuel consumption in energy industries accounts for 64% (average value for the period 1990 – 2006) of fuel consumption in stationary combustion. The average annual rate of increase for the period 1990 – 2006 is estimated at 2.1%, resulting in an increase of 39% in 2006 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 2006 increased by 26% compared to 1990 levels.

- Fossil fuels consumption in Other sectors increased by 76% from 1990 to 2006, as, according to the national energy balance, energy consumption in 1996 increased by approximately 33% 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 2006 (80.6 Mt CO_2 eq) increased by 28% compared to 1990 (62.9 Mt CO_2 eq), with an average annual rate of increase estimated at 1.6% for the period 1990 – 2006 (***Figure 3.4***). It is noted that emissions from stationary combustion account for approximately 60% of total national emissions (without *LULUCF*) for the period 1990 – 2006, while five key categories are included in this sector (CO_2 emissions from solid, liquid and gaseous fuels combustion –N_2O emissions from solid and liquid fuels combustion).

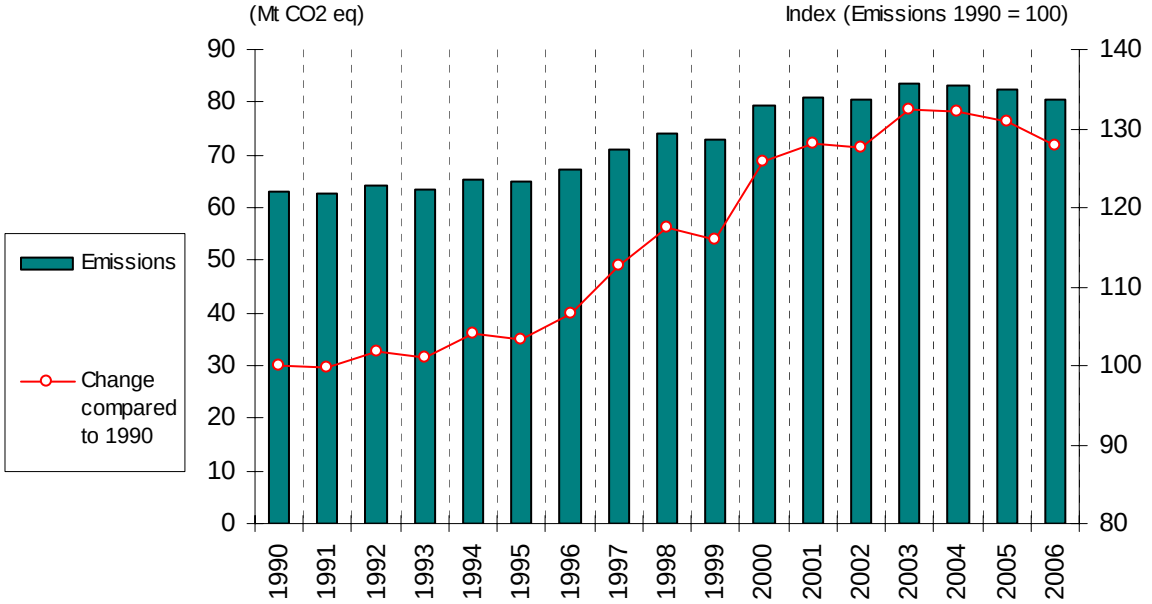


Figure 3.4 ***GHG emissions (in kt CO_2 eq) from stationary combustion for the period 1990 – 2006***

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 around 99% in 2006. Overall, CO_2 emissions in 2006 increased by 29% compared to 1990 levels, with an average annual rate of increase estimated at 1.6%. N_2O emissions in 2006 account for 0.7% of emissions from stationary combustion, decreasing with an average annual rate of 0.5% during the period 1990 – 2006. CH_4 emissions account for the rest 0.3% of total emissions of the sector, and decreased by 2% from 1990 to 2006.

Energy industries constitute the major contributor (approximately 70%) 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 3.3% for the period 1990 – 2006).

Table 3.5 GHG emissions per gas and source category from stationary combustion for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
GHG emissions per gas																	
CO_2 (in Mt)	60.94	60.60	61.87	61.39	63.25	62.86	64.64	68.46	71.51	70.44	76.50	77.89	77.48	80.47	80.30	80.05	78.31
CH_4 (in kt)	4.97	5.76	6.51	6.07	5.67	5.57	5.71	5.50	5.36	5.70	6.39	5.95	4.75	4.63	5.11	4.91	4.87
N_2O (in kt)	2.38	2.81	2.75	2.68	2.70	2.68	2.95	3.04	3.11	3.12	3.33	3.45	3.56	3.86	3.67	1.71	1.69
GHG emissions per source category (in Mt CO_2 eq)																	
Energy industries	42.56	42.17	44.45	44.36	46.35	45.12	44.31	47.77	50.31	50.61	55.11	55.63	55.06	56.31	57.64	57.86	54.94
Industry	10.44	10.30	9.66	9.41	9.23	10.01	10.71	10.82	11.00	9.80	10.79	10.82	10.43	10.27	9.57	8.41	9.68
Other sectors	8.78	9.11	8.74	8.58	8.63	8.68	10.66	10.93	11.27	11.12	11.76	12.63	13.19	15.18	14.33	14.40	14.31
TOTAL (Mt CO_2 eq)	**61.78**	**61.59**	**62.86**	**62.35**	**64.21**	**63.80**	**65.68**	**69.52**	**72.58**	**71.53**	**77.67**	**79.08**	**78.68**	**81.76**	**81.54**	**80.68**	**78.94**

3.2.2 Methodology

3.2.2.1 Previous Submissions Methodology Issues

The calculation of GHG emissions from stationary combustion was based on the application of the CORINAIR methodology, which requires the allocation of energy consumption by sector, fuel and technology (for CH_4 and N_2O emissions).

According to CORINAIR methodology 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:

$$E_{CO_2} = \sum_f FC_f \cdot NCV_f \cdot CC_f \cdot OX_f \cdot {}^{44}\!/_{12}$$

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.

For the estimation of CH_4 and N_2O emissions (as well as of other gases) from stationary combustion 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.

The national energy balance is the main source of information regarding fuel consumption by sector and activity (see Annex II). Further analysis of fuel consumption by technology is based on assumptions presented hereafter.

CH_4 and N_2O emission factors are differentiated by technology and fuel, while CO_2 emission factors are differentiated by fuel. Methane and nitrous oxide emissions calculation is based on the emission factors suggested by the IPCC Guidelines, the IPCC Good Practice Guidance and the CORINAIR methodology.

The basic characteristics of fuels used in the Greek energy system and the estimated CO_2 emission factors are presented in ***Table 3.6***.

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 (tC/TJ)	Oxidation factor (%)	Emission factor (tCO_2/TJ)
Liquid fuels				
Refinery gas	48.15	18.2	99.0	66.07
LPG	47.31	17.2	99.0	62.44
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	43.33	20.2	99.0	73.33
Heavy fuel oil	40.19	21.1	99.0	76.59
Naphtha	45.01	20.0	99.0	72.60
Petroleum coke	31.00	27.5	99.0	99.83
Other oil products	40.19	20.0	99.0	72.60
Solid fuels				
Steam coal	27.21	25.8	98.0	92.71
Lignite				
Electricity generation		34.0	98.0	122.00
Other sectors		27.6	98.0	99.18
Oven and gas coke	29.31	29.5	98.0	106.00
BKB / Patent fuel	15.28	25.8	99.0	93.65
Gaseous fuels				
Natural gas – Domestic		16.1	99.5	58.74
Natural gas – Imports		15.3	99.5	55.82
Gas works gas		15.3	99.5	55.82

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

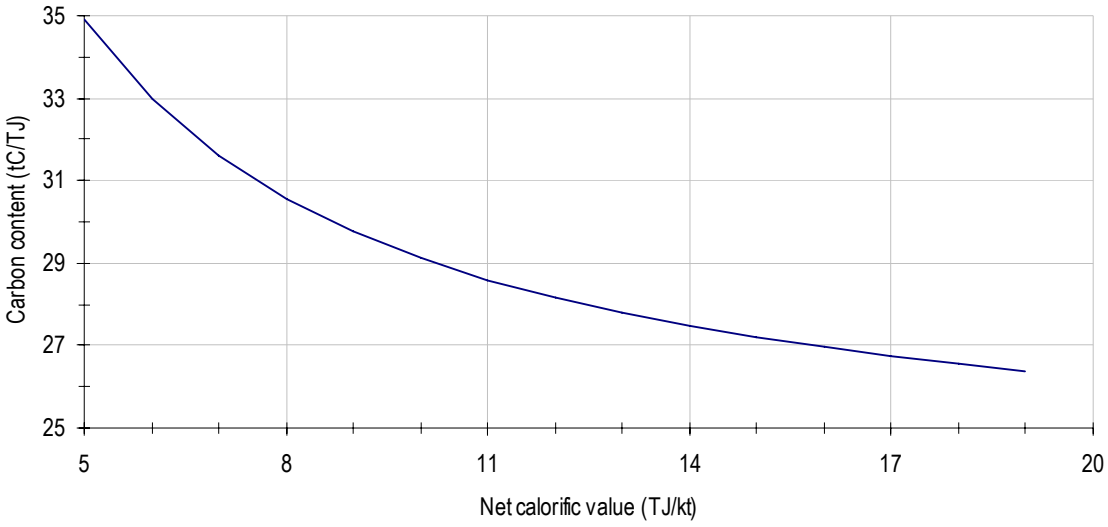
- The IPCC Guidelines constitute the main source of information regarding carbon content and fraction of carbon oxidised by fuel type (IPCC 1997, Tables 1-1 and 1-6), except for lignite used for electricity generation and domestic natural gas.
- Information on the net calorific value per fuel is provided 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.
- 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. Those data were collected during the formulation of the NAP for the period 2005 – 2007. The net calorific value of the domestic natural gas is higher than the net calorific value 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).
- 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 - 2006

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	5.257	9.485	9.485
2006	5.257	9.485	9.485

- The carbon content in lignite used for electricity production is based on studies of the Public Power Corporation (PPC) and the Ministry for Development (PPC 1994). The value of 34 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).



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

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

3.2.2.2 Current Submission Methodology Issues

In this inventory submission, the verified reports from installations under the EU ETS for years 2005 & 2006 were used, capitalizing on the methodology adopted in submissions of previous years.

The calculation of CO_2 emissions for the period of 1990 – 2005 and CH_4 emissions for the period 1990 - 2004 are based on the methodology described in the previous paragraph. For year 2006, detailed plant-level data from verified ETS reports were used for the estimation of emission factors per source category and fuel. More specifically, CO_2 emission factors (EF) per source category and fuel were estimated by using the verified CO_2 emissions and activity data (fuel consumption) obtained from year 2006 verified ETS installation reports (e.g. EF for stationary combustion in cement plants per fuel was estimated by using verified emissions and activity data (fuel consumption) from all greek cement plants). For CH_4 and N_2O, emission factors per source category and fuel were calculated by using activity data from verified ETS installation reports of year 2006 and IPCC default emission factors per fuel and technology type. These EFs were used for years 2005 & 2006 for CH_4 and for the period 1990-2006 for N_2O for estimating the respective

emissions. Emissions were calculated by multiplying the fuel consumption obtained from national energy balance by the emission factor of the respective source category and fuel, which has been estimated as above-mentioned.

Public electricity and heat production

Electricity production in Greece increases continuously at average annual rate of 3.8% for the period 1990 - 2006. Gross electricity production in 2006 (52.6 TWh) was approximately 61% higher compared to 1990 levels (***Figure 3.5***)[4].

Electricity generation relies mostly on the use of fossil fuels (approximately 90% of electricity production in 2006). 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 17% and 16% 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 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 as of the previous submission, 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.

[4] Data for 2004 are provisional

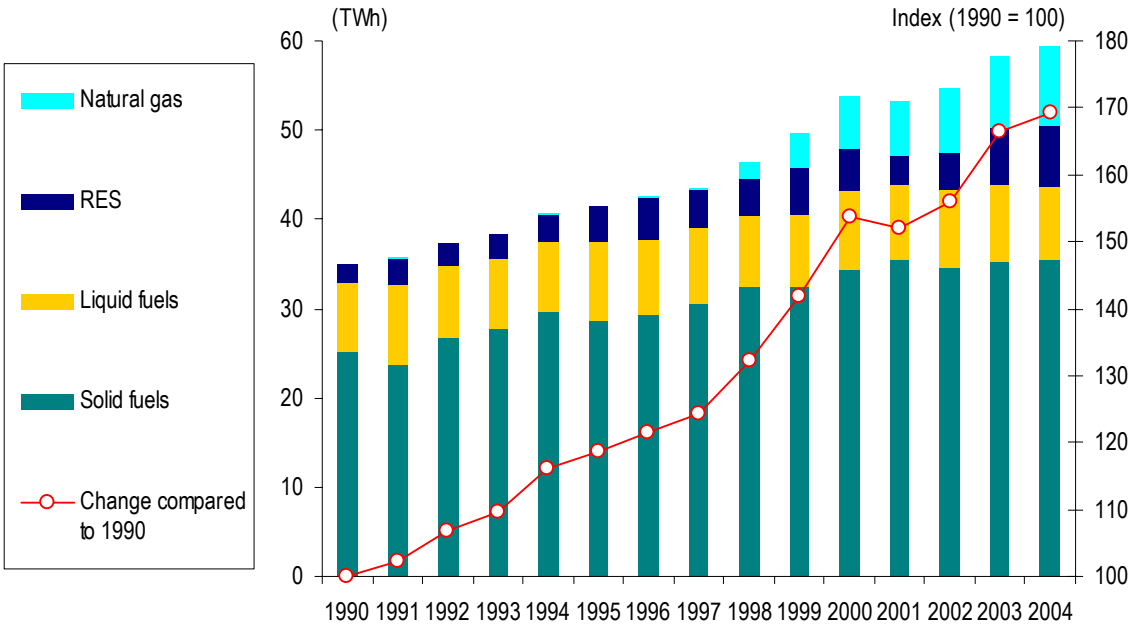


Figure 3.6 Electricity production (in TWh) by energy type for the period 1990 – 2006

GHG emissions from electricity and heat production for the period 1990 – 2006 are presented in ***Table 3.8***. The emission factors used were as described in paragraph 3.2.2.2.

Differences between the emissions estimates presented in the current submission and the estimates presented in the previous submission are attributed mainly to recalculations due to correction of CO_2 emission factor of lignite combustion for 1990-2005, the use of IPCC default emission factors of N_2O per technology and fuel for years 1990-2005, and correction of natural gas consumption activity data for year 2005.

GHG emissions from electricity generation in 2006 increased by 28% compared to 1990 levels at an average annual rate of 1.6% for the period 1990 – 2006. 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. Moreover, the last 2 years (2005 & 2006) a decreasing trend is observed, which is attributed to the further penetration of natural gas consumption.

CO_2 emissions in 2006 accounted for 99.6% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 79% of total emissions in

2006. 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 presented in Annex II (according to the national energy balance) and the estimated emission factors described in paragraph 3.2.2.2. 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 2006, compared to 1990 levels, is estimated at 51%, with an average annual rate of increase estimated at 2.8% for the period 1990 – 2006. This increasing trend is a result of the requirements for the production of sulphur-free fuels (sulphur content less than 10 ppm) set by the EU Directive 2003/17/EC.

Table 3.8 GHG emissions from public electricity and heat production per gas and fuel type and total emissions (in kt CO_2 eq) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2 emissions (in Mt)																	
Solid fuels	34.50	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	43.91	40.28
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
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	3.65	4.25
CH_4 emissions (in kt)																	
Solid fuels	0.17	0.17	0.18	0.18	0.19	0.18	0.17	0.19	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.36	0.33
Liquid fuels	0.10	0.10	0.11	0.10	0.11	0.11	0.12	0.11	0.11	0.13	0.13	0.13	0.13	0.14	0.14	0.25	0.25
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	0.07	0.08
N_2O emissions (in kt)																	
Solid fuels	0.29	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	0.54	0.50
Liquid fuels	0.03	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
Gaseous fuels	NO	NO	NO	NO	NO	NO	NO	0.00	0.02	0.05	0.08	0.08	0.08	0.09	0.10	0.01	0.01
TOTAL (Mt CO_2 eq)	**39.98**	**39.54**	**41.91**	**41.84**	**43.63**	**42.37**	**41.31**	**44.70**	**47.20**	**47.86**	**51.71**	**52.18**	**51.49**	**52.90**	**54.06**	**54.02**	**51.13**

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

Table 3.9 GHG emissions (in kt CO_2 eq) from petroleum refineries for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	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	3757.05	3709.30
CH_4	1.33	1.32	1.25	1.32	1.37	1.40	1.55	1.57	1.62	1.50	1.82	1.86	1.87	1.79	1.88	3.25	3.78
N_2O	4.55	6.36	6.13	6.17	6.59	6.69	7.34	7.50	7.66	6.95	8.33	8.52	8.78	8.44	8.81	9.58	11.15
TOTAL	**2470.74**	**2521.77**	**2445.90**	**2438.20**	**2613.23**	**2645.60**	**2899.56**	**2957.07**	**3029.50**	**2742.70**	**3289.30**	**3348.40**	**3459.27**	**3315.27**	**3462.74**	**3769.88**	**3724.23**

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 & 2006) were used in this inventory. On the basis of those data energy consumption, as given by the national energy balance, was allocated into gas turbines (CHP unit) and boilers. Emission factors were estimated as described in paragraph 3.2.2.2.

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 (Table 3.10) and the emission factors as described in paragraph 3.2.2.2.

GHG emissions from the other energy industries in 2006 decreased by approximately 13% compared to 1990. The annual variation of emissions is related to the changes of the primary production of crude oil and natural gas (see Paragraph 3.4).

Table 3.10 Allocation of natural gas consumption and GHG emissions (in kt CO_2 eq) from other energy industries for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Allocation of natural gas consumption																	
Boilers	56%	60%	59%	58%	65%	65%	61%	57%	84%	50%	79%	76%	77%	82%	89%	89%	90%
Gas turbines	44%	40%	41%	42%	35%	35%	39%	43%	16%	50%	21%	24%	23%	18%	11%	11%	10%
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	70.88	89.28
CH_4	0.08	0.08	0.07	0.07	0.08	0.07	0.08	0.09	0.05	0.01	0.07	0.07	0.07	0.06	0.06	0.03	0.03
N_2O	0.81	0.86	0.75	0.71	0.82	0.78	0.82	0.87	0.66	0.05	0.82	0.78	0.83	0.71	0.86	0.04	0.05
TOTAL	**102.92**	**109.42**	**94.97**	**90.28**	**104.03**	**99.44**	**104.78**	**111.34**	**84.34**	**6.24**	**104.93**	**99.70**	**105.20**	**91.06**	**109.88**	**70.94**	**89.35**

Manufacturing industries and construction

Emissions from energy consumption for the production of steam and process heat are 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 & 2006 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 – 2006 (***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 & 2006. 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 & 2006 activity data were available through the verified ETS reports. Emission factors as described in paragraph 3.2.2.2 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 & 2006. 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 & 2006 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.

  Emission factors as described in paragraph 3.2.2.2 were applied.

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

  Emission factors as described in paragraph 3.2.2.2 were applied.

- 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 & 2006.

- For years 1990-2004, it is assumed that steam coal and petroleum coke consumption refers only to cement production. Heavy fuel oil consumption for cement production is kept constant for the period 1990 – 2004 as no significant inter-annual variations are observed. For 2005 & 2006 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 & 2006 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 constitutes the only sub-source category in which emissions increased for the period 1990 – 2006 (by 11% from 1990 to 2006). Overall, GHG emissions from industry in 2006 decreased by 7% compared to 1990, with an average annual rate of 0.2% for the period 1990 – 2006.

Table 3.11 GHG emissions (in kt CO_2 eq) from manufacturing industries and construction for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	185.50	175.18
CH_4	0.55	0.48	0.48	0.43	0.42	0.39	0.28	0.31	0.29	0.34	0.30	0.32	0.35	0.32	0.24	0.08	0.07
N_2O	0.87	1.06	1.06	0.94	0.92	0.89	0.66	0.77	1.24	1.76	1.80	2.04	2.16	1.92	1.85	0.13	0.13
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	1631.81	1398.60
CH_4	0.73	0.67	0.58	0.63	0.63	0.65	0.74	0.64	0.67	0.64	0.82	0.79	0.84	0.90	0.83	0.74	0.75
N_2O	3.23	5.43	5.11	5.53	5.45	5.46	6.23	5.44	6.10	7.39	9.98	9.43	10.42	11.90	11.51	7.26	7.12
Chemicals																	
CO_2	1304.20	925.83	563.42	528.76	442.07	456.79	686.08	803.12	1129.33	740.06	825.21	724.38	765.23	970.38	1082.85	1115.68	1188.56
CH_4	0.41	0.26	0.24	0.25	0.24	0.24	0.41	0.47	0.56	0.37	0.38	0.37	0.36	0.36	0.45	0.98	0.75
N_2O	3.08	4.10	1.97	4.36	3.51	3.93	4.59	4.43	3.07	2.41	3.19	3.31	4.01	5.37	6.37	9.96	4.91
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	230.61	269.84
CH_4	0.25	0.24	0.23	0.22	0.20	0.17	0.24	0.28	0.24	0.30	0.31	0.27	0.27	0.28	0.18	0.14	0.16
N_2O	0.60	1.41	1.37	1.29	1.22	1.04	1.44	1.80	2.24	2.63	2.95	3.31	3.76	4.01	3.71	1.17	1.38
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	766.15	857.97
CH_4	0.83	0.83	0.85	0.86	0.83	0.80	3.00	3.00	2.96	2.91	3.46	3.34	3.56	3.15	3.07	6.08	5.53
N_2O	2.72	4.23	4.40	4.37	4.28	3.91	27.24	29.28	30.39	32.13	39.05	36.69	39.07	35.34	36.35	14.53	13.72
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	4347.44	5659.30
CH_4	16.14	16.96	16.13	15.85	15.49	16.15	13.71	13.44	13.53	11.51	12.31	12.76	10.22	8.59	8.05	3.25	3.29
N_2O	44.25	106.22	105.94	102.05	102.41	118.97	105.39	108.28	104.66	98.51	105.72	109.83	106.82	98.43	93.51	91.63	96.58
TOTAL	**10443.95**	**10302.83**	**9663.61**	**9412.43**	**9231.72**	**10008.38**	**10710.89**	**10818.04**	**10999.74**	**9800.54**	**10794.56**	**10815.65**	**10434.48**	**10273.54**	**9572.03**	**8413.14**	**9683.85**

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 almost exclusively by liquid fossil fuels, while the contribution of biomass (fuel wood), especially in the residential sector, is also significant (mainly in rural areas).

In this submission activity data of biomass consumption were not obtained by national energy balance, but from FAO fuelwood statistics. The biomass consumption reported in national energy balance was considered as inaccurate, since it has a constant value over the period 1990-2006. Recalculations were performed for years 1990-2005.

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 the emission factors of CH_4 and N_2O by fuel type and technology suggested by CORINAIR (SNAP 0201 and 0202 – EAA 2001) till year 2005. For year 2006 the emission factors of CH_4 and N_2O used are as described in paragraph 3.2.2.2.

GHG emissions from the residential and the commercial/institutional sector in 2006 increased substantially compared to 1990 levels (95% and 190% respectively), as a result of the great increase of liquid fuel consumption since 1996, according to the national energy balance.

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 – 2006.

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 CH_4 and N_2O emission factors per fuel and technology proposed by CORINAIR (SNAP 0201 for thermal needs and SNAP 0806 for movement of agricultural machineries – EEA 2001), for years 1990-2005. For year 2006 the emission factors of CH_4 and N_2O used are as described in paragraph 3.2.2.2.

Table 3.12 GHG emissions (in kt CO_2 eq) from the residential sector for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	11.41	5.55
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	9680.83	9213.55
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
CH_4 emissions																	
Solid fuels	4.45	6.27	5.99	5.87	6.59	5.45	6.31	7.13	6.05	3.27	3.64	3.42	1.45	0.72	1.72	0.00	0.00
Liquid fuels	2.71	2.70	2.65	2.60	2.60	2.69	3.66	3.82	4.03	3.97	4.30	4.64	4.82	5.72	5.45	8.26	7.84
Gaseous fuels	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.08	0.06	0.12
Biomass	62.80	76.75	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	56.96
N_2O emissions																	
Solid fuels	2.36	3.34	3.20	3.13	3.55	2.90	3.39	3.83	3.26	1.69	1.89	1.77	0.77	0.36	0.95	0.06	0.03
Liquid fuels	179.56	178.52	175.51	172.11	171.46	177.68	242.42	253.42	266.71	262.39	284.44	306.53	319.14	379.06	360.77	24.22	23.09
Gaseous fuels	0.04	0.05	0.07	0.06	0.04	0.05	0.05	0.05	0.42	0.35	0.44	0.47	0.78	1.70	3.15	0.09	0.18
Biomass	31.87	31.86	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	23.65

Table 3.13 GHG emissions (in kt CO_2 eq) from the commercial / institutional sector for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	7.67	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	1348.18	1392.15
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
CH_4 emissions																	
Solid fuels	0.39	0.34	0.11	0.06	0.06	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	NO
Liquid fuels	0.32	0.44	0.42	0.39	0.39	0.44	0.53	0.51	0.51	0.49	0.50	0.63	0.63	0.68	0.76	1.10	1.13
Gaseous fuels	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.06	0.10	0.06	0.08
N_2O emissions																	
Solid fuels	0.26	0.22	0.07	0.04	0.04	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.04	NO
Liquid fuels	21.34	28.02	26.39	24.62	24.47	26.47	31.94	30.87	31.23	30.35	30.99	40.07	40.45	43.44	46.47	3.14	3.27
Gaseous fuels	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.79	0.67	0.78	1.11	1.65	2.51	3.95	0.10	0.11

NO: Not Occurring

Table 3.14 GHG emissions (in kt CO_2 eq) from agriculture for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	2729.35	2881.58
CH_4	7.54	8.01	7.82	7.96	7.67	7.76	7.87	7.52	7.53	8.15	8.71	8.13	7.02	7.75	7.72	7.94	7.91
N_2O	340.77	356.26	329.61	320.16	322.34	298.34	304.13	303.55	303.56	303.90	304.19	308.68	339.20	370.92	315.78	159.93	168.03

The majority of GHG emissions from agriculture are attributed to agricultural machinery (approximately 95% for the period 1990 – 2006). Overall, in 2006 emissions from agriculture decreased by approximately 7% compared to 1990 emissions.

3.2.3 Recalculations

The recalculations of emissions that were performed in the present inventory, compared to the previous one, concern mainly the four adjustments concerning stationary combustion recommended by the Expert Review Team (ERT) that performed the in-country review of the initial report of Greece from 23 to 28 of April 2007:

- Public electricity and heat production (1.A.1(a) - CO_2 emissions from the consumption of solid fuels (lignite): Following ERT recommendations the emission factor 122 tCO_2/TJ was used in calculations for lignite consumption in category 1.A.1(a), according to a study of Public Power Corporation (PPC, 1993). CO_2 emissions for the years 1990-2005 were recalculated. A conservative factor of 0.98 has been applied to emission factor for base year calculations, according to 20/CMP.1.
- Energy industries (1.A.1) and manufacturing industries and construction (1.A.2) - N_2O emissions from the combustion of solid and liquid fuels: Following ERT recommendations a tier 2 with IPCC default emission factors was apllied. The methodology followed is described in paragraph 3.2.2.2. A conservative factor of 0.73 has been applied to emission factors for base year calculations, according to 20/CMP.1. Emissions for the years 1990-2005 were recalculated. Correspondingly, recalculations were performed to CH_4 emissions for 2005 to the above-mentioned sectors and for both N_2O and CH_4 emissions for the Other Sectors (1.A.4) for year 2005, according to the methodology described in paragraph 3.2.2.2.
- Chemicals (1.A.2 (c)) – CO_2 emissions from the combustion of lignite for ammonia production: This recalculation refers to 1990 exclusively. Following ERT recommendations the lignite used as feedstock for ammonia production was changed. A conservative factor of 0.98 has been applied to adjusted activity data, according to 20/CMP.1.
- Residential (1.A.4(b)) – CH_4 and N_2O emissions from biomass consumption: Following ERT recommendations, the biomass consumption in this sector was changed. Instead of obtaining the reported value of biomass consumption from the national energy balance, FAO fuelwood statistics of Greece were used. Biomass consumption from national energy balance was considered inaccurate, since it has a constant value for the period 1990-2006. Recalculations were performed for years 1990-2005. A conservative factor of 0.82 has been applied to activity data (biomass consumption) for base year calculations, according to 20/CMP.1.
- The use of the information collected from verified reports of installations under EU ETS in order to disaggregate energy consumption in industry into different activities / technologies (e.g. disaggregation of energy consumption in non-metallic minerals into energy consumption for cement, lime, ceramics and glass production) and estimate source category (or activity) emission factors.

↳ Correction of natural gas consumption activity data for year 2005.

In some cases recalculations performed due to (α) correction of errors while entering data in the calculation files, (β) the number of decimals used, especially for natural gas and (c) the use of revised energy balance information.

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

Key issues that need further consideration regarding the emissions inventory by stationary combustion concern the timely availability of national energy balance account and the availability of information on the share of different technologies used at the level of final energy consumption. Specifically,

1. The date of completion of the national energy balance account is not usually in accord with the deadlines of submission of the annual inventory of GHG emissions in the European Commission and in the Secretariat of the Convention. The establishment of a formal co-operation with data providing agencies and the training of data providing agencies' representatives are two supporting actions for managing this issue.
2. The availability of information regarding the structure of energy demand especially in industry has been improved significantly on the basis of the data collected during the formulation of the NAP for the period 2005 – 2007 and from verified reports from installations under the EU ETS (2005 & 2006). The further exploitation of verified ETS reports will contribute to the improvement of inventory emissions estimations.

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
Recalculations of CO_2 (%)																
Energy Industries	-1.75	0.00	0.85	0.08	0.06	0.15	0.25	0.10	-0.05	-0.07	-0.08	-0.09	-0.09	-0.04	-0.10	-0.91
Manufacturing Ind & Construction	-0.83															-1.82
Other Sectors																-0.31
Recalculations of CH_4 (%)																
Energy Industries																74.92
Manufacturing Ind & Construction					0.00				0.00							-0.39
Other Sectors	-63.26	-56.09	-48.36	-52.47	-56.42	-57.42	-56.61	-58.72	-60.13	-55.33	-49.99	-54.31	-64.48	396.75	436.24	-65.69
Recalculations of N_2O (%)																
Energy Industries	-94.02	-91.47	-92.06	-91.52	-91.45	-91.55	-91.67	-91.44	-91.08	-90.79	-90.41	-90.42	-90.32	-90.33	-90.20	-91.58
Manufacturing Ind & Construction	-86.82	-70.59	-70.45	-69.47	-69.38	-67.53	-67.74	-66.67	-66.57	-62.61	-62.58	-62.55	-60.90	-61.26	-60.31	-64.38
Other Sectors	-10.60	-10.25	-9.65	-10.46	-11.02	-11.42	-10.11	-10.26	-10.21	-9.61	-8.68	-8.77	-9.33	-8.41	-8.61	-75.53
Impact of Recalculations on Total Emissions excl LULUCF of CO_2 (%)																
Energy Industries	-0.72	0.00	0.35	0.03	0.03	0.06	0.10	0.04	-0.02	-0.03	-0.03	-0.04	-0.04	-0.02	-0.04	-0.39
Manufacturing Ind & Construction	-0.08															-0.11
Other Sectors																-0.03
Impact of Recalculations on Total Emissions excl LULUCF of CH_4 (%)																
Energy Industries																0.01
Manufacturing Ind & Construction																0.00
Other Sectors	-0.13	-0.11	-0.10	-0.11	-0.11	-0.11	-0.11	-0.11	-0.10	-0.10	-0.08	-0.09	-0.11	0.04	0.05	-0.11
Impact of Recalculations on Total Emissions excl LULUCF of N_2O (%)																
Energy Industries	-1.60	-1.52	-1.72	-1.60	-1.62	-1.57	-1.51	-1.53	-1.51	-1.51	-1.54	-1.55	-1.52	-1.52	-1.54	-1.58
Manufacturing Ind & Construction	-0.34	-0.28	-0.27	-0.25	-0.24	-0.25	-0.27	-0.25	-0.24	-0.20	-0.21	-0.21	-0.20	-0.19	-0.17	-0.17
Other Sectors	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.06	-0.06	-0.05	-0.49

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 items:

In total, GHG emissions from transport (***Table 3.16***) in 2006 increased by approximately 65% compared to 1990 emissions (from 14.65 Mt CO_2 eq in 1990 to 24.11 Mt CO_2 eq in 2006). The average annual rate of emissions increase from transport for the period 1990 – 2006 was 3.8% and is higher than the corresponding rate calculated for stationary combustion (2.3% for the same period). On an annual base, the highest increase of emissions (compared to the previous year) was observed in 1998 (approximately 9%) and the highest reduction in 2000 (4.4%). 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 2006, the majority of GHG emissions derived from road transport, the contribution of which increased from 82% in 1990 to 85% of total emissions of the sector, since the number of vehicles in the country has considerably increased between 1990 and 2006.

The share of internal navigation in the emissions of the transport sector decreased from 12.6% in 1990 to 9.5% in 2006. Additionally, the contribution of internal aviation increased from 4% in 1990 to 4.6% in 2006, while the contribution of railways decreased from 1.6% in 1990 to 0.6% in 2006. The contribution of other transport (pipeline transportation) is negligible.

During the period 1990 – 2006 GHG emissions from road transport present an average annual rate of increase of approximately 4.2%, while emissions from internal navigation increased with an average annual rate of 1.5%. Emissions from internal aviation increased by an average annual rate of 5.3% 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 1.2% for the period 1990 – 2006.

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 Mt CO_2 eq) and energy consumption (in PJ) in the transportation sector per category, for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Emissions (Mt CO2 eq)																	
Aviation	0.59	0.63	0.69	0.75	0.78	0.83	0.89	1.01	1.03	1.23	1.35	1.24	1.06	1.20	1.24	1.25	1.12
Road transport	11.99	12.86	13.18	13.49	13.67	14.13	14.83	15.18	15.96	16.27	16.48	16.86	17.51	18.59	18.72	19.54	20.55
Railways	0.23	0.18	0.17	0.18	0.19	0.16	0.16	0.15	0.17	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
Navigation	1.84	1.87	1.92	1.76	1.85	1.76	1.51	1.83	2.82	2.79	1.60	2.17	1.96	1.94	2.17	2.09	2.30
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00
Total	**14.65**	**15.54**	**15.96**	**16.18**	**16.49**	**16.88**	**17.39**	**18.17**	**19.98**	**20.44**	**19.58**	**20.42**	**20.68**	**21.88**	**22.28**	**23.02**	**24.11**
Energy consumption (in PJ)																	
Aviation	8.32	8.79	9.62	10.55	10.93	11.58	12.43	14.12	14.36	17.17	18.85	17.37	14.90	16.78	17.39	17.52	15.74
Road transport	167.16	179.05	183.36	187.64	190.26	196.37	205.85	210.65	221.21	225.13	227.90	232.93	241.64	256.19	257.91	264.93	273.14
Railways	2.76	2.15	2.06	2.11	2.28	1.89	1.98	1.85	2.04	1.77	1.77	1.77	1.77	1.77	1.77	1.73	1.73
Navigation	24.85	24.91	25.57	23.44	24.65	23.48	20.09	24.33	37.40	36.92	21.36	28.89	26.15	26.02	28.98	27.80	30.74
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.07	0.09
Total	**203.09**	**214.90**	**220.61**	**223.74**	**228.12**	**233.32**	**240.35**	**250.95**	**275.01**	**280.99**	**269.688**	**280.96**	**284.46**	**300.76**	**306.05**	**312.05**	**321.44**
Memo items 1) – International bunkers																	
Emissions (Mt CO2 eq)																	
International aviation	2.45	2.11	2.20	2.34	2.78	2.61	2.50	2.42	2.54	2.85	2.50	2.32	2.32	3.02	3.11	2.39	2.86
International marine	8.03	7.37	8.44	9.89	10.47	11.25	9.90	9.93	11.06	9.84	11.36	11.03	9.89	10.13	10.22	9.08	9.80
Total	**10.48**	**9.48**	**10.67**	**12.21**	**13.25**	**13.86**	**12.40**	**12.34**	**13.60**	**12.69**	**13.86**	**13.35**	**12.21**	**13.15**	**13.33**	**11.47**	**12.66**
Energy consumption (in PJ)																	
International aviation	34.65	29.88	31.17	33.17	39.37	36.92	35.36	34.20	35.89	40.31	35.36	32.86	32.86	42.78	43.97	33.76	40.50
International marine	106.58	97.91	112.59	130.94	138.96	149.53	131.45	131.75	146.34	130.42	150.50	145.96	131.22	134.07	135.40	119.73	129.21
Total	**141.22**	**127.78**	**143.75**	**164.12**	**178.33**	**186.45**	**166.81**	**165.95**	**182.24**	**170.73**	**185.86**	**178.83**	**164.08**	**176.84**	**179.37**	**153.49**	**169.71**

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

3.3.1 Methodology

Road transportation

For the estimation of emissions from road transportation the model COPERT III (Ntziachristos and Samaras, 2000), was applied. The model, developed within the framework of the activities of the European Topic Centre on Air Emissions, is to be used by EEA member countries for the compilation of CORINAIR emission inventories.

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 is calculated based on those data and a number of equations described in Ntziachristos and Samaras (2000).

It should be noted here that COPERT III, 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 driving conditions taken into account are presented in ***Table 3.17***, while the vehicle fleet by category, engine size or weight, for the period 1990-2006 are shown in ***Table 3.18.*** (Further details concerning the split of vehicle fleet, by emission control technologies, as well as the calculated emission factors and efficiency are presented in Annex II).

It should be also noted that, the average speed values and the mileage contribution by road category, shown in Table 3.17, are typical values for Greece suggested by the model. Considering that these values are taken to remain constant through all the period 1990-2006, their validity under the changing driving conditions in Greece, should be further investigated.

Table 3.17 ***Vehicle categories, mileage, average speed and mileage contribution by road vehicle category.***

Vehicle categories		Mileage				Average speed		
		Total (km)	Urban (%)	Rural (%)	Highway (%)	Urban (km/h)	Rural (km/h)	Highway (km/h)
Passenger cars	Gasoline	11000	44	42	14	19	60	90
	Diesel	75000	44	42	14	19	60	90
Light duty vehicles	Gasoline	12000	44	42	14	19	60	90
	Diesel	14000	35	35	30	19	60	90
Heavy duty vehicles	Diesel	40000	35	35	30	19	60	90
Buses & Coaches	Urban buses	40000	100			19		
	Coaches	25000	5	45	50	19	60	90
Mopeds & motorcycles	< 50 cc	4000	90	10		20	40	
	> 50 cc	9000	65	20	15	30	60	60

In 2006 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 2006). It must be pointed out that National Statistical Service of Greece (NSSG) published data, are considered as provisional since 1995.

Road transport is a key category of CO_2 and N_2O emissions. CO_2 emissions in 2006 increased by approximately 67% compared to 1990 emissions, CH_4 emissions increased by 73%, while N_2O emissions tripled from 1990 (***Table 3.19)***.

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. Although there is an important increase of N_2O emissions during the whole period of study, following the respective increase of passenger cars number, in 2006 the entrance in circulation of new technology (new catalytic converters) passenger cars (69% of total passenger cars in 2006) has overcome the emissions increase due to fleet augmentation and led to slightly lower N_2O emissions compared with those of 2005 (***Figure 3.6)***. Although the total number of circulating vehicles still increases, as there is a remarkable increase of less polluting vehicles, CO, NOx and NMVOC emissions decrease too. 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 3.18 Vehicle fleet (in 1000s) by category, engine size or weight for the period 1990-2006

Vehicle categories	By fuel type & engine size / weight	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Passenger cars	Gasoline <1,4 l	1456.2	1449.9	1454.4	1539.3	1619.3	1703.1	1789.7	1872.6	1996.1	2170.3	2335.6	2458.2	2574.1	2614.7	2743.7	2858.7	2913.2
	Gasoline 1,4 - 2,0 l	210.5	258.0	305.1	348.3	374.7	416.4	460.0	530.0	570.8	638.5	727.2	811.8	906.2	1040.5	1218.0	1299.0	1449.5
	Gasoline >2,0 l	37.3	38.1	38.1	39.6	48.9	52.9	55.8	60.7	67.9	74.4	81.3	96.4	103.7	119.0	128.9	130.3	170.7
	Diesel <2,0 l	17.1	17.1	17.1	17.1	17.1	18.1	18.7	19.5	20.5	21.8	23.1	23.9	24.8	25.3	24.1	24.2	23.9
	Diesel >2,0 l	11.4	11.4	11.4	11.4	11.4	12.1	12.9	15.0	18.5	22.0	25.9	31.5	35.4	38.0	40.3	40.3	40.5
	LPG	3.0	3.0	2.9	2.8	2.7	2.2	2.4	2.2	2.1	1.9	1.9	2.0	1.9	1.9	2.1	2.1	2.2
Light duty vehicles	Gasoline <3,5t	615.4	627.1	613.5	625.1	634.2	645.4	655.9	669.1	671.7	672.6	672.9	671.7	668.1	663.0	676.8	685.5	701.9
	Diesel <3,5 t	20.7	30.9	48.7	60.3	70.5	94.6	103.4	120.9	137.6	166.6	192.1	213.0	231.1	249.7	279.0	287.8	297.2
Heavy duty vehicles	Gasoline >3,5 t	6.5	6.6	6.7	6.8	6.8	7.1	7.2	7.3	8.0	8.3	8.6	8.8	9.1	9.3	9.3	6.1	5.3
	Diesel 3,5 - 7,5 t	42.2	43.6	43.9	45.4	46.7	48.6	50.3	52.3	57.6	59.8	63.1	68.3	74.1	79.7	84.2	86.7	88.1
	Diesel 7,5 - 16 t	34.5	35.7	35.9	37.2	38.2	39.8	41.2	42.8	48.4	50.2	51.8	53.2	54.3	55.4	58.0	60.3	61.4
	Diesel 16 - 32 t	39.1	40.4	40.7	42.1	43.3	45.1	46.7	48.5	51.3	53.2	55.0	56.5	57.7	58.8	63.6	63.1	66.0
	Diesel >32t	10.7	11.1	11.2	11.6	11.9	12.4	12.8	13.3	15.3	15.9	16.4	16.8	17.2	17.5	18.4	18.2	18.6
Urban buses	Diesel	4.3	4.3	4.2	4.3	4.5	5.0	5.1	5.0	5.2	5.3	5.3	5.3	5.3	4.3	4.3	4.8	4.8
	Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.03	0.03	0.5	0.5
Coaches	Diesel	12.2	12.7	13.5	13.9	14.3	14.7	15.0	15.6	15.6	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Mopeds	Gasoline	986.0	1079.1	1208.5	1271.6	1335.8	1396.8	1452.0	1507.1	1568.4	1620.9	1561.2	1607.9	1540.9	1616.6	1558.1	1470.0	1260.6
Motorcycles	Gasoline	259.2	298.6	342.9	391.8	429.0	475.7	517.9	571.0	633.8	710.8	781.4	853.4	910.6	969.9	1049.5	1076.8	1050.5

Table 3.19 GHG emissions (in kt CO_2 eq) and energy consumption (in PJ) from road transportation for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Emissions (in Mt CO2 eq)																	
CO_2 (Mt)	11.87	12.68	12.99	13.28	13.46	13.87	14.51	14.85	15.56	15.84	16.03	16.41	16.98	18.01	18.12	18.89	19.82
CH_4 (Mt)	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.15	0.15	0.19
N_2O (Mt)	0.12	0.13	0.14	0.14	0.14	0.17	0.19	0.21	0.25	0.28	0.30	0.33	0.38	0.42	0.45	0.54	0.54
TOTAL (Mt CO_2 eq)	**12.10**	**12.93**	**13.25**	**13.55**	**13.74**	**14.18**	**14.85**	**15.21**	**15.96**	**16.27**	**16.48**	**16.90**	**17.51**	**18.59**	**18.74**	**19.58**	**20.55**
Energy consumption (in PJ)																	
Gasoline	106.31	109.72	113.43	116.21	118.50	122.04	129.47	133.73	139.15	141.79	144.70	149.45	156.49	163.52	167.10	174.18	176.11
Diesel	59.02	67.12	67.46	68.81	69.37	71.93	74.14	75.05	80.20	81.81	81.89	82.11	83.41	90.99	89.17	89.04	95.28
LPG	1.42	1.75	1.99	2.13	1.89	1.89	1.70	1.32	1.28	0.95	0.71	0.76	0.71	0.57	0.52	0.52	0.52
Natural Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.45	0.44	0.49	0.52
Other liquids	0.41	0.47	0.48	0.49	0.50	0.51	0.54	0.55	0.58	0.59	0.59	0.61	0.63	0.67	0.67	0.69	0.71
TOTAL	**167,16**	**179,06**	**183,36**	**187,64**	**190,26**	**196,37**	**205,85**	**210,65**	**221,21**	**225,14**	**227,89**	**232,93**	**241,64**	**256,2**	**257,9**	**264,92**	**273,14**

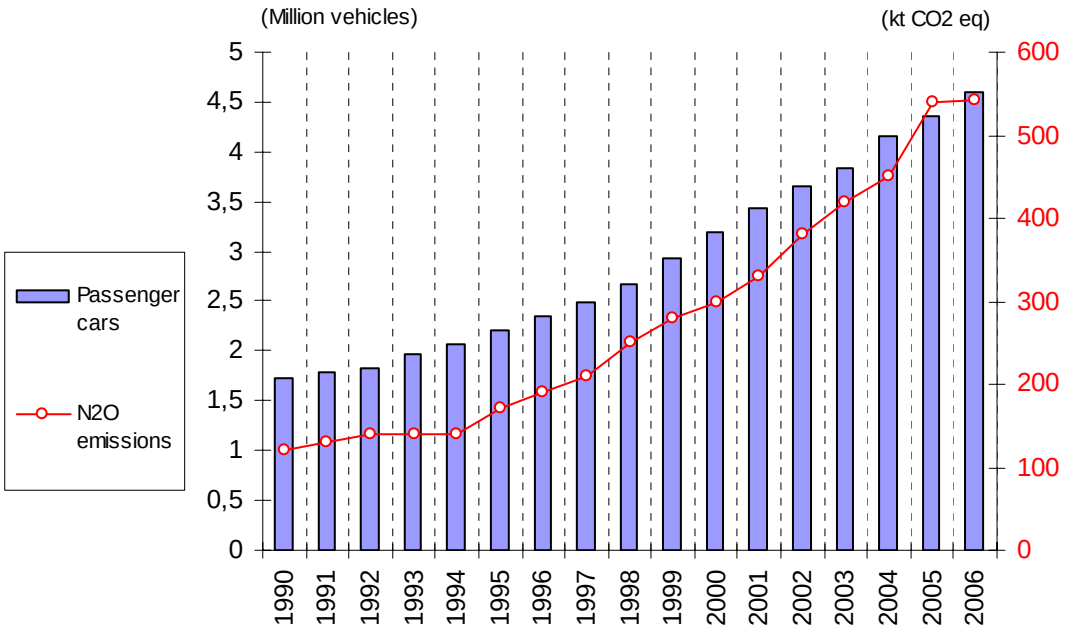


Figure 3.7 ***Total N_2O emissions from transport and catalytic passenger vehicles for the period 1990 - 2006***

Internal navigation

GHG emissions from internal navigation are calculated according to the default methodology of CORINAIR, which is based on the relative consumption of energy per fuel and default emission factors (SNAP 0804 – EEA 2001). 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.

Internal navigation (CO_2 emissions) is a key category. GHG emissions from navigation in 2006 were 25% higher than the emissions in 1990, on the basis of provisional data for fuel consumption from this sector (***Table 3.20***).

Table 3.20 GHG emissions (in kt CO_2 eq) and energy consumption (in PJ) from internal navigation for the period 1990 – 2006

	Emissions (in kt CO_2 eq)				Energy consumption (in PJ)			
	CO_2	CH_4	N_2O	Total	Diesel	Fuel Oil	Lubricants	Total
1990	1824.81	3.61	14.21	**1842.63**	14.56	9.53	0.76	**24.85**
1991	1851.18	3.70	14.58	**1869.47**	15.47	9.28	0.16	**24.91**
1992	1899.38	3.80	14.95	**1918.14**	15.08	10.25	0.24	**25.57**
1993	1738.05	3.47	13.66	**1755.19**	15.17	8.08	0.20	**23.44**
1994	1830.85	3.66	14.41	**1848.91**	14.08	10.29	0.28	**24.65**
1995	1743.61	3.48	13.71	**1760.81**	12.35	10.77	0.36	**23.48**
1996	1493.43	2.99	11.76	**1508.17**	9.92	9.85	0.32	**20.09**
1997	1812.48	3.63	14.28	**1830.40**	10.23	13.66	0.44	**24.33**
1998	2793.46	5.61	22.07	**2821.14**	15.25	21.62	0.52	**37.40**
1999	2760.82	5.54	21.82	**2788.18**	12.52	23.75	0.64	**36.92**
2000	1579.59	3.14	12.38	**1595.11**	11.40	9.48	0.48	**21.36**
2001	2144.87	4.28	16.86	**2166.02**	14.95	13.46	0.48	**28.89**
2002	1937.14	3.86	15.20	**1956.20**	14.30	11.37	0.48	**26.15**
2003	1923.09	3.82	15.05	**1941.97**	13.04	12.30	0.68	**26.02**
2004	2153.36	4.30	16.94	**2174.60**	13.35	15.07	0.56	**28.98**
2005	2071.53	4.12	16.22	**2091.87**	14.21	13.10	0.48	**27.80**
2006	2281.08	4.52	17.78	**2303.37**	15.51	14.43	0.80	**30.74**

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 data LTOs increased by 71% since 1990 while energy consumption (as recorded in the national energy balance) decreased by 15.6%. For this reason adjustments have been made to the energy consumption data as suggested in previous review (***Table 3.21***)

GHG emissions from internal aviation increased by 89% since 1990 with an average annual increase rate of 5.3% (***Table 3.21***).

Table 3.21 GHG emissions (in kt CO_2 eq), energy consumption (in PJ) and air movement (in thousands LTOs) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	Emissions (in Mt CO2 eq)																
CO_2	0.59	0.62	0.68	0.75	0.77	0.82	0.88	1.00	1.01	1.21	1.33	1.23	1.05	1.19	1.23	1.24	1.11
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	**0.59**	**0.63**	**0.69**	**0.75**	**0.78**	**0.83**	**0.89**	**1.01**	**1.03**	**1.23**	**1.35**	**1.24**	**1.06**	**1.20**	**1.24**	**1.25**	**1.12**
Energy consumption	8.32	8.79	9.62	10.55	10.93	11.58	12.43	14.12	14.36	17.17	18.85	17.37	14.90	16.78	17.39	17.52	15.74
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

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 36.5% from 1990 to 2006.

Table 3.22 GHG emissions (in kt CO_2 eq) from railways for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	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	125.63	128.78
CH_4	2.38	1.85	1.78	1.81	1.97	1.63	1.70	1.59	1.78	1.51	1.51	1.51	1.51	1.51	1.51	1.48	1.51
N_2O	24.22	18.84	18.07	18.45	19.99	16.53	17.30	16.14	18.07	15.38	15.38	15.38	15.38	15.38	15.38	15.03	15.4
Total	**229.29**	**178.90**	**171.70**	**175.29**	**189.70**	**157.30**	**164.50**	**153.70**	**169.18**	**145.44**	**145.44**	**145.44**	**145.44**	**145.44**	**145.44**	**142.14**	**145.69**

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 (***Figure 3.8,*** for the period 1990-2004) is based on data provided by the Civil Aviation Organisation. For 2005 LTOs from international aviation were 200,671 and 202,491 from domestic and international aviation, respectively. Finally, for 2006 LTOs from domestic and international aviation were respectively 211,854 and 217,565.

GHG emissions from international bunkers increased by 21% since 1990

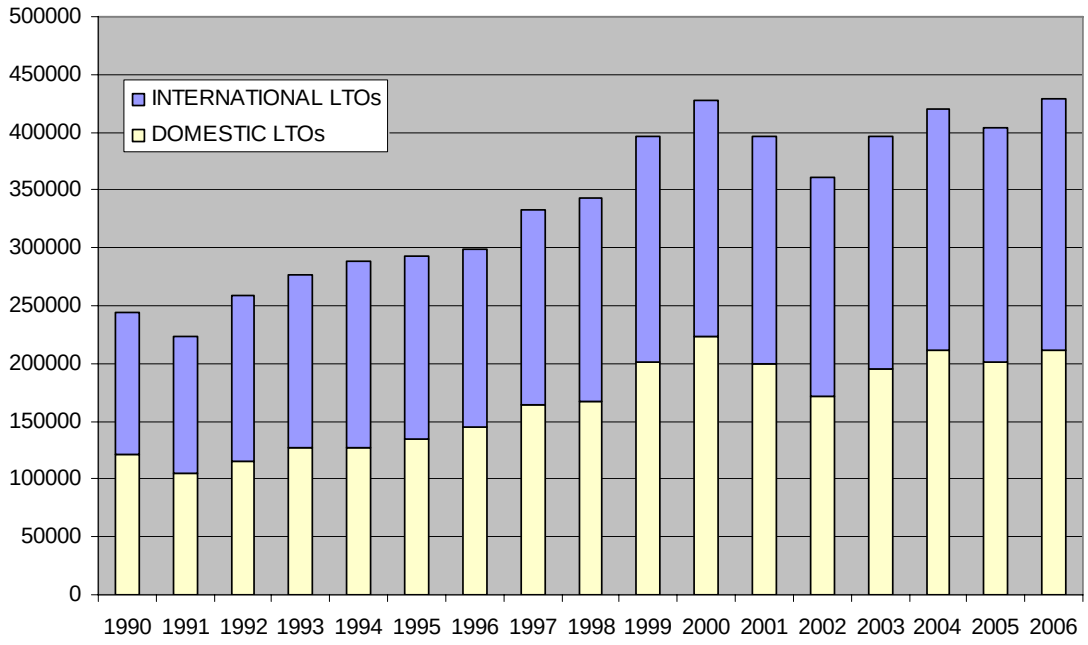


Figure 3.8 ***Allocation of LTOs to domestic and international aviation for the period 1990 – 2006***

3.3.2 Recalculations

Road Transportation

Recalculations have been performed in road transportation emissions as, during the in-country review the ERT identified a potential problem of overestimation of CO_2 emissions from combustion of lubricants in road transportation. The lubricant consumption per fuel consumption ratio in 1990, based on Greece.s activity data allocation, is 0.0236 (3.938,62 TJ/166.745,16 TJ), which is nine times higher than the average of other countries that report CO2 emissions from combustion of lubricants.

During the in-country review the ERT, with the assistance of the Greek inventory team, made a proxy bottom-up calculation (using fleet structure, and kilometres driven used by Greece for estimating emissions from fuel combustion for road transportation). The ERT.s calculation resulted in an estimate of CO_2 emissions, which is an order of magnitude lower than the CO_2 emission

estimates provided by Greece in CRF table 1.A(a) for the year. This estimate by the ERT is comparable with the estimates of CO_2 emissions from other countries (United Kingdom, Germany, and Romania) from the combustion of lubricants in road transportation in 1990.

Hence, an adjustment, in accordance with the Technical Guidance for Adjustments (attached to decision 20/CMP.1), was made by the use of an appropriate driver (lubricant consumption/fuel consumption) from a cluster of countries which estimate CO_2 emissions from the combustion of lubricants. The application of the adjustment led to a decrease in total estimated base year emissions, by approximately 0.1 %.

Civil aviation

CO_2 emissions from civil aviation are estimated to 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. The number of LTOs in 2004 was used as a driver for the extrapolation of GHG.

Navigation

Finally, because of a data entry error, recalculations of the CO_2 emissions for the years 2005 and 2006 were carried out, according to the methodology applied, IPCC Default EF Tier 1.

3.3.3 Planned improvements

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

- The availability of updated information to revise the parameters used for the description of driving conditions in Greece, will be examined.
- More detailed fleet composition data have already been used and further improvement in calculating vehicles number according to the type and the technology is planned
- For internal navigation, which constitutes a key category of (CO_2 emissions) the differentiation of the characteristics of fuels consumed (e.g. carbon content), compared to those used in the calculations presented in the present report, will be investigated.
- The examination of the availability of more detailed data on the composition of the fleet (technology of engines, etc.) in order to apply a more detailed methodology for the estimation of emissions from aviation and navigation.
- The examination of the availability of more detailed data on the routes performed in order to apply a more detailed methodology for the estimation of emissions from aviation and navigation.

The same actions as for the domestic sector will be performed for international aviation and navigation.

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 3.23***) from the mining of lignite in 2006 account for 1.3% of total GHG emissions from *Energy* and 1% 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 16.2% of total methane emissions in 2006. The average annual rate of emissions increase for the period 1990 – 2006, is estimated at 2% (a total increase of 24% in 2006 compared to 1990 levels).

Table 3.23 ***CH_4 emissions from lignite mining (in kt) and primary production of lignite (in kt) for the period 1990 – 2006***

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

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 2006 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 18.9 Mt of crude oil for year 2006.
- 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 3.24***) from oil and natural gas in 2006 accounted for 0.14% of total GHG emissions *Energy* and for 0.11% of total national emissions (without *LULUCF*). Overall, emissions in 2006 decreased by 6.6% compared to 1990 levels

Table 3.24 GHG emissions (in kt CO_2 eq) from oil and natural gas fro the period 1990 – 2006

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	87.51	49.16	0.01	**156.43**
2005	18.79	87.60	41.36	0.30	**148.07**
2006	18.76	87.64	44.65	0.30	**151.35**

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 f crude oil and natural gas (***Table 3.25a*** and ***table 3.25b*** 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 3.25a) 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 3.25a ***Key activity data for the estimation of GHG emissions from oil systems for the period 1990 - 2006***

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	18699	357
2006	94	10	19836	350

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

- Activity data for the estimation of emissions (Table 3.25b) 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 – 2006 derive from the IPCC Good Practice Guidance (Table 2.16, IPCC 2000).

Table 3.25b ***Key activity data for the estimation of GHG emissions from natural gas systems for the period 1990 - 2006***

Year	Primary production		Distribution	Transmission
	Natural gas (10^6 m^3)	Sour gas (%)	Pipeline (km)	Pipeline (km)
1990	123	29%		
1991	116	37%		
1992	109	33%		
1993	81	33%		
1994	38	79%		
1995	36	69%		
1996	38	68%	519	511
1997	37	51%	1000	558
1998	33	61%	1337	837
1999	2	50%	1720	837
2000	36	47%	1870	862
2001	35	46%	1940	960
2002	37	73%	2014	960
2003	27	7%	2751	960
2004	25	20%	2751	960
2005	25	20%	2751	960
2006	25	20%	2751	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 3.26*** 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

No recalculations were performed.

Table 3.26 GHG emissions (in t) from venting and flaring for the period 1990 – 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	1.60	1.52
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	180.31	170.81
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
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
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	1136.00	1917.00	142.00	355.00	245	245
CH_4																	
N.G. – Transmission																	
CO_2							4.34	4.74	7.11	7.11	7.33	8.16	8.16	8.16	8.16	8.16	8.16
CH_4							511.00	558.00	837.00	837.00	862.00	960.00	960.00	960.00	960.00	960.00	960.00
Flaring																	
Oil – Production																	
CO_2	66944.62	67103.57	54999.41	44904.42	42657.81	36566.96	41323.09	37413.55	25418.16	1287.42	22622.92	15620.17	15588.	11286.85	10910.3	8948.52	8477.44
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	18.03	17.08
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
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	30.06	30.06
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	0.18
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
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	153.64	153.64
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	0.10	0.10
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

Planned improvements

This is the first submission in which the Tier 1 methodology described in the IPCC Good Practice Guidance is applied. Further improvements will be based on the comments and proposals of the technical review of the present submission. In addition the possibility to apply the same method for natural gas for the period 1990 – 1995 will be examined.

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, 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 3.27***) and the fraction of the carbon stored by fuel type (***Table 3.28***), 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 for ammonia production is included in the non-energy consumption of the chemical industry but the available information does not allow for the allocation of the total figure to individual industrial sub-sectors. Thus, CO_2 emissions from ammonia production are reported under the energy sector instead of the industrial processes sector. Non-energy use of lignite (for 1990 and 1991) refers only to ammonia production (in one installation) 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.
- 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.
- 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.
- 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. However, there are two cases (ammonia and ferroalloys production) that need further consideration as emissions are not reported under the more appropriate sector (i.e. industrial processes).

Table 3.27 Non-energy fuel use (in PJ) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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
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	4.90
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
Natural gas	4.05	3.87	3.68	2.37	0.24	0.16	0.15	1.68	8.43	6.26	5.07	2.48	3.03	5.18	5.50	5.75	5.35
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
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

Table 3.28 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 3.29***. Carbon dioxide emissions in 2006 decreased by 42% 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 3.29 ***CO_2 emissions (in kt) from non-energy use and total amount of carbon stored (in kt) for the period 1990 - 2006***

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	462.64	607.92
2004	515.12	601.70
2005	394.34	482.67
2006	474.99	568.76

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 3.30***.

Table 3.30 ***CO_2 emissions (in kt) according to the reference and the sectoral approach for the period 1990 – 2006***

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%

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 3.31***) is mainly attributed to the statistical differences. The deviation -2.24% estimated for 2003 is mainly attributed to the high statistical differences of liquid fuels consumption as apparent consumption is by 3.4% lower that the actual consumption. This figure is the highest value recorded for the statistical difference of liquid fuels consumption for the period 1990 – 2006.
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. For that reason in Table 3.31 the deviation of gaseous fuels is relative high. For example, in 2006 distribution losses of natural gas were 393 TJ (GCV). If this quantity is taken into consideration in reference approach, the deviation of gaseous fuel consumption will be negligible.
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 3.31).

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 3.31 ***Deviations during the calculation of energy consumption (apparent and actual) for the period 1990 – 2006***

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%

4. Industrial processes

4.1 Overview

This chapter includes information on GHG emissions from *Industrial processes* and description of the methodologies applied per source for the calculation 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 2006, GHG emissions from industrial processes increased by 18% compared to base year emissions and by 48% compared to the emissions of 1990 (***Figure 4.1***), while the average annual rate of increase is estimated at 2.6% for the period 1990 – 2006.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2006, reaching a minimum value of 8.74 Mt CO2 eq in 1992 and a maximum value of 13.86 Mt CO2 eq in 1999, that are mainly attributed to changes in industrial production and especially in HCFC-22 production.

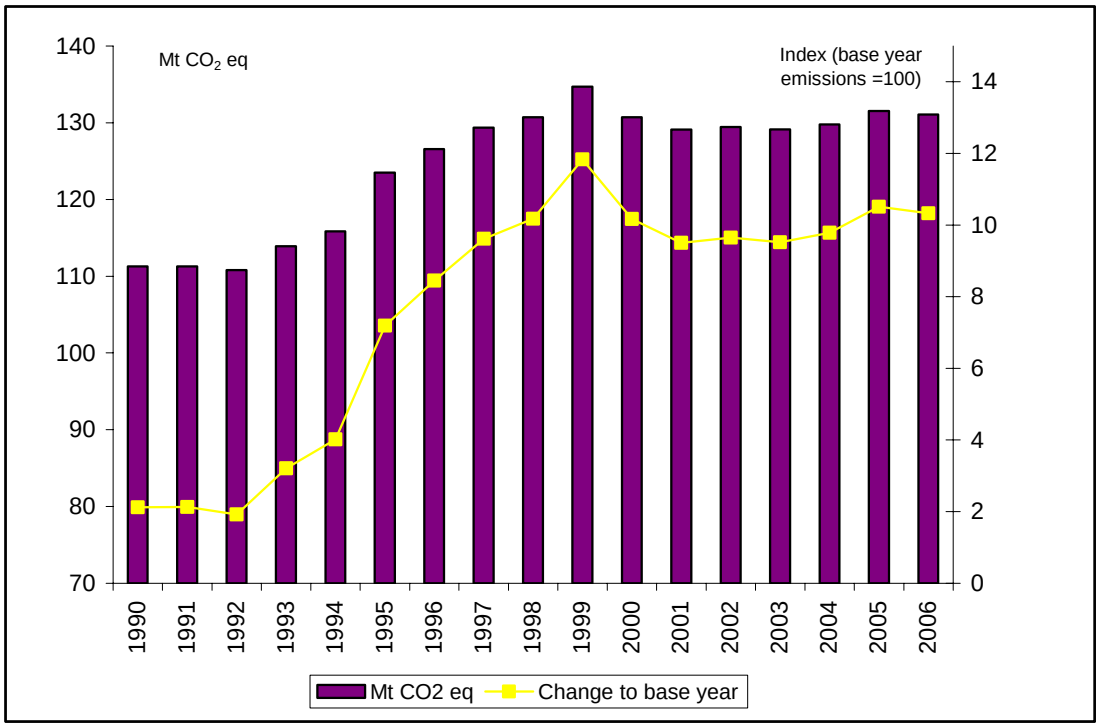


Figure 4.1 ***Total GHG emissions (in Mt CO_2 eq) from Industrial Processes for the period 1990 - 2006***

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% to 80%. Overall, CO_2 emissions in 2006 increased by 11.4% from 1990, with an average annual rate of increase estimated at 0.7%. 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 11% in 1990 to 36% in 2006. Total F-gases emissions in 2006 are more that three times higher than the 1990 levels, presenting an average annual rate of increase of 11%. F-gases emissions arise from the production of halocarbons and SF6 (production of HCFC-22) and the consumption of halocarbons and SF6 (refrigeration and air-conditioning equipment, electrical equipment).

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2006, with an average annual rate of change of 1.13%. The reduction of N_2O emissions in 2006 compared to 1990 levels is 11%.

The contribution of CH_4 emissions (from chemical industry) to total emissions from the sector is negligible.

Table 4.1 GHG emissions (in kt CO_2 eq) per gas from industrial processes for the period 1990 – 2006

Year	CO_2	CH_4	N_2O	HFC	PFC	SF_6	TOTAL
1990	6.936.36	0.52	712.96	935.06	257.62	3.07	8.845.58
1991	6.894.04	0.55	587.83	1.106.82	257.56	3.16	8.849.96
1992	6.963.06	0.52	614.70	908.39	252.30	3.26	8.742.23
1993	7.063.02	0.55	583.74	1.606.64	152.59	3.35	9.409.90
1994	7.016.16	0.60	567.54	2.143.91	93.62	3.45	9.825.28
1995	7.476.94	0.61	564.75	3.336.67	82.97	3.59	11.465.53
1996	7.468.87	0.61	644.92	3.928.61	71.74	3.68	12.118.43
1997	7.736.67	0.64	566.42	4.246.67	165.34	3.73	12.719.47
1998	7.592.44	0.65	466.11	4.741.49	203.75	3.78	13.008.22
1999	7.679.34	0.67	484.05	5.564.02	131.72	3.87	13.863.66
2000	7.870.84	0.67	495.69	4.486.01	148.38	3.99	13.005.57
2001	7.999.26	0.68	416.62	4.150.09	91.38	4.06	12.662.08
2002	7.872.59	0.69	401.10	4.368.94	88.33	4.25	12.735.91
2003	7.931.14	0.71	370.22	4.285.96	77.30	4.25	12.669.59
2004	8.004.58	0.74	351.99	4.373.27	71.71	4.47	12.806.75
2005	7.891.22	0.74	633.68	4.579.97	71.71	4.47	13.181.79
2006	7.730.08	0.74	633.68	4.648.01	70.53	4.47	13.087.51

The main sources of emissions from *Industrial processes* (***Figure 4.2***) are mineral products, production of halocarbons and SF6 and consumption of halocarbons and SF6. Emissions from the first two source categories 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 84% in 1990 to 72.5% in 2006. The contribution of halocarbons consumption to total emissions from the sector increased considerably (18% in 2006 against 0.8% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons. The average annual rate of increase is 37% for the period 1995 – 2006. Finally, the contribution of the chemical and metal industry decreases also from 16% in 1990 to 9% in 2006.

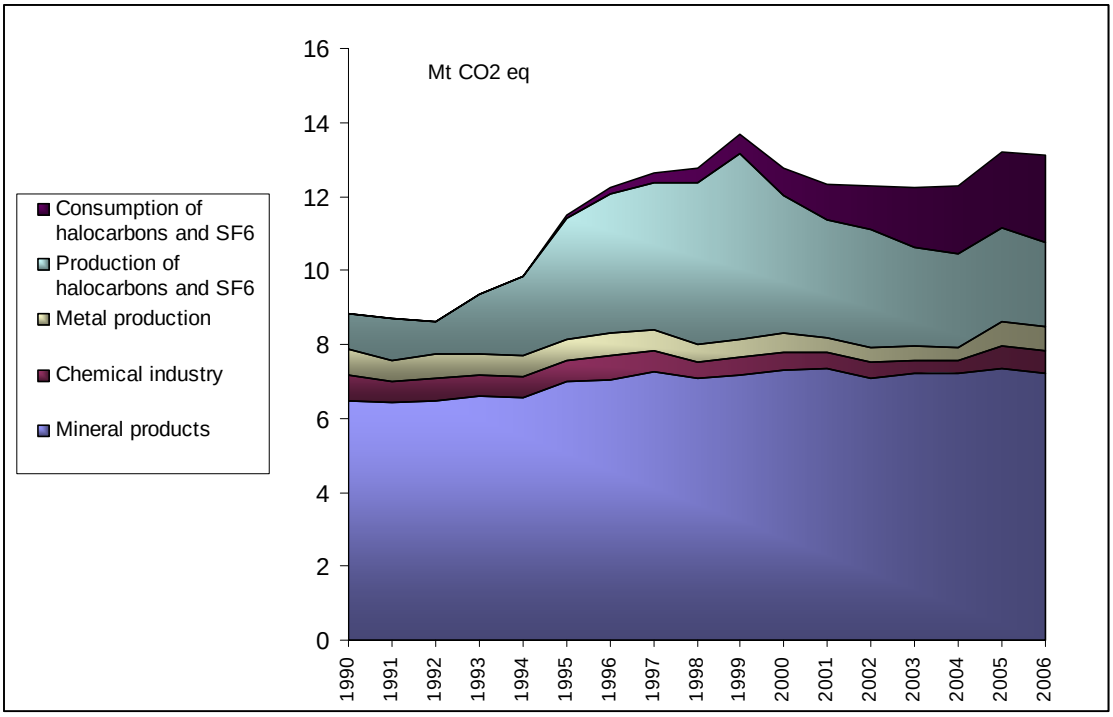


Figure 4.2 ***GHG emissions (in Mt CO_2 eq) from Industrial processes, per main source category, for the period 1990 – 2006***

4.1.2 Methodology

The calculation of GHG emissions from Industrial processes is based on the methodologies described in Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, the 2000 IPCC Good Practice Guidance and the 2006 IPCC Guidelines

- For the period 1990-2004, CO_2 emissions from cement and iron & steel production as well as PFC emissions from primary aluminium production are estimated on the basis of country-specific emission factors. 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. For the years 2005-2006 plant specific data have been available for most of the mineral and metal industries, leading to the use of plant specific emissions factors.
- For the period 1990-2004, the necessary activity data for the calculation of emissions from industrial processes are provided by the National Statistical Service of Greece (NSSG). Additionally, plant specific information, collected for the formulation of the NAP for the period 2005 – 2007, has been used. For the years 2004-2005, data from the reports of plants according to the ETS have been extensively used, whenever it was possible. It should be noted that in some cases (primary aluminium production, ferroalloys production and HCFC-22 production) such data are considered confidential and, therefore, are not presented in the current report or in the CRF tables.

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	CR, T1, T2, T3	D, CS, PS						
Chemical industry			T1	D	T1	D		
Metal production	T2, T3	CS, PS					T3b	CS
Production of F-gases							T1	D
Consumption F-gases							T2a, CS [1)]	D, CS [1)]

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

[1)] Country specific method applied for the estimation of SF_6 emissions

Key categories

The key categories 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		☒
Iron and steel production	CO_2		☒
HCFC-22 production	HFC-23	☒	☒
Consumption of halocarbons and SF_6	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 availability of activity data constitutes the main problem for the calculation of GHG emissions from industrial processes, and as a result no emission estimates are reported in many cases ("NE" in the table below). In some cases emissions are not estimated due to the lack of emission factors (e.g. CH_4 emissions from ammonia, aluminium, iron and steel production –CO_2 emissions from the non-energy use of bitumen).

CO_2 emissions from ammonia and 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.

It should be noted that only actual emissions are calculated regarding consumption of halocarbons and SF_6, as, for the time being, imports/exports of the relative compounds are not reported separately and therefore the estimation of potential emissions is not possible. Finally, emissions from the use of SF_6 in aluminium and magnesium foundries are not estimated. However, it should be mentioned that emissions related to the use of SF_6 as above, are more likely to be characterised as NA (Not Applicable) for the Greek installations.

In the years 2005-2006 plant-specific data have been accessed via the reports sent to the Ministry of Environment according to the ETS. This has led to the use of Tier 3 methods for the estimation of emissions, using carbonate(s) input data. However, for reasons of consistency, the activity data in the CRF tables have been entered according to the previous years' expression, by using the same emission factor.

Finally, in 2006 two new categories of emissions have been entered to the system. The first concerns the emissions of Transport Refrigerations (Consumption of F-gases and SF6-Refrigerations and Air-conditioning equipment) and the second refers to the emissions from metered dose inhalers.

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	NE					
5. Asphalt roofing	NE					
6. Road paving with asphalt	NE					
7. Other						
Glass production	☒					
B. Chemical industry						
1. Ammonia production	IE	NE				
2. Nitric acid production			☒			
3. Adipic acid production			NO			
4. Carbide Production	NO	NO				
5. Other						
Sulphuric acid production	NA	NA	NA			
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						NE / NA
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				NE	NE	NE
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 2006 (***Table 4.5***) ccounted for 49.37% of total GHG emissions from industrial processes and for 4.85% of total national emissions (without LULUCF). The average annual rate of increase of CO2 emissions from cement production during the period 1990 – 2006 was 0.73% (emissions increased by 12% from 1990 to 2006). 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 1994-1995, 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 ***CO_2 emissions from cement production (in kt) and clinker production (in kt) for the period 1990 - 2006***

Year	Clinker production (kt)	CO_2 emissions (kt)
1990	10645.13	5778.28
1991	10561.79	5732.22
1992	10831.27	5878.01
1993	10851.82	5891.94
1994	10930.92	5933.44
1995	11743.73	6374.69
1996	11773.83	6392.60
1997	11831.56	6426.14
1998	11789.07	6401.61
1999	11761.21	6384.69
2000	12071.73	6555.58
2001	12130.78	6584.82
2002	11666.18	6331.44
2003	11754.73	6386.46
2004	11754.73	6382.22
2005	12591.73	6648.74
2006	12305.35	6460.86

Methodology

Calculation of CO_2 emissions from cement production, for 2005 and 2006 is based on detailed plant-level data on the carbonate raw materials (Tier 3 methodology) of the eight operating plants in Greece, according to the following equation (IPCC 2006 Guidelines):

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

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 uncalcinated carbonate in CKD not recycled to the kiln, M_k is the weight or mass of organic or other carbon-bearing non fuel raw material k, X_k is the fraction of total organic or other carbon in specific non fuel raw material k and EF_k is the emission factor for kerogen (or other carbon-) bearing non fuel raw material k.

According to the collected data, the carbonate content of raw materials in Greek cement production plants concern $CaCO_3$ and $MgCO_3$. More specifically, the average content of the raw materials in $CaCO_3$ and $MgCO_3$ has been estimated at 77% and 3%, whereas the fraction calcination was 44% and 52.2%, respectively.

As regards to the emissions from the uncalcinated CKD not recycled to the kiln, 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. What is more, the CO_2 emissions from non-carbonate carbon have been ignored, as no such data were available.

For the period 1990-2004, calculation of CO_2 emissions from cement production is based on clinker production (Tier 2 methodology) according to 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 CO_2 contained in the non-recycled calcined cement kiln dust.

For reasons of consistency, the activity data of 2005 and 2006 have been expressed in kt of clinker produced. In order to do so, it was assumed that the clinker production is equal to the raw materials quantity minus the CO_2 emissions. However, it should be noted that the clinker/raw materials fraction was between 1.517 and 1.534, which corresponds to the fractions provided by two of these industrial plants (1.52 and 1.532), and therefore the transmission from raw materials to clinker production is considered successful.

The values of the parameters mentioned in the above equation (*CaO*, *MgO* and *CKD*) as well as clinker production derive from:

- Plant specific information for the period 1990 – 2003, collected during the formulation of the NAP for the period 2005 - 2007.

- The following assumptions for 2004: (a) the CO_2 emission factor used is the average value of the emission factors for 2001, 2002 and 2003 and (b) clinker production is kept constant at 2003 levels.
- Plant specific information for 2005-2006, collected during the reporting of the plants for the ETS.

The implied emission factors are presented in ***Table 4.6***.

Table 4.6 Country specific CO_2 emission factor (in t / t) for cement production for the period 1990 - 2006

Year	Emission factor ($t CO_2$ / t clinker)
1990	0.5428
1991	0.5427
1992	0.5427
1993	0.5429
1994	0.5428
1995	0.5428
1996	0.5429
1997	0.5431
1998	0.5430
1999	0.5429
2000	0.5431
2001	0.5428
2002	0.5427
2003	0.5433
2004	0.5429
2005	0.5280
2006	0.5250

Recalculations

CO_2 emissions from cement production for 2005 have been recalculated, as plant-specific data became available from the information reported for the ETS.

The difference (%) between present and previous submission estimates is 0.51%, while the impact on total emissions is 0.026 (incl. LULUCF) and 0.025 (excl. LULUCF).

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 (***Table 4.7***) account for 3.75% (average value for the period 1990 – 2006) of total GHG emissions from Industrial processes and for 0.37% 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 – 2006, is estimated at 2.67%.

Table 4.7 ***CO_2 emissions (in kt) from lime production and production of lime (in kt) for the period 1990 - 2006***

Year	CO_2 emissions (kt)	Lime production(kt)
1990	367.25	492.46
1991	344.14	461.46
1992	284.63	381.67
1993	423.19	567.47
1994	410.18	550.03
1995	419.39	562.38
1996	426.44	571.83
1997	596.23	799.51
1998	401.13	537.89
1999	519.05	696.01
2000	489.56	656.47
2001	498.60	668.59
2002	483.02	647.70
2003	489.52	656.41
2004	489.52	656.41
2005	372.30	499,23
2006	409.00	548,44

Methodology

For years 2005 – 2006, 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 (Tier 3 methodology). The emissions are estimated according to the following equation (2006 IPCC Guidelines):

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

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 uncalcined carbonate.

The principal carbonates detected in the greek lime industry were $CaCO_3$, $MgCO_3$ whereas three of the industries reported also a small content in Ka_2CO_3 and Na_2CO_3. The activity data resulted in 936.54 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 uncalcinated 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.

For the period 1990-2004, the calculation of carbon dioxide emissions from lime production is based on the lime production according to the following equation (IPCC 2000):

$$E = 0{,}785 \cdot p_{CaO} \cdot PROD \cdot \left(1 - x \cdot y \right)$$

where, E is carbon dioxide emissions, p_{CaO} is the content of lime in the final product, $PROD$ is the total production of high-calcium lime and hydrated lime, x is the proportion of hydrated lime in total production and y the water content in commercial hydrated lime. However, and for this period, emissions from the production of hydraulic lime have not been estimated, because the available data do not allow for a reliable estimation.

For consistency reasons, the activity data of 2005 and 2006 have been expressed in kt of lime produced. In order to do so, the country's emission factor of 2004 has been used.

In relation to the estimation of CO_2 emissions from lime production, it should be noted that:

- For the period 1990-2003, lime and hydrated lime production were estimated taking into consideration both information collected during the formulation of the NAP for the period 2005 – 2007, and data provided by the NSSG However, plant specific information covers the period 2000 – 2003 and presents significant differences compared to NSSG data. In order to improve consistency, total production (Table 4.7) is estimated by applying the production trend and ratio between lime and hydrated lime production calculated according to NSSG data to the plant specific information collected.
- Lime production in 2004 is kept constant at 2003 levels, due to lack of data.
- For 2005-2006, plant specific data have been available via the reporting under the ETS framework. Although these data result in an abrupt decrease from 2004 to 2005 level of emissions, they are considered to be valid as they are plant specific.

Recalculations

CO_2 emissions from lime production for 2005 have been recalculated following the collection of the information submitted by the installations under the EU emissions trading scheme.

The difference (%) between present and previous emissions estimates was 1.98%, having an impact of 0.007 on total emissions (excl. LULUCF).

Planned improvements

The emissions estimates for 2005-2006 show an abrupt decrease, in comparison to 2004 level of emissions. However, as they are plant-specific, they are considered to be valid. This abrupt shift will be further investigated in next submissions, and gaps in the activity data series previous to 2005 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 2006 (***Table 4.8***) accounted for 2.4% of total GHG emissions from *Industrial processes* and for 0.2% of total national emissions (without *LULUCF*).

Table 4.8 Limestone use (in kt) and CO_2 emissions (in kt) for the period 1990 – 2006

Year	Limestone (kt)	CO_2 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	678.75	315.18

Methodology

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

For 2006, CO_2 emissions are estimated according to the following general equation (Tier 3 methodology, 2006 IPCC Guidelines):

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

where, CO_2 emissions refer to the emissions from iron & steel, primary aluminium and ceramics, M_i is mass of carbonate i consumed, , EF_i is the emission factor for carbonate i, and F_i is the fraction of calcination achieved for the particular carbonate.

For the previous period (years 1990-2005) the following equation has been used:

$$E = \left[(P_{St} \cdot c_{st} + P_{Al} \cdot c_{Al}) + C_{cer} \right] \cdot 0{,}44$$

where, E is CO_2 emissions, P_{St} is steel production, c_{St} is the specific limestone consumption for steel production, P_{Al} is primary aluminium production, c_{Al} is the specific limestone consumption for aluminium production and C_{cer} is limestone consumption for ceramics production.

In relation to the estimation of CO_2 emissions from limestone and dolomite use, the following are noted:

- **Steel production**: For 2006 data on steel production are plant specific (in the context ETS reports of the plants) and refer to the emissions due to the carbonate content of the limestone and dolomite used. The total $CaCO_3$ equivalent amounts to 71.24 kt. For the period 1990-2003 the data derived from the NAP formulation and from NSSG for 2004 and 2005.
- **Primary aluminium production**: Data on primary aluminium production for 2006 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 – 2003. The specific limestone consumption is estimated on the basis of the available information (for the years 1990 and 1998 – 2003) 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 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 412.61 kt. Limestone conusumption 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. For 2005 there are not available activity data, so the activity data of 2004 were used.
- It should be noted that, provided that data on the fraction calcinations achieved are not available, it has been assumed tha the fraction calcinations is equal to 1, according to the 2006 IPCC Guidelines.
- Finally, it should be mentioned that for reasons of consistency 2006 activity data have been expressed in terms of limestone consumption, assuming that the consumed limestone quantity is equal to the sum of $CaCO_3$ and $MgCO_3$ used.

Recalculations

No recalculation of emissions was performed.

Planned improvements

The porribility to get access to activity data for 2005 will be examined.

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 2006 decreased by 37.2% compared to 1990 levels (***Table 4.9***) and represent 0.11% of total GHG emissions from *Industrial processes*.

Table 4.9 Glass production (in kt) and CO_2 emissions (in kt) for the period 1990 - 2006

Year	Glass production (kt)	CO_2 emissions (kt)
1990	134.94	23.07
1991	124.57	21.30
1992	97.26	16.63
1993	99.71	17.05
1994	102.22	17.48
1995	104.79	17.92
1996	107.42	18.37
1997	110.12	18.83
1998	112.89	19.30
1999	115.73	19.79
2000	118.64	20.29
2001	169.91	25.81
2002	170.75	29.83
2003	147.27	24.83
2004	138.16	23.62
2005	106.20	18.46
2006	84.77	14.50

Methodology

The estimation of carbon dioxide emissions from glass production in 2005-2006 is based on accounting for the carbonate input to the glass melting furnace (Tier 3 methodology), by using the following equation (2006 IPCC Guidelines):

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

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.

For the period 1990-2004, the calculation of carbon dioxide emissions from glass production is based on the glass production, according to the following equation:

(CO_2 emissions) = (Glass production) * (Emission factor)

In relation to the estimation of CO_2 emissions from glass production, it should be noted that:

- Activity data (glass production) for the period 1990 – 1992 are provided by the NSSG, while activity data for the period 2001 – 2003 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. Glass production in 2004 was estimated by taking into account the production of the largest installation. Finally, the activity data for 2005-2006 have been collected in the context of the ETS reports.

- The estimation of CO_2 emissions for the period 2001 – 2003 was based on data regarding the carbonates consumption collected in the framework of the formulation of the NAP for the period 2005 – 2007. Taking into consideration that (a) the estimated emission factor (using the above mentioned data) for the period 2001 – 2003 varies from 152 kg CO_2 / t glass to 174 kg CO_2 / t glass and (b) glass production in Greece mainly refers to the production of container glass, CO_2 emissions for the years 1990 – 2000 and 2004 were estimated using an emission factor of 171 kg CO_2 / t glass (CORINAIR, SNAP 030314 – 030317 & 040613). For reasons of consistency, the same factor has also been used to estimate the glass production for the years 2005-2006 by the emissions calculated via the Tier 3 methodology (described above).
- As described above, the estimations 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.

Recalculations

Plant specific activity data on the use of carbonates have become available, based on the ETS reports, for 2005. The use of Tier 3 methodology led to a difference (%) between present and previous emissions estimates of -4.23, which had an impact on total emissions of -0.003%.

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.

Ammonia production in Greece is based on natural gas consumption as feedstock, while up to 1991 there was an installation in operation using lignite as feedstock. CO_2 emissions from ammonia production (data on ammonia production for the period 1990 – 2004 are presented in ***Table 4.10***) are included in the energy sector, because the information provided in the national energy balance refers only to total non energy use of fuels in the chemical industry. By doing so, double-counting of emissions is avoided.

Table 4.10 Ammonia production (in kt) for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Production	313.03	255.61	167.94	69.70	54.89	79.87	110.28	171.63	218.82	153.85	147.48	68.70	94.14	150.18	159.92	159.92	200.53

Ammonia production data presented in Table 4.10 are provided by the NSSG for the period 1990 – 1993 and by individual industrial units for the period 1993 – 2004. For the years 2005-2006 such data were not available, so 2006 production data derived via extrapolation, whereas the production level of 2005 is assumed to be the same with 2004.

Planned improvements

The possibility to get access to production data, preferably plant specific, for 2005 and 2006 will be examined.

Improvements planned are mainly related to the collection of the necessary data regarding fuels use as feedstock in ammonia production in order to include the relevant emissions under the industrial processes sector.

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 2006 (***Table 4.11***), account for 4.8% of total GHG emissions from *Industrial processes* and for 0.5% of total national emissions (without *LULUCF*). Emissions have decreased by 11% from 1990 to 2006.

Table 4.11 Nitric acid production (in kt) and N_2O emissions (in kt) for the period 1990 – 2006

Year	HNO_3 production (kt)	N_2O emissions (kt)
1990	511.08	2.30
1991	421.38	1.90
1992	440.65	1.98
1993	418.45	1.88
1994	406.84	1.83
1995	404.84	1.82
1996	462.31	2.08
1997	406.04	1.83
1998	334.13	1.50
1999	346.99	1.56
2000	355.33	1.60
2001	298.65	1.34
2002	287.53	1.29
2003	287.53	1.19
2004	252.32	1.14
2005	454.25	2.04
2006	454.25	2.04

Methodology

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

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

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 for units operating under atmospheric pressure (4.5 kg N_2O / t HNO_3).
- Nitric acid production data derives from NSSG and the individual industrial units for 1990-2004. For 2005 production data derives from the RAINS database of MINENV. Due to lack of data, production level of 2006 was the same with the one of 2005.
- The abatement system used by the Greek installations for reduction of NOx 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

No recalculations have been performed

Planned improvements

It has been noticed that while the production data for the period 1996-2004 show a continuous decrease, the production from 2004 to 2005 is increased by 80%. As mentioned above, the 2005 production data derive from the RAINS database of the MINENV. Provided that nitric acid production is a key category, plant-specific and destruction data availability will be investigated, according to the IPCC good practice guidance. These data will possibly clarify the existence of this abrupt shift in the activity data trend.

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 – 2006).

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. The available data cover the period 1990 – 1994 and missing data are filled in by taking into account the relevant production in Western Europe for the period 1992 – 2005 (www.petrochemistry.net) and assuming a similar trend for the production from Greek installations .
- Due to lack of activity data, 2006 production of ethylene and 1,2 dichloro-ethane was considered the same with the production data of 2005.

Recalculations

No recalculations were performed.

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 2006 (***Table 4.12***), accounted for 1.7% of total GHG emissions from *Industrial production* and for 0.17% of total national emissions (without *LULUCF*). The CO_2 emissions from steel production are characterized by intense fluctuations during the period 1990 – 2006, reaching a minimum value of 173.61 kt in 1996 and a maximum value of 476.41 kt in 2004. Emissions have increased by 9% from 1990 to 2006.

Table 4.12 Steel production (in kt) and CO_2 emissions (in kt) for the period 1990 – 2006

Year	Steel production (kt)	CO_2 Emissions (kt)
1990	999.10	202.83
1991	980.00	200.21
1992	924.00	188.19
1993	980.00	204.61
1994	848.00	186.33
1995	939.00	211.72
1996	809.82	173.61
1997	1015.67	219.46
1998	1108.29	252.05
1999	951.53	217.93
2000	1104.78	252.91
2001	1281.51	322.70
2002	1839.80	442.53
2003	1700.90	399.44
2004	1966.19	476.41
2005	915.93	221.66
2006	917.44	222.02

Methodology

For 2005-2006 facility specific CO_2 emissions data have been collected from verified reports of the installations under the EU ETS (Tier 3 methodology, 2006 IPCC Guidelines).

For the previous years (1990-2004) CO_2 emissions from iron and steel production are calculated using a tier 2 methodology that is based on tracking carbon through the production process according to the following equation (IPCC 2000):

$$E = \left[\left(C_{SCR} \cdot SCR - C_{ST} \cdot ST\right) + C_{RED} \cdot RED + C_{EL} \cdot EL\right] \cdot {}^{44}\!/_{12}$$

where, E is CO_2 emissions, C_{SCR} is the carbon content of the scrap input to EAF, SCR is the scrap input to EAF, C_{ST} is the carbon content of the steel produced, ST is the steel production, C_{RED} is the carbon content of the reduction agents used, RED is the consumption of the reduction agents, C_{EL} is the carbon content of the electrodes consumed in the EAF and EL is the electrodes consumption.

In relation to the estimation of CO_2 emissions from iron and steel production, it should be noted that:

- The emissions of 2005-2006 are plant-specific, as it was mentioned above, and were reported by the plants in the context of the EU ETS.
- For the period 1990-2004, all necessary input parameters and activity data for the calculation of CO_2 emissions from iron and steel production were estimated on the basis of the information 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 for the period 2005 – 2007, according to the EU Directive 2003/87/EC. Data on steel production for 1990-2003 were plant specific (in the context of the NAP formulation) while for 2004 activity data derived from the NSSG.
- The national energy balance did not provide any information regarding the use of fuels as reduction agents in the steel making industry and as a result the relevant emissions were estimated under this source category.

The values of the parameters C_{SCR} and C_{ST}, used in the period 1990-2003 derive from the quationnaires mentioned above and are within the range suggested in the IPCC Good Practice Guidance. For the same period, carbon content of the scrap input to EAF is estimated at an average value of 4%, while the carbon content of the steel produced is 0.3%. Electrode consumption decreases from 3.5 kg/t steel in 1990 to 2 kg/t steel in 2003. These values although higher than the suggested ones by IPCC Good Practice Guidance (1 – 1.5 kg/t steel) are within the range found in the literature (e.g. EC 2001, where electrodes consumption varies from 1.5 – 4.5 kg/t steel).

On the basis of those data a country specific CO_2 emission factor is estimated (0.242 t/t) which is used for the estimation of GHG emissions for 2004. For consistency reasons, the same factor has been used to estimate the equivalent steel production in electric arc furnaces for 2005-2006 (using the emission data reported by plants).

Recalculations

CO_2 emissions from steel industry for 2005 have been recalculated, as plant-specific data became available from the information reported by the plants for the EU ETS.

The difference (%) between present and previous submission estimates is -56.7, while the impact on total emissions is -0.23% (incl. LULUCF) and -0.22% (excl. LULUCF).

Planned improvements

The emissions level of the period 2001-2004 presents a maximum in relation to the rest of the period examined. In addition, emissions of the following years are abruptly decreased (53 % decrease from 2004 to 2005). Provided that the emissions data of 2005-2006 derive from plant-specific measurements, they are considered valid and trustworthy. The shift might be explained due to the fact that in the industries' reports the amount of slag of the EAF and the amount of iron production not converted into steel have been taken into account. Future improvements include the verification of such an approach and the clarification of the issue.

In the same time, planned improvements also include carrying out calculations for CH_4 emissions estimations from the iron and steel production.

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 calcinations of carbonates fluxes such as limestone or dolomite contribute to these emissions.

The CO_2 emissions in 2006 account for the 0.42% of total emissions from Industrial processes, and for the 0.04% of the total national emissions (incl LULUCF). As there is only one unit operating in Greece the data are plant specific and are characterized by fluctuations. In the years 2002-2006 the emissions tend to decrease with an average rate of 9.2%.

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

For the years 2005-2006 the data are plant specific and account for both sources of emissions described above. For the previous years, the estimation 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 2005-2006 derive from the verified report of the industry under the EU ETS.
- Laterite consumption data for the period 2000 -2003 were collected during the formulation of the NAP for the period 2005 – 2007. These 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 periof estimation, the carbon content of Laterite used is less than 1%, according to plant specific information.

Recalculations

CO_2 emissions from steel industry for 2005 have been recalculated, as plant-specific data became available from the information reported by the plants for the EU ETS.

The difference (%) between present and previous submission estimates is -10, while the impact on total emissions is -0.006 %(incl. LULUCF) and -0.005% (excl. LULUCF).

Planned improvements

Gaps in activity data time series will be filled in as soon as new data become available. The decrease of emissions in the recent years (2002-2006) will be furter investigated.

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 2006 (***Table 4.13***) accounted for 1.94% and 0.5%, respectively, of total GHG emissions from *Industrial processes*. The average annual rate of increase of CO_2 emissions during the period 1990 – 2006 was 0.7 %. The average annual rate of decrease of PFC emissions is estimated at 2.33%, while emissions have decreased by 15%, 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.

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 levels due to equipment maintenance problems according to information provided by the installation involved. Since 2001, this trend changes again and emissions were about the same as in 1995 – 1996.

Table 4.13 CO_2 emissions (in kt) and PFC emissions (in kt CO_2 eq) from primary aluminium production, for the period 1990 – 2006

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
CO_2	251.99	251.16	254.05	257.84	258.29	258.29	254.06
PFC	148.38	91.38	88.33	77.30	71.71	71.71	70.53

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. Due to lack of data for 2006, pet coke consumption has been used as a driver in order to calculate the aluminium production.

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

Recalculations

No recalculation of emissions was performed.

Planned improvements

The availability of aluminium production data for 2006 will be examinated. 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.

Production of F-gases is a key source. HFC-23 emissions from HCFC-22 manufacture in 2006 (***Table 4.14***) accounted for 17.5% of total GHG emissions from *Industrial processes* and for 1.8% of total national emissions (without *LULUCF*). HFC-23 emissions have decreased by 30% from 1995 (base year) emissions.

Table 4.14 HFC-23 emissions (in kt CO_2 eq) from HCFC-22 production, for the period 1990 – 2006

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
HFC-23 (kt CO_2 eq)	3735.11	3181.46	3194.57	2661.05	2550.60	2550.60	2290.39

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 is 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.

For 2006 production data were not available, so the emissions have been estimated by means of extrapolation.

Recalculations

No recalculations were performed.

Planned improvements

The availability of production data for HCFC-22 will be investigated. In addition, the possibility of collecting data from on-site measurements in order for the analytical methodology of HFC-23 emissions calculation to be applied, will be examined.

4.6 Consumption of halocarbons and SF_6

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) only 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.

The consumption of F-gases is a key category. Emissions from the consumption of F-gases in 2006 (***Table 4.15***) accounted for 18% of total GHG emissions from *Industrial processes* and for 1.8% of total national emissions (without *LULUCF*). The average annual rate of emissions increase for the period 1995 – 2006 is estimated at 37%. 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.

Because of the existence of cheap air conditioning equipement, in combination with credit services offered by the household electrical equipment stores, the “price” factor has lost the significant and decisive role that used to occupy in the past. The climatological conditions represent the fundamental element that determines the demand for air conditioning products, resulting in both monthly and annual seasonal fluctuations, depending on summer temperature levels.

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 and in 1995 for mobile air-conditioning. 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 .

Table 4.15 HFC emissions (in kt CO_2 eq) per gas, from the consumption of F-gases for the period 1990 - 2006

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			83.60	3.59	87.19
1996			182.27	3.68	185.95
1997			286.46	3.73	290.19
1998			381.60	3.78	385.38
1999			540.97	3.87	544.84
2000			750.90	3.99	754.89
2001			968.62	4.06	972.68
2002	4.27	12.23	1151.09	4.25	1171.84
2003	12.42	35.14	1557.82	4.25	1609.63
2004	23.99	67.81	1693.19	4.47	1789.46
2005	35.78	101.38	1835.87	4.47	1977.50
2006	48.66	137.98	2090.32	4.47	2281.43

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.

Taking into consideration the lifetime of the above mentioned equipment, the year that F-gases enter in the market (1993 for the refrigeration equipment and 1995 for mobile air conditioning and 2000 for stationary air conditioning equipment) and assuming that there is not early final disposal of these equipment (i.e. because of unnatural damage) there are not emissions from the final disposal of these equipments for domestic refrigeration, transport refrigeration and air-conditioning equipment.

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 4.16***) the following should be mentioned:

- Data on the air conditioning equipment stock for the period 1993 – 2002 and 2005 are provided by market surveys (ICAP 2000, 2002, 2003, 2005). Data for 2003, 2004 and 2006 are not available and hence equipment for 2003 is estimated as the average of the available values for the three previous years, equipment for 2004 remained constant at 2003 levels and equipment for 2006 remained at 2005 levels.
- For 2006, data on the residential refrigeration equipment stock were not available, so the average of the available values for 2000-2005 has been used. Data for the period 1993 – 2001 are provided by market surveys (ICAP 2000, 2002). Data for the period 2002 - 2005 are not available and are estimated using the rate of increase observed for the years 1999 – 2000.
- Data on the commercial refrigeration equipment stock are provided from the elaboration of 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 for the years 1993-1994 are not available.
- 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 2006 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 4.17***.

HFC emissions from the above mentioned applications are presented in ***Table 4.18*** for the period 1993-2006.

Table 4.16 Refrigeration and air conditioning equipment for the years 1993 – 2006

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Refrigeration														
Residential	**311000**	**319553**	**334602**	**349240**	**355000**	**365000**	**360000**	**387000**	**376000**	**364682**	**353033**	**341041**	*329559*	*358553*
Domestic production	80000	82000	90000	120000	185000	235000	260000	327000	324000	321028	318082	315164	312205	319580
Imports	283000	315000	325000	350000	340000	340000	335000	340000	342000	344012	346035	348071	350090	345035
Exports	52000	77447	80398	120760	170000	210000	235000	280000	290000	300357	311084	322194	332736	306062
Large commercial applications			**31556**	**25832**	**24480**	**20284**	**26665**	**22852**	**15151**	**567**	**25825**	**4738**	*4738*	*12312*
Domestic production			20820	14800	20520	17680	20200	16080	13050	7254	20310	23004	23004	17117
Imports			14908	17410	13519	9532	18634	14795	17568	26114	21357	30000	30000	23306
Exports			4172	6378	9559	6928	12169	8023	15467	32801	15842	48266	48266	28111
Small commercial applications			**73642**	**74179**	**79243**	**67761**	**79885**	**73586**	**79347**	**48352**	**64395**	**51667**	*51781*	*61521*
Domestic production			58640	71680	63730	57140	69090	61900	67168	51759	56461	54886	55000	57862
Imports			16195	11062	24111	21231	19160	19868	20218	16835	18000	15000	15000	17487
Exports			1193	8563	8598	10610	8365	8182	8039	20242	10066	18219	18219	13828
Transport Refrigeration														
In circulation														17370
Stationary air-conditioning														
Split unit systems and semi-central systems	**89570**	**126730**	**154200**	**150880**	**188900**	**229550**	**330655**	**431385**	**617800**	**305750**	**451645**	**451645**	*367110*	*367110*
Domestic production	12320	17550	22000	21200	2800	2250	1750	1750	1400	1250	1467	1467	1268	1268
Imports	82250	115180	141200	137380	189700	240000	342205	445035	647000	341000	477678	477678	385009	385009
Exports	5000	6000	9000	7700	3600	12700	13300	15400	30600	36500	27500	27500	19167	19167
Chillers	**1100**	**1080**	**1120**	**1180**	**1140**	**1240**	**1315**	**1585**	**2350**	**4750**	**2895**	**2895**	**9993**	**9993**
Domestic production	350	380	400	430	420	500	600	950	1600	1800	1450	1450	8195	8195

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Imports	750	700	740	770	780	840	835	945	1500	3350	1932	1932	1866	1866
Exports	0	0	20	20	60	100	120	310	750	400	487	487	68	68
Other applications of air conditioning	**28800**	**31500**	**32000**	**35700**	**39850**	**43250**	**44830**	**48300**	**53800**	**65600**	**55900**	**55900**	*41742*	*41742*
Domestic production	32900	33500	35200	34300	34500	37730	37900	39300	40100	37900	39100	39100	21461	21461
Imports	4900	5300	6300	9300	9600	12120	12130	14200	18900	35500	22867	22867	21136	21136
Exports	9000	7300	9500	7900	4250	6600	5200	5200	5200	7800	6067	6067	856	856
Mobile air-conditioning			**133757**	**141589**	**166778**	**183857**	**268716**	**302620**	**289943**	**277567**	**273870**	**317508**	*344339*	*346551*
Domestic production			0	0	0	0	0	0	0	0	0	0	0	0
Imports			133757	141589	166778	183857	268716	302620	289943	277567	273870	317508	344339	346551
Exports			0	0	0	0	0	0	0	0	0	0	0	0

Table 4.17 Basic assumptions for the calculation of HFC emissions

	Charge	Leakage rate (%)		Lifetime	Refrigerant
	(kg/unit)	Charge	Operation	(years)	used
Refrigeration - Residential	0.275	0.6	0.3	15	HFC-134a
Refrigeration – Large commercial applications	100	0.5	10	10	HFC-134a
Refrigeration – Small commercial applications	3	1.75	5	10	HFC-134a
Transport Refrigeration	2.38[(a)]	8	0.6	15	HFC-134a
Air conditioning – Split units and semi central systems	2.5	0.6	3	15	R-410a
Air conditioning – Chillers	50	0.6	3	25	R-407c
Air conditioning - Other applications of central air conditioning	10	0.6	3	15	R-407c
Mobile Air conditioning	0.8	0.5	15	12	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 4.18 HFC emissions (in kt CO_2 eq) from refrigeration and air conditioning equipment for the period 1993 – 2006

Year	Residential Refrigeration	Refrigeration - Large commercial applications	Refrigeration - Small commercial applications	Transport Refrigeration	Stationary air-conditioning	Mobile air-conditioning
1993	0.01	N.E.	N.E.	N.A.	N.A.	N.A.
1994	0.02	N.E.	N.E.	N.A.	N.A.	N.A.
1995	0.07	81.14	2.47	N.A.	N.A.	3.13
1996	0.14	176.87	5.40	N.A.	N.A.	7.55
1997	0.25	276.89	9.57	N.A.	N.A.	14.05
1998	0.43	367.80	13.81	N.A.	N.A.	22.66
1999	0.72	521.31	19.67	N.A.	N.A.	37.33
2000	1.28	721.12	29.78	N.A.	3.65	70.37
2001	1.85	923.73	44.89	N.A.	12.06	115.61
2002	2.30	928.61	53.95	N.A.	30.61	158.91
2003	2.67	1272.82	66.83	N.A.	80.95	201.63
2004	3.03	1336.17	76.80	N.A.	155.51	251.16
2005	3.38	1397.76	86.90	N.A.	236.45	304.88
2006	3.78	1553.99	99.10	17.47	324.01	358.94

N.E.: Not estimated due to lack of relevant data

N.A.: Not Applicable since the use of HFC started later.

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. However, in order to have an assessment of the HFCs, emissions level from metered dose inhalers has been estimated. The percentage emission factor used was 100%, assuming that the charge will be escaped in one year from purchase. In absence of activity data, the estimation has been performed using data from other countries with climate conditions similar to Greece's (Portugal, Spain), according to country's population. The estimated emissions amount to 0.26 t HFC-134a (0.34 kt CO_2 eq).

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 – 2004. Emissions estimates from the transmission system and for the years 2003 and 2004 are the results of measurements performed by PPC. Emissions from the distribution system as well as from the transmission system (for the years 1995 – 2002) are estimated (by PPC) according to the rate of updating the installed equipment. Emissions for the period 1990 – 1994 are estimated (by the inventory team) by mean of a linear extrapolation. For the years 2005-2006 data have not been available and the emissions have remained constant to the 2004 level. SF6 emissions from electrical equipment are presented in ***Table 4.19***.

Table 4.19 SF6 emissions (in kg) from electrical equipment for the period 1990 - 2006

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
Transmission	130	132	140	140	148	148	148
Distribution	37	38	38	38	39	39	39
Total	**167**	**170**	**178**	**178**	**187**	**187**	**187**

4.6.2 Recalculations

HFC-134a emissions from transport refrigeration and from metered dose inhalers are estimated for the first time in the present inventory. Moreover, emissions of 2005 have been recalculated because of updated data availability concerning mostly the air conditioning equipment. In addition, an error has been detected in the working files concerning the emissions from the large commercial refrigerations.

The difference between the previous and the current submission is depicted in ***Table 4.20***.

Table 4.20 Recalculations of HFC emissions from consumption of halocarbons and SF6

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Difference	-49.25	-49.25	-49.15	-49.08	-49.07	-48.99	-48.81	-44.16	-43.92	-42.30	-39.60
Impact on total emissions (excl LULUCF)	-0.07	-0.16	-0.23	-0.30	-0.42	-0.56	-0.71	-0.72	-0.95	-1.00	-0.99

4.6.3 Planned improvements

Taking into consideration the high annual rate of increase of these emissions, as well as the international estimates concerning the contribution of this sector in the total GHG emissions, a reliable and accurate estimation of emissions is necessary.

In this context, actions foreseen include the following:

1. Data availability regarding sources that are currently not reported would be examined, with a view to improve completeness in reporting GHG emissions from industrial processes. Planned improvements include the introduction of emissions from more aerosols (esp. personal care products and industrial products) and from fire extinguishers.
2. Availability of the necessary information in order to apply the Tier 1 methodology (potential emissions) will be examined.
3. The availability of data regarding disposal emissions for commercial refrigeration and mobile airconditioning will be investigated in cooperation with the Greek Cold Storage and Logistics Cooperation (www.cold.org.gr).

4. Availability of transport refrigeration data will be investigated in order to estimate the trend.
5. In the case of metered dose inhalers activity data availability will be further examined.
6. The possibility of collecting data from market surveys will be examined to improve the current available estimations of refrigeration and air conditioning equipement.

5. Solvents and other products use

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 2006 were 159.65kt (0.1% of the total GHG emissions in Greece, without *LULUCF*), while NMVOC emissions have been estimated at 53.7 kt, accounting for approximately 18% of the total NMVOC emissions in the country.

CO_2 and NMVOC emissions in 2006 decreased by 5.9% and 5.2% 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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	169.71	175.78	172.84	170.12	163.22	154.65	152.16	153.07	152.39	159.96	145.66	154.67	155.12	155.50	155.87	157.70	159.65
NMVOC	56.65	58.27	57.45	56.16	54.31	51.64	51.05	51.43	51.36	53.75	49.44	52.35	52.49	52.61	52.73	53.05	53.68

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_2O	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_2O in medicine [2]	☒						
6. N_2O from fire extinguishers [2]				NE			
7. N_2O from aerosol cans [2]				NE			
8. Other use of N_2O [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, will be 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

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 13.86% between 1990 and 2006 (***Figure 6.1***), with an average annual rate of decrease of 0.86%.

Emissions from *Agriculture* and especially N_2O emissions from agricultural soils, are characterized by intense fluctuations during the period 1990 – 2006. The annual variations of agricultural production and of the amount of synthetic fertilizers applied are the main causes for these fluctuations. Agricultural production data derived from the National Statistical Service of Greece (NSSG), while data for the quantities of synthetic fertilizers applied in soils derive from the United Nations Food and Agriculture Organization (FAO) database.

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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N_2O	10060	9886	9707	9091	9303	9033	9307	9010	8866	8880	8858	8642	8576	8507	8439	8293	8203
CH_4	3459	3420	3394	3412	3433	3453	3470	3477	3476	3485	3499	3502	3503	3491	3498	3441	3442

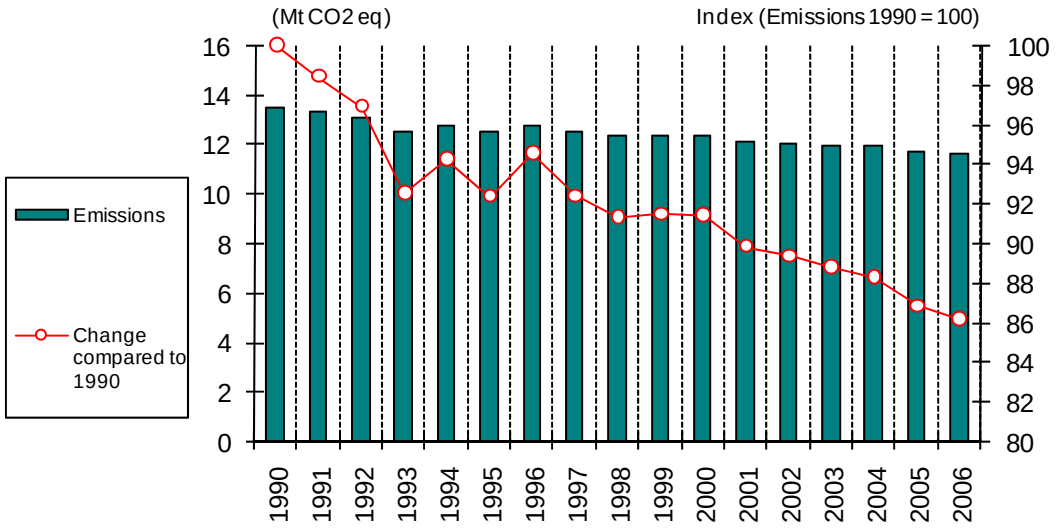


Figure 6.1 ***Total GHG emissions (in kt CO_2 eq) from Agriculture for the period 1990 – 2006***

Nitrous oxide represents the major GHG from *Agriculture*, with a contribution ranging from 74% to 70%. Nitrous oxide emissions in 2006 decreased by 18.46% compared to 1990 levels, with an average annual rate of decrease estimated at 1.15%.

Agricultural soils are the main source of emissions from *Agriculture* (***Figure 6.2***), accounting for 68% - 72% of total emissions from the sector.

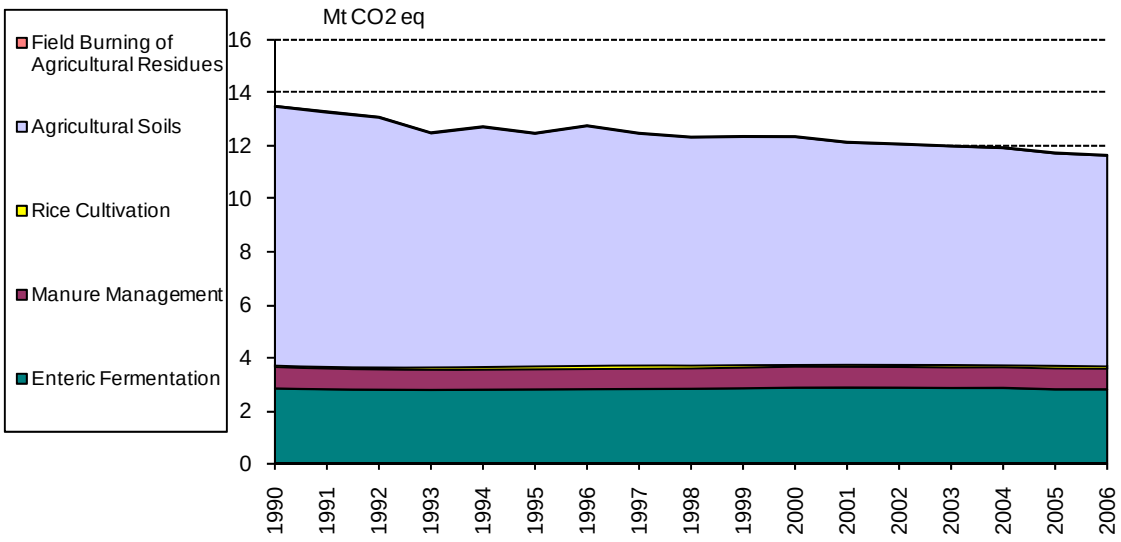


Figure 6.2 ***GHG emissions (in kt CO_2 eq) from Agriculture per source category, for the period 1990 – 2006***

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 FAO. Data on agricultural production and areas for years 2002 – 2006 are provisional estimations published by NSSG, due to a few years delay from the time the relative statistical data are collected until their elaboration and publication as final estimations. As far as animal population for years 2002 – 2004 is concerned, data are calculated by extrapolation based on the existed data of the previous 10 years, as no provisional estimations exist.

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

	CH_4		N_2O	
	Method	Emission factor	Method	Emission factor
Enteric fermentation	T2,T1	CS, D		
Manure management	T1	D	D	D
Rice cultivation	D	D		
Agricultural soils			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 *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 48% 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 status of emissions estimates from all sub-sources in agriculture.

Table 6.3 Agriculture – Inventory completeness

	CO_2	CH_4	N_2O
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 2006 account for 24.32% of total GHG emissions from *Agriculture* and for 2.12% of total national emissions (excluding *LULUCF*). The average annual rate of decrease of emissions from enteric fermentation for the period 1990 – 2006, is estimated at 0.07% (decrease by 1.18% in 2006 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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CH_4 emissions (kt)	136.47	134.82	134.07	133.90	134.15	134.76	135.09	135.28	135.80	136.67	137.84	137.95	137.82	137.27	137.43	134.85	134.85

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 on the various management systems of animals. 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 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 emission factor for CH_4 (kg CH4/head/yr), GE_i is gross energy intake (MJ/head/day) and Ym is methane conversion rate which is the fraction of 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:

$$GE_i = \begin{cases} \dfrac{NE_i \cdot NE_{ma} / DE}{DE / 100}, \text{maintenance} \\ \dfrac{NE_i \cdot NE_{ga} / DE}{DE / 100}, \text{growth} \end{cases}$$

where, NE_i is net energy for each activity, DE is digestible energy expressed as a percentage of gross energy, $NEma/DE$ is the ratio of net energy available in a diet for maintenance to digestible energy consumed and $NEga/DE$ the similar ratio for growth. The first equation concerns activities related to animal's maintenance, activity, lactation, milk production and pregnancy. The second equation concerns animal's growth and wool production.

The characterization and classification of sheep was based on data from NSSG and the statistic 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***. Data for the period 2002 – 2006 are estimated through extrapolation (based on the trend observed for the years 1990 – 2000) due to the lack of the necessary information. It should be noted that there is not always a one-to-one the correspondence between the sub-categories presented in the following table and the activities mentioned above.

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 in 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. Lactation 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 22.3 MJ/day. The number of animals is a three-year average centred at the year of reference. For the years 2002-2006 provisional data from NSSG were used.

Table 6.5 ***Number of sheep (in 1000s) for each sub-category (three-year average), for the period 1990 – 2006***

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002†	2003†	2004†	2005†	2006†
Milking ewes	5650	5637	5647	5671	5715	5756	5774	5787	5799	5823	5865	5887	5906	5904	5926	5737	5713
Other female sheep > 1 year old	734	733	734	737	743	748	751	752	754	757	762	765	768	768	770	746	743
Males > 1 year old	395	395	395	397	400	403	404	405	406	408	411	412	413	413	415	402	400
Female lambs	1530	1526	1529	1536	1547	1559	1563	1567	1570	1577	1588	1594	1599	1599	1605	1554	1547
Male lambs	382	382	382	384	387	390	391	392	393	394	397	398	400	400	401	388	387
Grazing flat pasture	2148	2155	2159	2164	2175	2188	2187	2180	2171	2176	2190	2199	2203	2202	2210	2140	2131
Grazing hilly pasture	5623	5594	5604	5634	5686	5721	5750	5780	5820	5849	5894	5915	5940	5937	5959	5770	5746
Housed fattening lambs	921	924	925	927	932	938	937	934	930	933	939	942	944	944	947	917	913
Domestic / in flock sheep milked	6475	6510	6513	6529	6524	6616	6648	6617	6644	6606	6633	6700	6763	6761	6785	6569	6542
Nomadic sheep milked	547	551	554	546	526	533	533	539	537	511	515	529	550	550	552	535	532
For wool production	2408	2418	2627	2677	2399	2395	2371	2348	2348	2353	2412	2382	2371	2377	2388	2312	2303
Births	8490	8487	8590	8664	8728	8787	8841	8855	8882	8910	8966	8980	8994	8992	9025	8738	8702
Total population (at the end of each year)	8692	8673	8688	8725	8792	8856	8883	8904	8922	8958	9024	9057	9087	9083	9117	8827	8790

† Provisional data

Methodology for enteric fermentation of the other animals

Methane emissions from enteric fermentation of 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 and the emission factors used were the ones suggested by IPCC Guidelines (*for cattle*: Eastern European countries, Table 4-4, IPCC 1997 - for the rest animal categories: Developed countries, Table 4-3, IPCC 1997). The selection for cattle of the emission factor that corresponds to the characteristics of Eastern Europe was based on data from NSSG regarding the rate of milk production per animal, which fluctuates from 2500 kg to 3300 kg for the period 1990 – 2000. Data on milk production per animal for years 2001 – 2006 derive from FAO and fluctuate from 3400 kg in 2001 to 3800 kg in 2006.

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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002†	2003†	2004†	2005†	2006†
Dairy cows	246	242	238	235	233	230	229	227	226	226	225	223	220	217	215	219	219
Other cattle	380	363	351	346	347	350	351	354	362	374	387	387	383	376	376	584	399
Buffalo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Goats	5339	5345	5360	5395	5449	5513	5565	5595	5610	5623	5639	5671	5706	5744	5777	5509	5421
Horses	46	42	40	38	36	35	33	32	31	30	29	28	26	25	23	27	27
Mules and ashes	187	174	161	150	140	130	122	114	108	104	98	93	86	79	74	73	69
Swine	994	994	1000	1008	1005	997	993	995	990	986	969	949	950	964	962	940	949

† Provisional data

Recalculations

CH_4 emissions from enteric fermentation have been recalculated because of the availability of updated activity data concerning the population of the animals for 2005. Emissions for 2005 in the present inventory are lower by 1.99% compared to the emissions estimated in the previous submission.

Planned improvements

Activity data will be updated as soon as they become available. Furthermore, 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 2006 accounted for 4.19% and 2.49% 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 2006 decreased by 1.67% compared to 1990 levels, with an average annual rate of decrease estimated at 0.10% for the period 1990 - 2006. N_2O emissions in 2006 decreased by 3.65% compared to 1990 levels, with an average annual rate of decrease estimated at 0.23%. CH_4 and N_2O emissions from manure management for the period 1990 – 2006 are presented in ***Table 6.7***.

Table 6.7 CH_4 and N_2O emissions (in kt) from manure management, for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CH_4 (kt)	23.66	23.30	23.15	23.11	23.07	23.01	23.00	23.03	23.15	23.29	23.42	23.18	23.12	23.20	23.19	22.95	23.26
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	0.93	0.92	0.91	0.91	0.99	0.94

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 6.8***. 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 6.8 Livestock population (in 1000) for poultry and sheep (three-year average), for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002†	2003†	2004†	2005†	2006†
Poultry	28747	28648	28972	29151	29231	29198	29266	29482	30005	30196	30856	30327	30629	31756	32064	30587	31565
Sheep	8692	8673	8688	8725	8792	8856	8883	8904	8922	8958	9024	9057	9087	9083	9117	8827	8790

† 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 6.9)***, 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 – 2006.

Table 6.9 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 emissions from manure management have been recalculated because of the availability of updated activity data as far as the population of the animals for 2005 is concerned. Emissions for 2005 in the present inventory are lower by 7.12% compared to the emissions estimated in the previous submission.

Planned improvements

Activity data will be updated as soon as they become available.

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 will be examined in collaboration with other research institutes (e.g. Agricultural University).

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 2006 account for 0.80% of total GHG emissions from *Agriculture* and for 0.07% of total national emissions (without *LULUCF*). CH_4 emissions increased by 35.5% in 2006 compared to 1990, with an average annual rate of increase of 2.22% for the period 1990 - 2006. CH_4 emissions from rice cultivation for the period 1990 – 2006 are presented in ***Table 6.10***.

Table 6.10 CH_4 emissions (in kt) from rice cultivation for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CH_4	3.29	2.95	2.94	4.05	4.74	5.22	5.72	5.82	5.25	4.67	3.98	4.22	4.48	4.52	4.55	4.62	4.46

The fluctuations in emissions trends are attributed to the annual changes in 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 29.09% of total GHG emissions from *Agriculture* and for 2.54% of total national emissions (without *LULUCF*) in 2006. Emissions decreased in 2006 by 0.1% compared to 1990 levels, with an average annual rate of decrease of 0.01% for the period 1990 – 2006. Direct N_2O emissions from agricultural soils in 2006 accounted for 14.59% of total GHG emissions from *Agriculture* and for 1.57% of total national emissions (without *LULUCF*). Direct emissions in 2006 decreased by 38.44% compared to 1990 levels, with an average annual rate of decrease of 2.4% for the period 1990 - 2006. Finally, indirect N_2O emissions in 2006 accounted for 24.18% of total GHG emissions from agriculture and for 2.11% of total national emissions (without LULUCF). Indirect emissions in 2006 decreased by 21.89% compared to 1990 levels, with an average annual rate of decrease estimated at 1.37% for the period 1990 - 2006. Emissions from agricultural soils for the period 1990 – 2006 are presented in ***Table 6.11***.

Table 6.11 N_2O emissions (in kt) from agricultural soils for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Animal production	10.91	10.88	10.89	10.93	11.01	11.1	11.16	11.2	11.23	11.26	11.31	11.35	11.39	11.44	11.49	11.03	10.93
Direct emissions	8.9	8.67	8.33	7.16	7.49	6.91	7.36	6.79	6.48	6.47	6.39	5.97	5.81	5.65	5.5	5.57	5.48
Indirect emissions	11.63	11.35	11.14	10.29	10.56	10.19	10.55	10.13	9.94	9.95	9.9	9.59	9.5	9.41	9.29	9.13	9.01

The reduction of N_2O emissions from agricultural soils is mainly due to the reduction in the use of synthetic nitrogen fertilizers. 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 – 2006.

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 – 2006 are presented in ***Table 6.12***.

Table 6.12 Nitrogen input (in kt) and N_2O emissions (in kt) from pasture, range and paddock, for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N input	347.27	346.25	346.36	347.68	350.18	353.06	355.15	356.35	357.20	358.27	359.94	361.10	362.55	364.06	365.64	351.10	347.6
N_2O emissions	10.91	10.88	10.89	10.93	11.01	11.10	11.16	11.20	11.23	11.26	11.31	11.35	11.39	11.44	11.49	11.03	10.93

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 during the period 1990 – 2002 derive from FAO, while data for the last two years result from extrapolation based on the trend of the last five years. 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 – 2006 are presented in ***Table 6.13***.

Table 6.13 Synthetic nitrogen applied (in kt) and N_2O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003†	2004†	2005†	2006†
N input	384.75	367.56	353.7	295.2	311.4	283.5	306	276.3	262.8	261.9	256.5	234.9	227.7	220.14	210.65	214.2	208.9
N_2O emissions	7.56	7.22	6.95	5.8	6.12	5.57	6.01	5.43	5.16	5.14	5.04	4.614	4.47	4.32	4.14	4.21	4.10

† Provisional data

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 6.14*** nitrogen input to soils from animal manure and subsequent N_2O emissions are presented, for the period 1990 – 2006.

Table 6.14 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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N input	39.49	38.76	38.40	38.24	38.11	37.94	37.87	37.90	38.08	38.35	38.53	38.10	37.90	37.89	37.79	37.8	38.4
N_2O emissions	0.78	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.75	0.75	0.76	0.75	0.75	0.74	0.74	0.74	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). As far as the fractions of residues used as fuel and for construction, there has not been any estimation yet because of lack of the 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 for the period 1990 – 2001 and from the provisional statistical data of the NSSG for the period 2002 – 2006.

N_2O emissions from N-fixing crops and crop residues for the period 1990 – 2006 are presented in ***Table 6.15***.

Table 6.15 N_2O emissions (in kt) from N-fixing crops and crop residues, for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	0.021	0.021	0.020	0.019	0.018	0.018
Crop residues	0.463	0.581	0.516	0.504	0.520	0.490	0.502	0.515	0.466	0.470	0.491	0.506	0.493	0.474	0.512	0.512	0.522

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 – 2006 are presented in ***Table 6.16***.

Table 6.16 Deposited nitrogen (in kt) and indirect N_2O emissions (in kt) from agricultural soils, for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Atmospheric deposition																	
N deposited	122.08	119.78	118.17	111.90	114.16	111.60	114.50	111.45	110.16	110.34	110.12	107.84	107.28	106.74	105.98	103.47	102.92
N_2O emissions	1.92	1.88	1.86	1.76	1.79	1.75	1.80	1.75	1.73	1.73	1.73	1.69	1.69	1.68	1.67	1.63	1.62
Leaching/Run off																	
N deposited	247.24	240.93	236.21	217.05	223.14	214.65	222.75	213.22	209.04	209.16	207.93	200.92	198.88	196.81	194.08	184.81	190.1
N_2O emissions	9.71	9.47	9.28	8.53	8.77	8.43	8.75	8.38	8.21	8.22	8.17	7.89	7.81	7.73	7.62	7.26	7.47

6.5.2 Recalculations

N_2O emissions from agricultural soils have been recalculated because of the availability of updated activity data as far as the population of the animals for 2005 is concerned. Emissions for 2005 in the present inventory from animal manure deposited to soils during pasture, range and paddock are higher by 7.30%, from direct N_2O emissions from agricultural soils lower by 0.88 and from indirect

N_2O emissions are higher by 3.51% compared to the emissions estimated in the previous submission.

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 them on-site. According to the IPCC Good Practice Guidance, 10% constitutes an indicative value of the residues are burned annually on the field. Burning of agricultural residues is responsible for emissions of CH_4, N_2O, CO and NOx.

CH_4 and N_2O emissions from field burning of agricultural residues in 2006 accounted for 0.33% of total GHG emissions from *Agriculture* and for 0.025% of total national emissions (without *LULUCF*). Emissions in 2006 increased by 2.18% compared to 1990 levels, with an average annual rate of increase estimated at 0.14%. CH_4 and N_2O emissions from field burning of agricultural residues for the period 1990 – 2006 are presented in ***Table 6.17***.

Table 6.17 GHG emissions (in kt) from field burning of agricultural residues, for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	1.42	1.38	1.27	1.42	1.43	1.32
N_2O emissions	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04	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

No recalculations were performed.

7. Land Use, Land Use Change and Forestry

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[5] 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 – 2006. The magnitude of this sink increased from approximately 3.21 Mt CO_2 eq in 1990, to 5.20 Mt CO_2 eq in 2006 (***Figure 7.1***), i.e. an increase of 62%.

[5] 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 2.98 Mt CO_2 eq in 2000 and a maximum value of 5.55 Mt CO_2 eq in 2003, that are mainly attributed to fluctuation in areas of Forest Land burnt by wildfires each year.

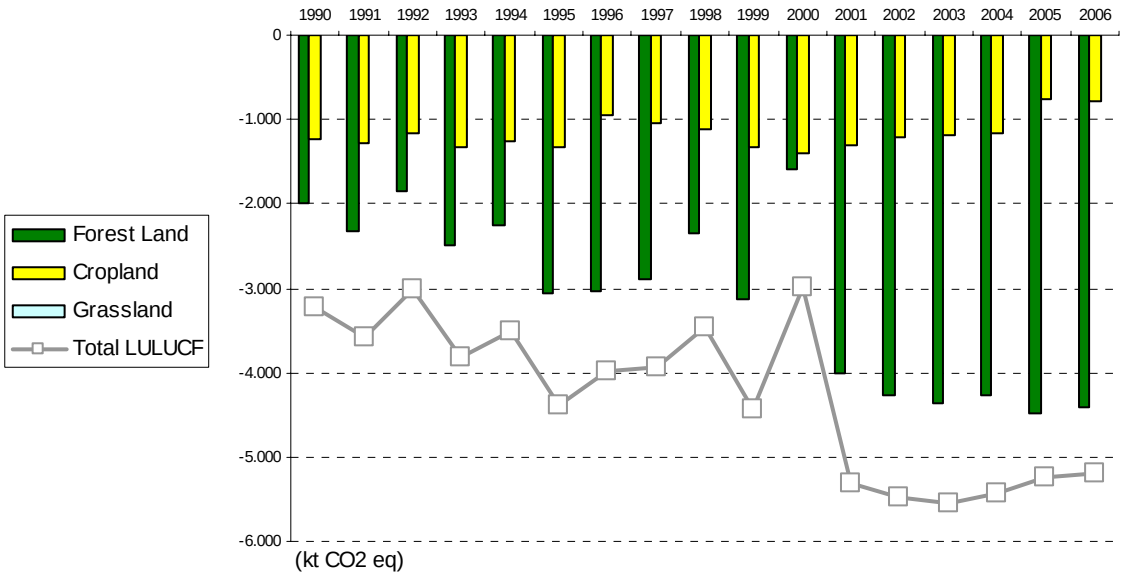


Figure 7.1 ***Net GHG emissions / removals (in kt CO_2 eq) from the Land Use, Land Use Change and Forestry sector by category (bars) and total (line) for the period 1990 – 2006***

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 – 2006. Emissions / removals from the Forest Land category are the result of the balance mainly in biomass increment from forest growth and biomass loss due to fellings and wildfires. Net removals from the Forest Land show an upward trend that is attributed mainly to the reduction in fellings, and to a lesser degree, to the smaller area burnt by wildfires the last years and the afforestation programmes started in 1994.

Removals from Cropland, caused by changes in management practices and crop type, fluctuates between 0.75 - 1.4 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 – 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	-4270.33	-4493.24	-4432.02
B. Cropland	-1226.07	-1271.89	-1166.69	-1331.61	-1250.56	-1336.15	-957.08	-1045.72	-1124.47	-1317.26	-1390.22	-1306.32	-1208.26	-1193.09	-1164.85	-751.08	-785.10
C. Grassland	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	10.36	7.93	16.56
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
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	0.72	0.37	0.18
N_2O 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	1.05	0.80	1.68
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
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	0.07	0.04	0.02
TOTAL LULUCF	**-3213.92**	**-3588.63**	**-3012.59**	**-3827.31**	**-3505.51**	**-4389.34**	**-3989.92**	**-3926.27**	**-3473.67**	**-4446.39**	**-2979.59**	**-5319.08**	**-5476.86**	**-5549.19**	**-5422.97**	**-5235.18**	**-5198.69**

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	T1	T1	T1	D	T1	D
C2. Land converted to Grassland	T1	T1	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 the 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

A mix of Approach 1 and 2 as described in the GPG LULUCF was used for representing land areas. In order to develop the land use database needed for this greenhouse gas inventory, existing databases were combined. These are:

- 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)

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. The various forms of land uses in 2000 are presented in ***Figure 7.2***.

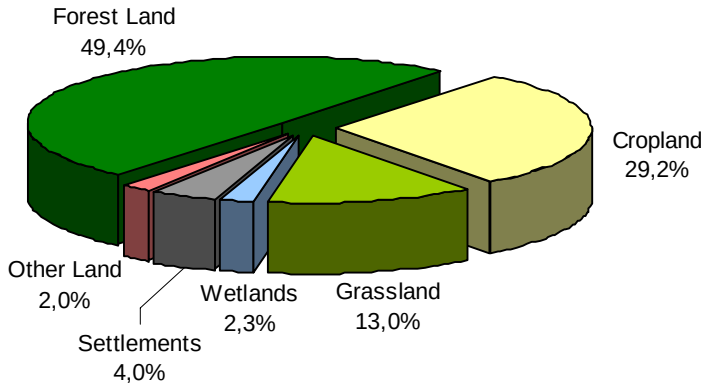


Figure 7.2 Distribution of the area of Greece in 2000 by land-use category

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 – 2006 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 7.5***.

The sink capacity of Forest Land has increased from 1990 kt CO_2 eq in 1990 to 4414 kt CO_2 eq in 2006, i.e. an increase of about 122%. This rising trend is attributed mainly to the reduction in fellings observed since 1990 (by 50%), and to a lesser degree to the smaller area burnt by wildfires the last years, 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.

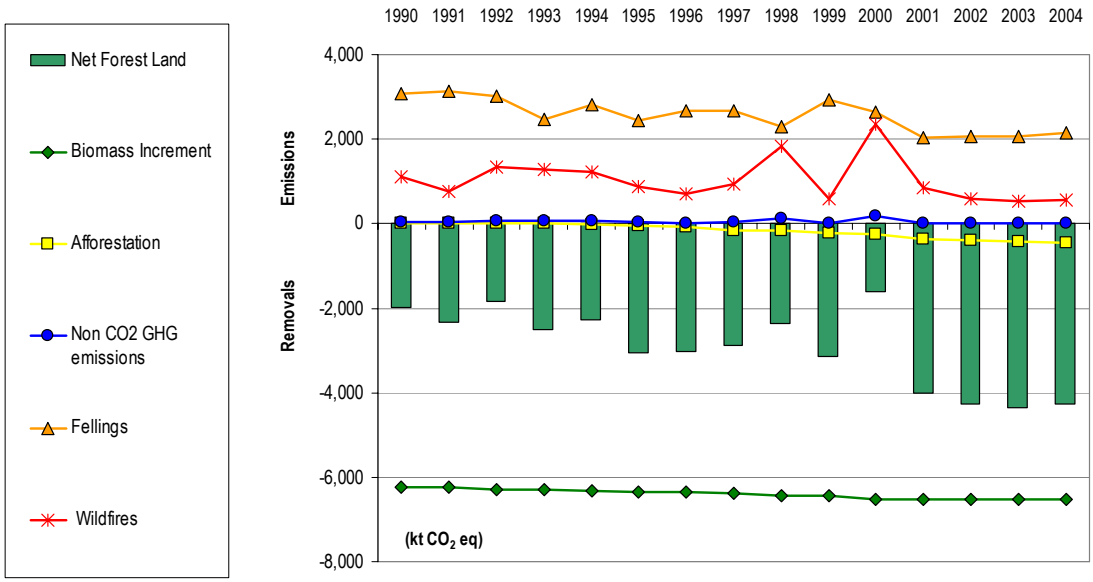


Figure 7.3 ***Emissions / removals of GHG (in CO2 eq) from different activities (lines) and net removals from the Forest Land category (bars)***

Table 7.5 Net GHG emissions / removals (kt CO_2 eq) from Forest Land by subcategory for the period 1990 - 2006

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Forest land remaining forest land	**-1989.83**	**-2318.91**	**-1849.82**	**-2498.20**	**-2236.20**	**-2995.89**	**-2946.18**	**-2736.91**	**-2186.02**	**-2917.09**	**-1359.33**	**-3640.74**	**-3870.55**	**-3931.96**	**-3809.08**	**-4017.17**	**-3939.69**
Biomass	-2047.29	-2602.91	-1730.69	-2433.10	-2274.27	-3150.61	-3279.15	-2816.61	-1419.12	-3326.28	-292.15	-4056.53	-4394.45	-4385.35	-4163.84	-4361.18	-4176.21
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	354.76	344.01	236.52
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
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**	**-476.066**	**-492.33**
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	-476.066	-492.33
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	**-1989.83**	**-2318.91**	**-1849.82**	**-2498.20**	**-2261.27**	**-3054.37**	**-3035.99**	**-2889.38**	**-2357.28**	**-3130.12**	**-1597.18**	**-4015.01**	**-4268.86**	**-4356.73**	**-4258.92**	**-4493.24**	**-4432.02**

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 7.6.*** 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 7.6 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:

$$L_{F+FG} = \sum_{i=1}^{7} (H_i / UB + FG_i) \cdot D_i \cdot BEF2_i \cdot CF$$

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}, $BEF2_i$ 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 1990-2006 between 3132 kt CO_2 in 1991 and 2002 kt CO_2 in 2006. 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.

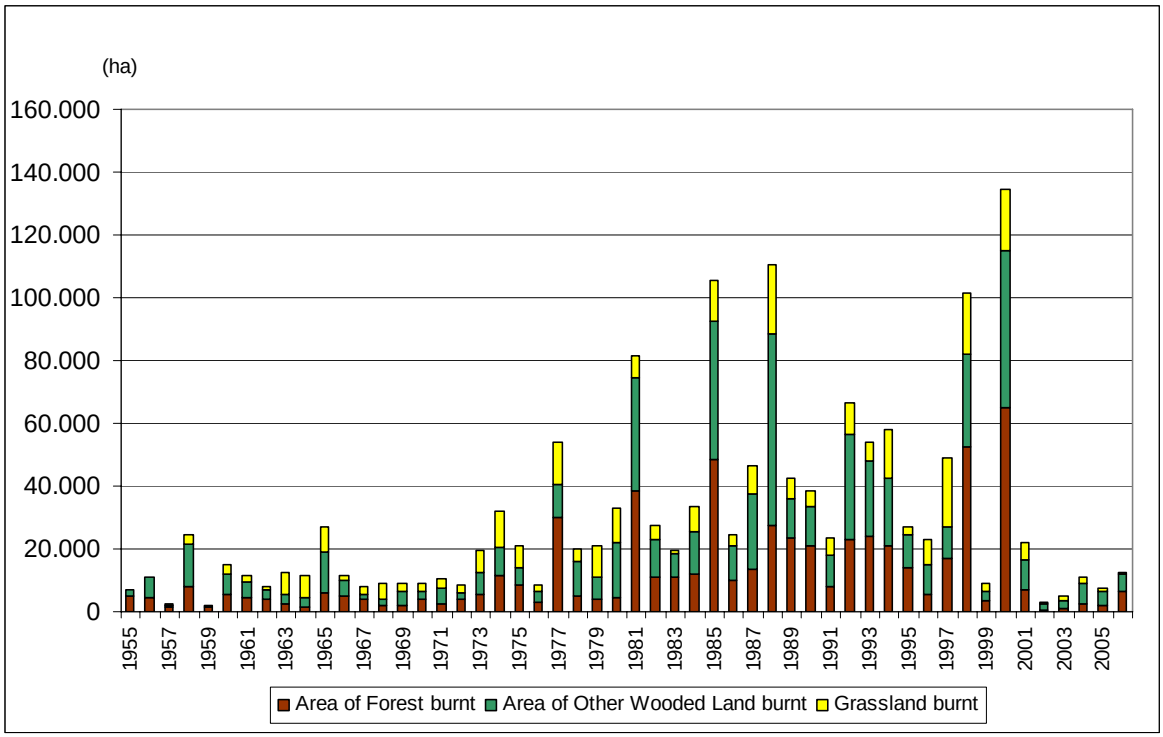


Figure 7.4 Areas of Forest, Other Wooded Land and Grassland burnt since 1955

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.

$$L_{Wildfires} = L_{W_{oxid}} + L_{W_{trans}}$$

where, $L_{W_{oxid}}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere, t C yr^{-1} and $L_{W_{trans}}$ 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:

$$L_{W_{oxid}} = \sum_{i} A_{disturbance\ i} \cdot B_{W\ i} \cdot (1 - f_{BL\ i}) \cdot CF \ \kappa\alpha\iota$$

$$L_{W_{trans}} = \sum_{i} A_{disturbance\ i} \cdot B_{W\ i} \cdot f_{BL\ i} \cdot CF$$

where, $A_{disturbance\ i}$ is the forest areas affected by wildfires, by forest type (i = 21), ha yr^{-1}, $B_{W\ i}$ 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:

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

where, V is the average volume of growing stock, overbark, m^3 ha^{-1}, D is the basic wood density, t d.m. m^{-3}, BEF_2 is the biomass expansion factor for converting volumes of growing stock to total aboveground biomass, $B_{W_{understorey}}$ 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 ($\Delta C_{FF_{GR}}$) is the sum of 1/35th of the annual carbon losses due to wildfires ($L_{Wildfires}$) in each of the last 35 years.

$$\Delta C_{FF_{GR}} = \sum_{i=k-34}^{k} {}_i (1/35) \cdot L_{Wildfires\,i}$$

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 ($L_{W_{trans}}$) 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, $1/10^{th}$ 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 $1/10^{th}$ 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:

$$\Delta C_{FF_{DWinto}} = L_{W_{trans}}$$

$$\Delta C_{FF_{DWout}} = \sum_{i=k-9}^{k}{}_{i} (1/10) \bullet \Delta C_{FF_{DWinto\,i}}$$

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***.

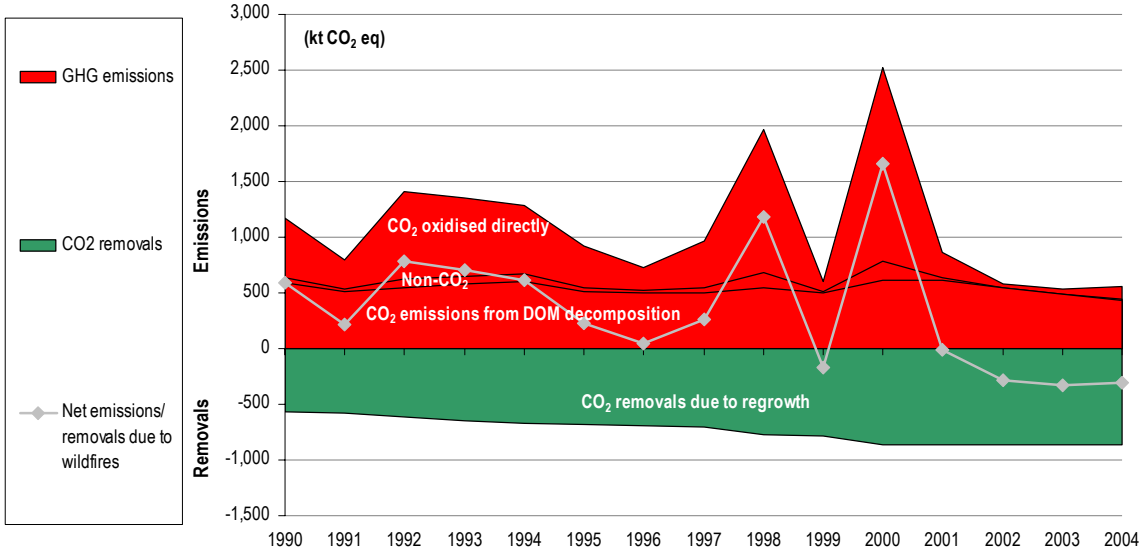


Figure 7.5 GHG emissions and removals (in CO2 eq) from wildfires (various processes and their net effect) during the period 1990 - 2004

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_2O 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_2O 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).

$$CH_4 \text{ emissions} = Lw_{oxid} \bullet 0.012 \bullet 16/12$$

$$CO \text{ emissions} = Lw_{oxid} \bullet 0.06 \bullet 28/12$$

$$N_2O \text{ emissions} = Lw_{oxid} \bullet (N/C \text{ ratio}) \bullet 0.007 \bullet 44/28$$

$$NO_x \text{ emissions} = Lw_{oxid} \bullet (N/C \text{ ratio}) \bullet 0.121 \bullet 46/14$$

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.

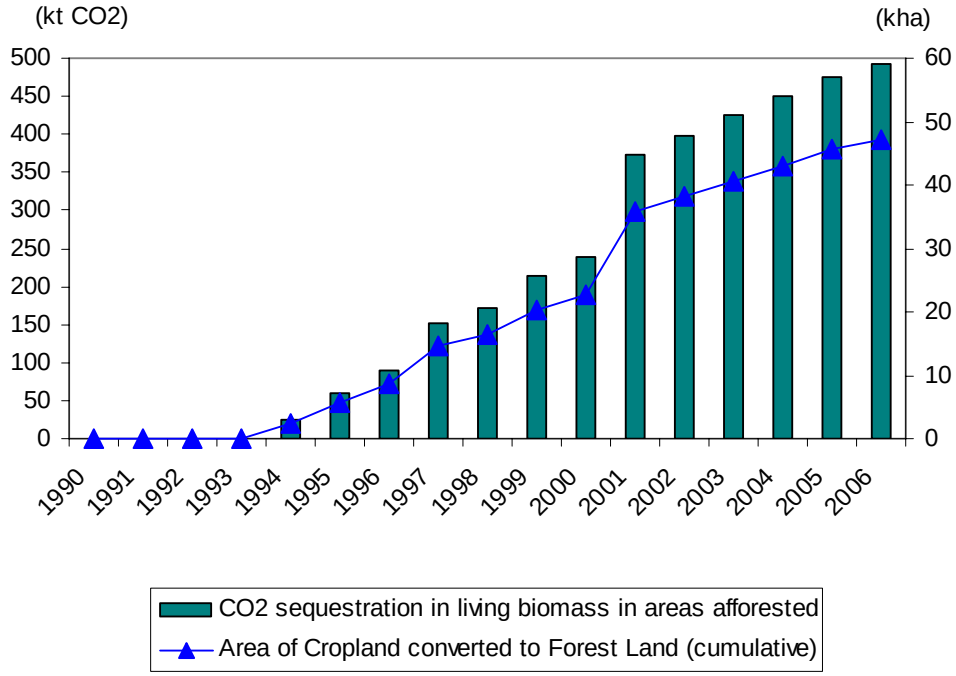


Figure 7.6 Carbon sequestration in living biomass and area of Croplands converted to Forest land during 1990-2006

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:

$$\Delta C_{LF_{Soils}} = \Delta C_{LF_{Mineral}} = [\sum_{t} (SOC_{REF} - SOC_{Cropland\ i}) \bullet A_{aff\ i}] / T_{aff}$$

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 year 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.

The difference (%) between present and previous emission estimations, along with the impact of recalculation on total emissions including LULUCF are presented in **Table 7.7.** As presented in the table, although the % difference is high between present and previous estimations, the impact on total emissions is negligible.

Table 7.7 Recalculations of CO_2 removals and CH_4 and N_2O emissions (%) of Forest Lands for year 2005

Gas	Difference (%)	Impact on total emissions incl LULUCF (%)
CO_2	1.41	-0.05
CH_4	349	<0.00%
N_2O	-35	<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_2O from these lands were estimated as part of *Agriculture* (Chapter 6). The net CO_2 emissions / removals from each subcategory are presented in ***Table 7.8.***

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 – 2006. 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 – 2006. 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 – 2005 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 year 2005. However, the activity data for year 2006 were provisional.

Table 7.8 Net CO_2 emissions / removals (kt CO_2) from Cropland by subcategory for the period 1990 - 2006

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cropland	**-1205.41**	**-1251.23**	**-1146.04**	**-1310.96**	**-1229.90**	**-1315.50**	**-936.42**	**-1025.06**	**-1103.81**	**-1296.61**	**-1369.57**	**-1285.67**	**-1187.61**	**-1172.44**	**-1144.19**	**-751,08**	**-785,10**
Biomass	-1226.07	-1271.89	-1166.69	-1331.61	-1250.56	-1336.15	-957.08	-1045.72	-1124.47	-1317.26	-1390.22	-1306.32	-1208.26	-1193.09	-1164.85	-771,73	-805,75
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
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
Total	**-1205.41**	**-1251.23**	**-1146.04**	**-1310.96**	**-1229.90**	**-1315.50**	**-936.42**	**-1025.06**	**-1103.81**	**-1296.61**	**-1369.57**	**-1285.67**	**-1187.61**	**-1172.44**	**-1144.19**	**-751,08**	**-785,10**

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***.

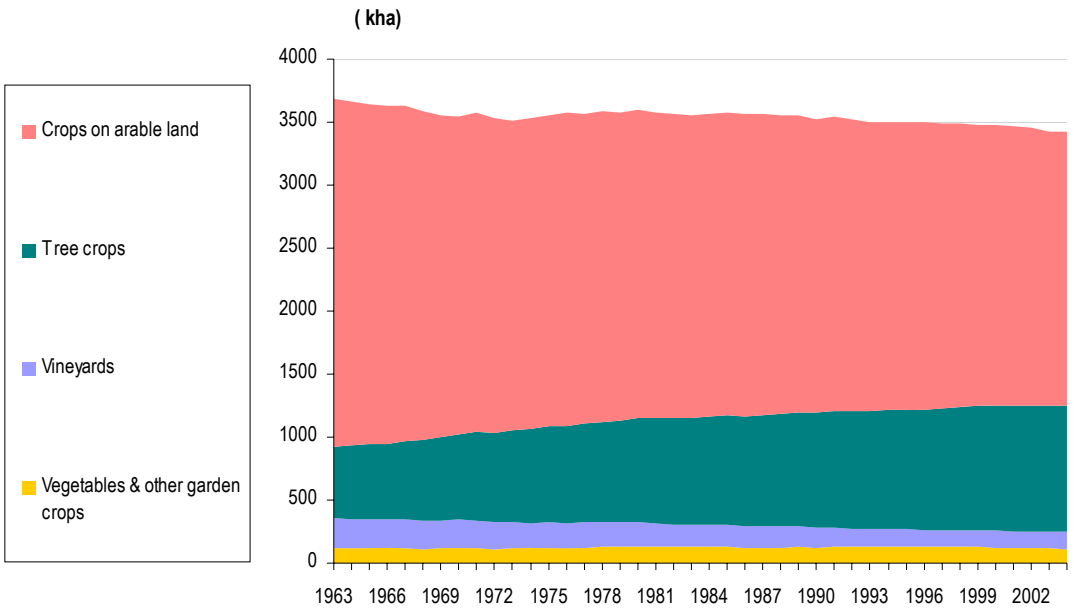


Figure 7.7 Areas of cropland in Greece since 1963 (fallow land excluded)

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:

$$\Delta C_{CC_G} = \sum_i \sum_{j=k-(\lambda i/2)-1}^{k} \frac{1}{\lambda_i / 2} \cdot A_{planted_{ij}} \cdot GW_i \cdot CF,\ G_{W,i} = {B_{M,i}}/{(\lambda_i / 2)}$$

where, $A_{planted_{ij}}$ is the area where new plantations were established, by crop type (i = 17), ha yr^{-1}, GW_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.

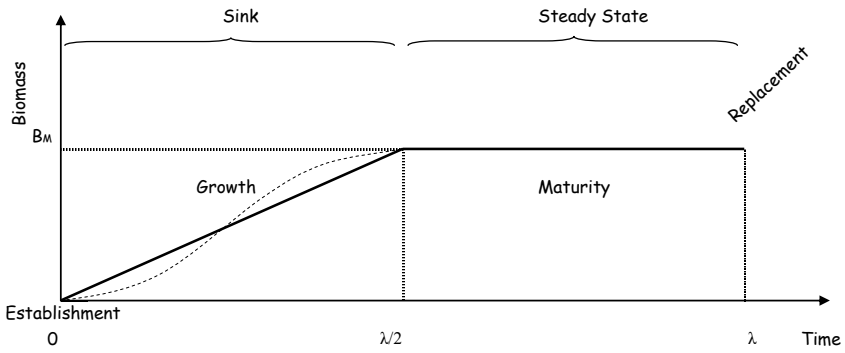


Figure 7.8 Assumed biomass accumulation in new plantations

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_{CC_L}) was estimate as:

$$\Delta C_{CC_L} = \sum_i A_{eradicated_i} \bullet B_{M\,i}$$

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 7.9***.

Table 7.9 ***Average biomass stock at maturity and replacement cycle for different crop types***

Crop Type	B_M (tonnes d.m. ha^{-1})	λ (yr)
Vineyards	12	26
Citrus trees (orange, lemon, mandarin, 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[6]	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 ($\Delta C_{CC_{Soils}}$, tonnes C yr^{-1}) was estimated as the difference in the annual emissions from cultivated organic soils ($\Delta C_{CC_{Organic}}$, tonnes C yr^{-1}) from the annual change in organic carbon stocks in mineral soils ($\Delta C_{CC_{Mineral}}$, tonnes C yr^{-1}).

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

[6] 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.

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:

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

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

where, SOC_0 is the soil organic carbon stock in the inventory year, t C yr^{-1}, $SOC_{(0\text{-}T)}$ 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 • 38 + 0.2 •88 = 48 tonnes C ha^{-1}, Table 3.3.3 of GPG LULUCF). Similarly, one weighted average land use factor, management factor and input factor was assumed for each crop type, selected from table 3.3.4 of GPG LULUCF. The stock change factors used are presented in ***Table 7.10.***

Carbon stocks in mineral soils were estimated to increase over the period 1990 – 2006 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 7.10 Stock change factors used for different crop types

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

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 for the period 2000 – 2005 used, 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 year 2005. Thus, the difference of CO_2 removals between present and previous emission estimations were -26%, with an impact on total emissions including LULUCF of 0.2%.

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 7.11***). Changes in soil carbon stock in Cropland converted to Grassland are estimated and reported in the Cropland remaining Cropland category.

Table 7.11 Emissions / removals of greenhouse gases (in kt CO_2 eq) from Grassland for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	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	0.72	0.37	0.18
N_2O	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	0.07	0.04	0.02
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**	**0.80**	**0.40**	**0.19**

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 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 are presented in **Table 7.12.** As presented in the table, although the % difference is high between present and previous estimations, the impact on total emissions is negligible.

Table 7.12 Recalculations of CH_4 and N_2O emissions of Grassland (%) for year 2005

Gas	Difference (%)	Impact on total emissions incl LULUCF (%)
CH_4	-83	<0.00%
N_2O	-83	<0.00%

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[7]. 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[8], 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.

[7] Parties do not have to prepare estimates of emissions and removals from Wetlands remaining Wetlands, although they may do so if they wish.
[8] 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

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 2006 GHG emissions from *Waste* decreased by 20.38% compared to 1990 levels (***Figure 8.1***), while the average annual rate of decrease of emissions for the period 1990 – 2006 is estimated at 1.27%.

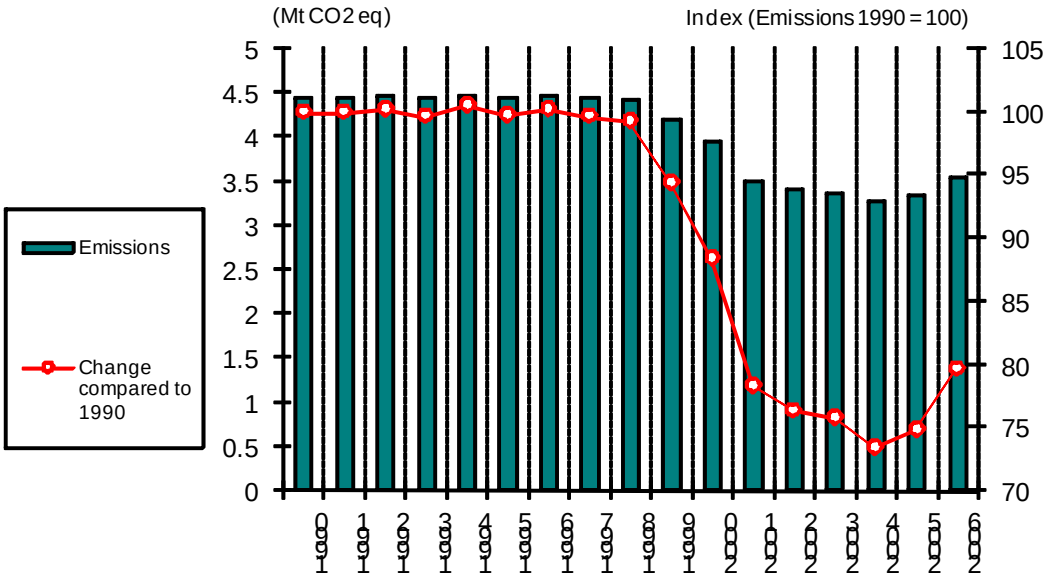


Figure 8.1 Total GHG emissions (in kt CO_2 eq) from Waste for the period 1990 – 2006

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 CO_2 eq) from Waste per gas for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.41	0.79	0.98	1.00	1.00
CH_4	4119.90	4112.83	4118.84	4092.22	4119.48	4079.55	4102.99	4070.13	4053.19	3827.03	3563.39	3117.20	3026.26	2999.96	2893.43	2956.40	3166.38
N_2O	325.05	331.23	338.10	337.30	350.79	353.84	352.63	360.46	361.06	369.82	367.63	364.97	365.30	366.34	367.42	370.01	372.00
Total	**4445.10**	**4444.21**	**4457.09**	**4429.67**	**4470.42**	**4433.54**	**4455.77**	**4430.75**	**4414.40**	**4197.01**	**3931.16**	**3482.32**	**3391.97**	**3367.09**	**3261.83**	**3327.41**	**3539.38**

Methane represents the major greenhouse gas from *Waste*, with a contribution which, however, decreased from 93% in 1990 to 89% in 2006. Overall, CH_4 emissions in 2006 decreased by 23% compared to 1990 levels, with an average annual rate of -1.45%.

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 41% in 1990 to 76% in 2006. On the contrary, GHG emissions from wastewater handling present a declining trend, with an average annual rate of -3.6% for the period 1990 – 2006. Carbon dioxide emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2006; though the contribution of this source to total GHG emissions of the sector is negligible.

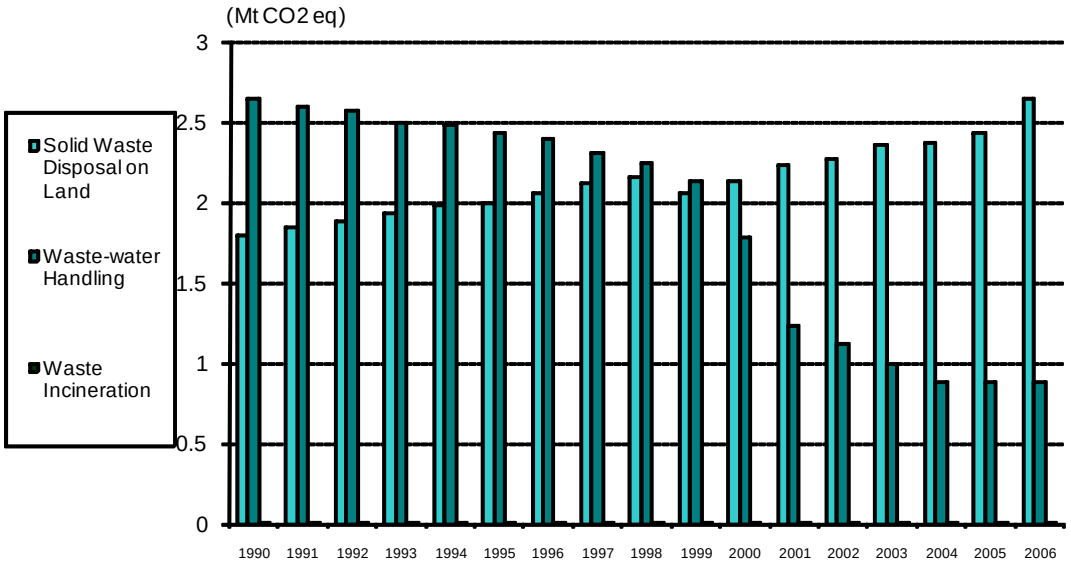


Figure 8.2 Greenhouse gases emissions (in kt CO_2 eq) from Waste per source category for the period 1990 – 2006

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 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 rest of the necessary data and parameters are the Ministry for Environment, 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

	CO_2	CH_4	N_2O
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.

It should be noticed that CH_4 emissions were calculated using the First Order Decay (FOD) method (Tier 2) for the last three years inventory reports (2004, 2005 and 2006) according to the IPCC Good Practice Guidance. The application of the FOD method resulted in a considerable decrease of emissions in the base year, in the order of 33%, as well as in the rest of the years examined (33% - 54%), compared to Tier 1 method. ***Figure 8.3*** is showing the emissions calculated by the IPCC default model and the FOD model respectively for the inventory period 1990-2004.

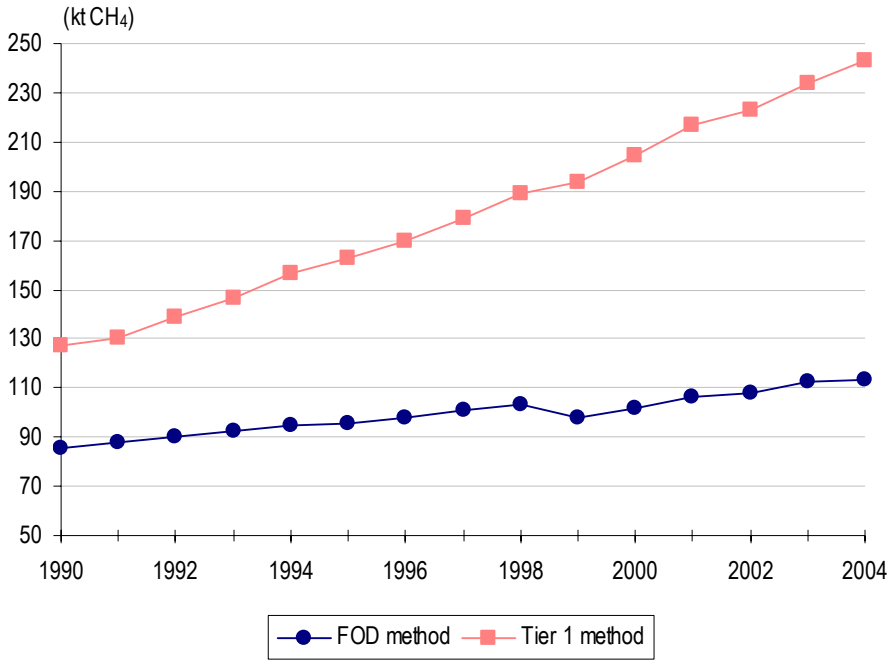


Figure 8.3 ***Methane emissions (in kt) from solid waste disposal on land, estimated by the FOD method and the Tier 1 method***

The difference of the results obtained by the application of the two methodologies is completely justified considering the fact that the default method (Tier 1) is based on the assumption that all potential CH_4 is released in the year the waste is disposed of, resulting in an overestimation of the annual emissions. The trend of emissions using the FOD method is still ascending, but the rate of increase is lower due to the fact that the degradation process is better simulated.

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. It should be noticed that CO_2 emissions from biogas flaring were improperly included in previous inventory reports, and therefore, these emissions have been excluded since last year inventory report. Recovery and flaring of biogas constitute a waste management practice in the major managed SWDS of Greece since 1990. The quantities of waste disposed in these sites represent a significant fraction of total waste landfilled in managed SWDS, rising from 21% in 1990 to 80% in 2006 The amounts of biogas flared have been revised compared to the previous inventories, taking account of detailed data for biogas recovery in the largest SWDS of the country, in Athens, in which the waste landfilled in 2006 represent the 50% of the total waste disposed in managed sites.

Methane emissions from sewage sludge (generated during municipal wastewater handling) landfilled, were estimated for the first time in the 2004 year inventory. 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 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 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.

CH_4 emissions from solid waste disposal on land in 2006 accounted for 76% of total GHG emissions from *Waste* and for 1.98% of total national emissions (without *LULUCF*). The average annual rate of increase of emissions from solid waste disposal on land, for the period 1990 – 2006 is estimated at 2% (32% total increase between 1990 and 2006). CH_4 emissions from managed and unmanaged solid waste disposal sites are presented in ***Table 8.5***.

Table 8.5 CH_4 emissions (in kt) from managed and unmanaged solid waste disposal

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Manages SWDS	25.82	27.08	28.13	29.28	30.58	29.95	31.52	33.12	33.77	27.61	30.45	34.40	34.95	39.00	39.16	41.22	47.00
Unmanaged SWDS	59.77	60.41	61.25	62.25	63.28	64.39	65.59	66.75	67.84	68.77	69.63	70.28	70.96	71.51	71.76	72.64	76.86
Sludge treatment	0.17	0.33	0.48	0.61	0.75	0.90	1.01	1.24	1.46	1.67	1.86	2.03	2.20	2.20	2.20	2.20	2.20

CH_4 emissions from managed SWDS in 2006 increased by 82% compared to 1990 levels, while the corresponding increase of emissions from unmanaged SWDS is 29% approximately. This difference is due to the reduction of the number of the unmanaged SWDS in operation. Emissions from sewage sludge disposal in 2006 are 13 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.

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.
- All managed SWDS, the oldest of which exists since 1965, are assumed to be similar concerning the composition and management of the waste disposed.

The equations used for the estimation of CH_4 emissions are the following:

CH_4 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 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 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 (MEPPPW 1987). According to the Ministry for Environment, 2182 unmanaged SWDS were still operating in 2000 (MEPPPW 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 by the end of 2008, 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. For this reason, 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.

Permanent population on prefectural level was disaggregated in urban, semi-urban and rural, while foreign visitors overnight staying were taken into consideration, as well as the number of emigrants. The estimated total population served is presented in ***Table 8.6***.

Table 8.6 Total population served (in thousands)

Year	Permanent population	Tourists (in equivalent permanent)	Total population served
1960	8,350.54	79.73	8,430.27
1965	8,540.59	81.75	8,622.34
1970	8,730.63	83.83	8,814.46
1975	9,157.35	85.96	9,243.31
1980	9,643.24	88.14	9,731.38
1985	9,948.21	97.24	10,045.45
1990	10,156.90	99.45	10,256.35
1991	10,256.29	83.62	10,339.91
1992	10,369.87	101.09	10,470.96
1993	10,465.53	101.67	10,567.19
1994	10,553.04	113.49	10,666.53
1995	10,634.39	106.22	10,740.61
1996	10,709.17	97.25	10,806.43
1997	10,776.50	108.80	10,885.30
1998	10,834.88	115.53	10,950.41
1999	10,882.58	124.61	11,007.19
2000	10,917.48	127.18	11,044.66
2001	10,949.96	119.05	11,069.01
2002	10,987.54	110.55	11,098.09
2003	11,019.04	110.71	11,129.74
2004	11,050.62	111.97	11,162.60
2005	11,103.92	111.60	11,215.53
2006	11,148.46	117.96	11,266.42

For 1997, MSW generation rates were considered to be 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). For the estimation of generation rates for the period 1990 – 2006, starting from 1997, the following assumptions were made taking into account relevant estimations developed by the Ministry for Environment: 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	1.114	2.100	1.124
2002	1.146	2.100	1.155
2003	1.178	2.100	1.187
2004	1.210	2.100	1.219
2005	1.242	2.100	1.251
2006	1.126	2.100	1.135

On the basis of the above, the following MSW quantities for the years 1990 – 2006 were estimated (***Table 8.8***).

Table 8.8 Estimated quantities of MSW generated by year (in kt)

Year	1960	1965	1970	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Generated MSW	1.765	1.951	2.142	2.384	2.651	2.877	3.075	3.119	3.273	3.410	3.556	3.686	3.815	3.958	4.112
Year	1999	2000	2001	2002	2003	2004	2005	2006							
Generated MSW	4.266	4.411	4.543	4.680	4.823	4.967	5.121	5.275							

It should be noted that the figures regarding the MSW quantities generated for the years 1991 and 1997 are in agreement with the official estimations developed in the past by the Ministry for Environment (MEPPPW 1998) for these two years.

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, MEPPPW 1999). Recent estimates of the composition of MSW at national level exist only for 1997 (MEPPPW 1998). In order to estimate the composition of MSW generated on an annual basis the following assumptions were made (MEPPPW 2001a), considering the estimation for 1997 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.

For the period 1960 – 1990 an annual increase (backwards) of 0.2% was assumed for putrescibles, metals and glass are also assumed to increase (backwards) by 0.1% and 0.02% respectively, while paper and plastics are assumed to decrease annually (backwards) by 0.1% and 0.2% respectively.

The estimated composition of generated MSW on an annual basis is presented in ***Table 8.9***.

Table 8.9 Estimated composition (%) of MSW generated for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Putrescibles	49.1	48.8	48.5	48.2	47.9	47.6	47.3	47.0	46.7	46.4	46.1	45.8	45.5	45.2	44.9	44.6	44.3
Paper	18.6	18.8	19.0	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.8
Plastics	7.1	7.3	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3
Metals	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.6
Glass	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Rest	15.4	15.4	15.4	15.4	15.4	15.5	15.5	15.5	15.5	15.5	15.6	15.6	15.6	15.6	15.6	15.6	15.6

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 2006, the percentage of MSW recycled is estimated at 7.1 %, which is very low but is expected to increase in the near future 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). However, it should be mentioned that a certain amount of this remaining quantity is open-burned, but there are no data to quantify this amount.

The estimated composition of the disposed municipal solid wastes in the two categories of SWDS (managed and unmanaged) is presented in ***Table 8.10***.

Table 8.10 Estimated composition of MSW disposed for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Putrescibles	54.2	53.8	53.3	52.8	52.2	51.8	51.3	50.5	50.0	49.6	49.2	48.8	48.4	48.0	47.5	47.1	46.7
Paper	11.6	11.9	12.5	13.0	13.5	13.9	14.3	14.9	15.3	15.7	16.1	16.5	16.8	17.1	17.5	17.9	18.3
Plastics	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.1	9.3	9.5	9.6	9.8	10.0	10.2	10.4	10.6	10.8
Metals	5.7	5.6	5.4	5.2	5.1	5.0	4.9	4.8	4.6	4.5	4.4	4.3	4.1	4.0	3.9	3.8	3.7
Glass	3.7	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Rest	17.0	17.0	16.9	16.9	16.8	16.8	16.8	16.9	16.9	16.9	16.9	16.9	16.8	16.8	16.8	16.8	16.8

According to the most recent data of the Ministry for Environment (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. There are two large managed SWDS operating previous to 1990, one in Athens since 1965 and the other in Thessalonica since 1981.

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%.

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, 12 years for food waste and 9 years for sewage sludge disposed on land.

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			1,764.55	255.95		
1965	381.09	42.74	1,519.58	221.18		
1970	454.18	48.94	1,619.21	236.49		
1975	541.28	55.55	1,749.37	256.37		
1980	645.09	62.36	1,876.93	276.00		
1985	1,037.11	107.48	1,689.83	249.33		
1990	1,160.08	114.70	1,624.67	240.53	60.00	24.00
1991	1,198.41	120.90	1,630.78	242.01	60.00	24.00
1992	1,246.11	128.92	1,733.44	257.81	60.00	24.00
1993	1,295.02	136.75	1,821.28	271.49	60.00	24.00
1994	1,406.13	153.97	1,854.61	277.07	65.00	26.00
1995	1,477.90	165.33	1,912.22	286.19	71.40	28.56
1996	1,544.44	175.96	1,973.34	296.02	61.00	24.40
1997	1,639.62	191.67	1,983.06	298.17	110.00	44.00
1998	1,799.82	216.65	1,974.55	297.56	110.00	44.00
1999	2,005.12	248.57	1,921.72	290.39	110.00	44.00
2000	2,160.65	273.10	1,909.25	289.19	110.00	44.00
2001	2,410.07	311.36	1,821.48	276.48	110.00	44.00
2002	2,523.77	329.69	1,843.79	280.51	110.00	44.00
2003	2,710.19	359.21	1,799.45	274.39	59.49	23.80
2004	2,920.14	393.34	1,672.19	255.72	56.00	22.40
2005	3,027.76	412.53	1,729.82	265.18	56.00	22.40
2006	3,235.02	444.01	1,665.05	255.84	56.00	22.40

Biogas flaring

According to data from the Ministry for Environment, 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	2001	2002	2003	2004	2005	2006
Waste landfilled in the SWDS of Patra. Thessalonica and Larissa (kt)	241	247	261	274	288	366	383	402	422	497	520	539	564	590	618	638	727
Biogas flared in the SWDS of Athens (10^6 m^3)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.60	21.90	21.90	21.00	30.00	30.00	42.05	48.20	54.90
Total CH_4 recovery (kt)	7.35	7.67	8.31	8.93	9.72	12.60	13.43	14.47	16.93	26.80	28.08	28.94	33.40	34.81	40.65	47.20	53.80

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 (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

No recalculations were performed.

8.2.3 Planned improvements

The collection of data concerning the quantities of MSW disposed – at least in managed SWDS – as well as the consideration of data from potential systematic measurements of the composition of disposed wastes and the emitted biogas in these sites (particularly in managed sites) carried out by the responsible governmental agencies, local authorities etc., will provide the possibility to reduce the uncertainty of the emissions estimate. The development of a central database which will include most of the above data has already been scheduled by the Ministry for Environment 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 2005 accounted for 0.4% of total GHG emissions and for 15.6% 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 2006 account for 0.39% of total greenhouse gases emissions and 14.67% 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 8.13*** CH_4 and N_2O emissions from wastewater handling for the period 1990 – 2006 are presented.

Table 8.13 CH_4 and N_2O emissions (in kt) from wastewater handling

Year	Gas	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Domestic and commercial wastewater	CH_4	103.74	101.53	97.34	96.03	94.15	92.19	88.15	84.31	79.67	61.94	35.56	30.41	25.17	19.25	19.31	19.31
Industrial wastewater	CH_4	4.29	4.75	5.38	5.52	4.87	5.07	4.55	5.63	4.52	5.80	6.16	5.59	4.96	5.41	5.41	5.41
Human sewage	N_2O	1.07	1.09	1.09	1.13	1.14	1.14	1.16	1.16	1.19	1.19	1.18	1.18	1.18	1.19	1.19	1.20

CH_4 emissions from industrial wastewater and indirect N_2O emissions increased in 2006 by 5.65% and 14.35% respectively compared to 1990. On the contrary, CH_4 emissions from domestic wastewater handling in 2006 decreased by 81.66% compared to 1990 levels, with an average annual rate of decrease estimated at 5.1%. 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 Environment the penetration of such facilities increased from 32% (of total population served) in 1999 and to 84% in 2006.

Considering the fact that there are not sufficient data regarding all the wastewater handling facilities of the country and as a result methane emissions are calculated based on the total population served, emissions from 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 8.14*** the degradable organic waste (as kt BOD) for the period 1990 – 2006, is presented.

The calculation of BOD from sludge removed and disposed on land (Table 8.14) 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 Environment on the implementation of EU Directive 91/71 regarding the collection, treatment and disposal of municipal wastewater.

Table 8.14 ***BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2006***

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	194.20	4.46	198.66
1998	195.39	4.46	199.85
1999	196.42	4.46	200.88
2000	197.11	4.46	201.57
2001	197.55	4.46	202.01
2002	198.08	4.46	202.54
2003	200.71	2.41	203.12
2004	201.45	2.27	203.72
2005	202.41	2.27	204.68
2006	202.41	2.27	204.68

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 – 2005. Data on industrial production for 2005 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 (m^3 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/m^3 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 (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 8.15*** the degradable organic waste (as COD) for the period 1990 – 2006, is presented.

Table 8.15 Total COD (in kt) from industrial wastewater for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
COD (kt)	20.48	17.17	19.01	21.52	22.10	19.48	20.30	18.19	22.52	18.09	23.22	24.64	22.36	19.85	21.66	21.66	21.66

Indirect N_2O 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:

$$N_2O \text{ emissions} = \text{Protein} * P * Frac_{NPR} * EF\ (N_2O\text{-}N/N)$$

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* (N_2O-N/N)] are those suggested by the IPCC Guidelines.

In ***Table 8.16*** the consumption of protein (kg/person/year) for the period 1990 – 2006, is presented.

Table 8.16 Annual protein consumption (in kg/person) for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	42.30	42.23	42.23	42.23	42.23	42.23

8.3.2 Recalculations

No recalculations were performed.

8.3.3 Planned improvements

The availability of data concerning biogas emitted in the wastewater handling systems and management practices is examined.

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 8.17***, the amount of clinical waste incinerated and CO2 emissions released for the period 1990 – 2006 are presented.

Table 8.17 Clinical waste (in kt) and CO_2 emissions (in kt) for the period 1990 - 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Clinical waste	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.49	0.94	1.17	1.20	1.20
Emissions	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.41	0.79	0.98	1.00	1.03

CO_2 emissions from the incineration of clinical waste are estimated for the first time in the present inventory.

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 the various review process (mainly the in-country review of the initial report of Greece from 23 to 28 of April 2007), while prioritisation is based on the key source analysis and the availability of resources.

The reasons for recalculations made, can be classified as follows:

7. ***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
8. ***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.
9. ***Allocation***. Changes in allocation of emissions to different sectors or sources/sub-sources.
10. ***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	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
1.AA.1.B	Petroleum Refining	CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
1.AA.1.C	Manufacture of Solid Fuels and Other Energy Industries	CO_2 / CH_4 / N_2O	M	Updated activity data.
1.AA.2.A	Iron and Steel	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
1.AA.2.B	Non-Ferrous Metals	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
1.AA.2.C	Chemicals	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
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 and IPCC default EFs. Updated activity Data.
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 and IPCC default EFs. Updated activity Data.
1.AA.2.F	Manufacturing Industries and Construction. Other \ Other non-specified \ Liquid Fuels	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with EFs calculated based on plant specific data and IPCC default EFs. Updated activity Data.
1.AA.3.B	Road Transportation	CO_2	E	Corrected activity data.
1.AA.3.D	Navigation	CO_2	M	IPCC default EmF used.
1.AA.3.E	Other Transportation	CO_2 / CH_4 / N_2O	M	Updated activity data.
1.AA.4.A	Commercial/Institutional	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs. Updated activity Data.
1.AA.4.B	Residential	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs. Updated activity Data.
1.AA.4.C	Agriculture/Forestry/Fisheries	CO_2 / CH_4 / N_2O	M	Tier 2 methodology used with IPCC default EFs.
2	Industrial Processes	CO_2 / HFCs / HFC-32 / HFC-125 / HFC-134a	M	Updated activity data.
2.A	Mineral Products	CO_2	M	Updated activity data.
2.A.1	Cement Production	CO_2	M	Tier 3 Method: Use of carbonate(s) input data Use of plant specific data on the use of carbonates to produce clinker.
2.A.2	Lime Production	CO_2	M	Tier 3 Method: Use of carbonate(s) input data Use of plant specific data on the use of carbonates to produce lime.
2.A.7.1	Glass Production	CO_2	M	Tier 3 Method: Emissions based on carbonates input Use of plant specific data on various types of carbonates consumed for glass production.
2.C	Metal Production	CO_2	M	Updated activity data.

2.C.1.1	Steel	CO_2	M	Tier 3 Method Use of plant specific data.
2.C.2	Ferroalloys Production	CO_2	M	Use of plant specific data.
2.F	Consumption of Halocarbons and SF6	HFCs / HFC-32 / HFC-125 / HFC-134a	M	Updated activity data. Correction of errors.
2.IIA.F.1.2	Commercial Refrigeration	HFC-134a	E	Correction of errors
2.IIA.F.1.5	Stationary Air-Conditioning	HFC-125 / HFC-134a / HFC-32	E	Updated activity data.
2.IIA.F.1.6	Mobile Air-Conditioning	HFC-134a	M	Updated activity data.

Table 9.1 Overview of recalculations

4.A	Enteric Fermentation	CH_4	M	Updated activity data.
4.B	Manure Management	CH_4	M	Updated activity data.
4.D	Agricultural Soils	N_2O	M	Updated activity data.
4.D.1.2	Animal Manure Applied to Soils	N_2O	M	Updated activity data.
4.D.2	Pasture, Range and Paddock Manure	N_2O	M	Updated activity data.
4.D.3.1	Atmospheric Deposition	N_2O	M	Updated activity data.
4.D.3.2	Nitrogen Leaching and Run-off	N_2O	M	Updated activity data.
5.A.1	Forest Land remaining Forest Land	CO_2 / CH_4 / N_2O	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.

E: Correction of errors, M: Change or refinement of methodology

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	2001	2002	2003	2004	2005
Energy	**-1821.03**	**-886.65**	**-528.93**	**-878.33**	**-660.86**	**-369.84**	**-307.59**	**-208.53**	**-151.74**	**84.86**	**-279.12**	**-184.66**	**-218.01**	**-8.90**	**-76.10**	**-784.23**
Fuel Combustion Activities	-1821.03	-886.65	-528.93	-878.33	-660.86	-369.84	-307.59	-208.53	-151.74	84.86	-279.12	-184.66	-218.01	-8.90	-76.10	-784.23
Energy Industries	-754.17	-2.03	372.92	34.51	28.75	65.99	109.39	49.02	-26.98	-35.25	-44.54	-49.57	-47.94	-22.30	-56.37	-527.81
Manufacturing Industries and Construction	-86.83															-153.14
Transport	-980.04	-884.63	-901.85	-912.85	-689.61	-435.83	-416.98	-257.55	-124.76	120.10	-234.58	-135.10	-170.07	13.39	-19.73	-60.07
Industrial processes																**-384.39**
Mineral products																-87.72
Metal production																-296.67
Land Use, Land-Use Change and Forestry																196.48
Forest Land																-62.56
Cropland																259.05
TOTAL	**-1821.03**	**-886.65**	**-528.93**	**-878.33**	**-660.86**	**-369.84**	**-307.59**	**-208.53**	**-151.74**	**84.86**	**-279.12**	**-184.66**	**-218.01**	**-8.90**	**-76.10**	**-972.13**

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	2001	2002	2003	2004	2005
Energy	**-134.87**	**-120.62**	**-103.60**	**-112.33**	**-121.04**	**-122.61**	**-122.02**	**-126.90**	**-129.43**	**-117.79**	**-107.00**	**-116.12**	**-136.12**	**59.72**	**69.01**	**-135.03**
Fuel Combustion Activities	-134.87	-120.62	-103.60	-112.33	-121.04	-122.61	-122.02	-126.90	-129.43	-117.79	-107.00	-116.12	-136.12	59.72	69.01	-135.03
Energy Industries																7.46
Manufacturing Industries and Construction																-0.04
Transport	-0.15	0.15	0.16	0.18	0.19	0.20	0.21	0.24	0.25	0.30	0.33	0.30	0.26	0.29	0.00	0.00
Other Sectors	-134.72	-120.77	-103.76	-112.51	-121.23	-122.81	-122.24	-127.15	-129.68	-118.09	-107.33	-116.42	-136.38	59.43	69.01	-142.44
Agriculture																**-94.43**
Enteric Fermentation																-57.40
Manure Management																-37.03
Land Use, Land-Use Change and Forestry																**4.38**
Forest Land																6.16
Grassland																-1.79
TOTAL	**-134.87**	**-120.62**	**-103.60**	**-112.33**	**-121.04**	**-122.61**	**-122.02**	**-126.90**	**-129.43**	**-117.79**	**-107.00**	**-116.12**	**-136.12**	**59.72**	**69.01**	**-225.08**

Table 9.4 Recalculation of N_2O emissions (differences compared to previous submission, in kt CO_2 eq)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Energy	**-2110.29**	**-1972.52**	**-2189.20**	**-2045.77**	**-2108.06**	**-2085.09**	**-2103.13**	**-2193.50**	**-2237.89**	**-2176.07**	**-2317.06**	**-2346.10**	**-2304.80**	**-2347.46**	**-2364.31**	**-2991.95**
Fuel Combustion Activities	-2110.29	-1972.52	-2189.20	-2045.77	-2108.06	-2085.09	-2103.13	-2193.50	-2237.89	-2176.07	-2317.06	-2346.10	-2304.80	-2347.46	-2364.31	-2991.95
Energy Industries	-1672.95	-1602.60	-1834.33	-1703.15	-1766.88	-1733.30	-1725.09	-1820.72	-1870.96	-1868.11	-1980.55	-2004.13	-1969.92	-2024.49	-2059.80	-2114.51
Manufacturing Industries and Construction	-360.46	-293.87	-285.74	-269.74	-266.86	-279.12	-305.61	-300.03	-294.08	-242.48	-272.07	-274.99	-258.92	-248.20	-232.93	-225.40
Transport	-8.52	-7.68	-7.83	-7.94	-5.76	-3.46	-3.47	-1.73	-0.79	1.77	-1.66	-0.43	-1.11	0.79	0.00	0.00
Other Sectors	-68.36	-68.37	-61.30	-64.93	-68.55	-69.21	-68.97	-71.01	-72.06	-67.25	-62.78	-66.56	-74.84	-75.56	-71.58	-652.03
Agriculture																**310.12**
Agricultural Soils																310.12
Land Use, Land-Use Change and Forestry																**-0.61**
Forest Land																-0.43
Grassland																-0.18
TOTAL	**-2110.29**	**-1972.52**	**-2189.20**	**-2045.77**	**-2108.06**	**-2085.09**	**-2103.13**	**-2193.50**	**-2237.89**	**-2176.07**	**-2317.06**	**-2346.10**	**-2304.80**	**-2347.46**	**-2364.31**	**-2682.44**

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	2001	2002	2003	2004	2005
HFC	0.00	0.00	0.00	0.00	0.00	-2.37	-4.31	-6.12	-7.20	-8.57	-13.85	-18.21	-17.53	-22.90	-23.40	-22.51
PFC	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
SF_6	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
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-2.37**	**-4.31**	**-6.12**	**-7.20**	**-8.57**	**-13.85**	**-18.21**	**-17.53**	**-22.90**	**-23.40**	**-22.51**

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. CO_2, CH_4, N_2O and F gases emissions estimated in the current inventory are lower compared to those estimated in the previous one.

Table 9.6 Comparison of the 2005 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	2001	2002	2003	2004	2005
CO_2 emissions																
2007 submission	80.97	80.18	82.09	81.46	83.69	82.96	85.57	90.34	95.32	93.68	100.78	100.85	100.40	104.34	104.84	106.23
2008 submission	79.15	79.29	81.56	80.58	83.03	82.59	85.26	90.14	95.16	93.77	100.50	100.66	100.18	104.34	104.77	105.26
Change (%)	-2.25	-1.11	-0.64	-1.08	-0.79	-0.45	-0.36	-0.23	-0.16	0.09	-0.28	-0.18	-0.22	-0.01	-0.07	-0.92
CH_4 emissions																
2007 submission	9.17	9.12	9.20	9.16	9.25	9.22	9.36	9.34	9.47	9.14	9.12	8.58	8.56	8.28	8.23	8.50
2008 submission	9.03	9.00	9.09	9.05	9.13	9.10	9.23	9.22	9.34	9.02	9.01	8.47	8.42	8.34	8.29	8.27
Change (%)	-1.47	-1.32	-1.13	-1.23	-1.31	-1.33	-1.30	-1.36	-1.37	-1.29	-1.17	-1.35	-1.59	0.72	0.84	-2.65
N_2O emissions																
2007 submission	14.12	13.82	13.89	13.08	13.36	13.08	13.55	13.33	13.21	13.20	13.43	13.22	13.17	13.25	13.16	13.10
2008 submission	12.01	11.85	11.70	11.03	11.25	10.99	11.45	11.14	10.97	11.03	11.11	10.87	10.86	10.90	10.79	10.41
Change (%)	-14.95	-14.27	-15.76	-15.64	-15.78	-15.95	-15.52	-16.45	-16.95	-16.48	-17.26	-17.75	-17.50	-17.71	-17.97	-20.48
F-gases emissions																
2007 submission	1.20	1.37	1.16	1.76	2.24	3.50	4.18	4.69	5.32	6.22	5.36	5.17	5.39	5.64	5.79	5.99
2008 submission	1.20	1.37	1.16	1.76	2.24	3.42	4.00	4.42	4.95	5.70	4.64	4.25	4.46	4.37	4.45	4.66
Change (%)	0.00	0.00	0.00	0.00	0.00	-2.32	-4.23	-5.90	-6.92	-8.38	-13.45	-17.87	-17.23	-22.57	-23.09	-22.23
Total emissions																
2007 submission	108.67	108.08	109.35	109.29	112.04	113.15	116.65	121.64	126.78	126.69	131.66	133.14	132.99	137.07	137.43	139.24
2008 submission	104.60	105.10	106.53	106.25	109.15	110.49	113.94	118.83	123.89	123.96	128.23	129.57	129.41	133.50	133.73	133.83
Change (%)	-3.74	-2.76	-2.58	-2.78	-2.58	-2.35	-2.32	-2.31	-2.28	-2.16	-2.60	-2.68	-2.70	-2.60	-2.70	-3.89

9.3 Implications for emissions trends

Total GHG emissions (without LULUCF) in the current submission are lower compared to emissions reported in the 2007 submission. Taking into consideration that in most cases the recalculations concerned the whole period (see Tables 9.2 – 9.5), emissions trends have not been affected significantly (***Figure 9.1***).

Thus, the average annual rate of emissions increase for the period 1990 – 2005 in the present inventory is calculated to be almost unaffected compared to the one that had been calculated in the previous inventory (1.68% and 1. 67% respectively). However, the annual rate of emissions increase for the period 2004 – 2005 has decreased from 1.3% to 0.1%, due to the use of verified reports from installations in the context of EU ETS, as well as to the availability of updated data for the *Agriculture* sector.

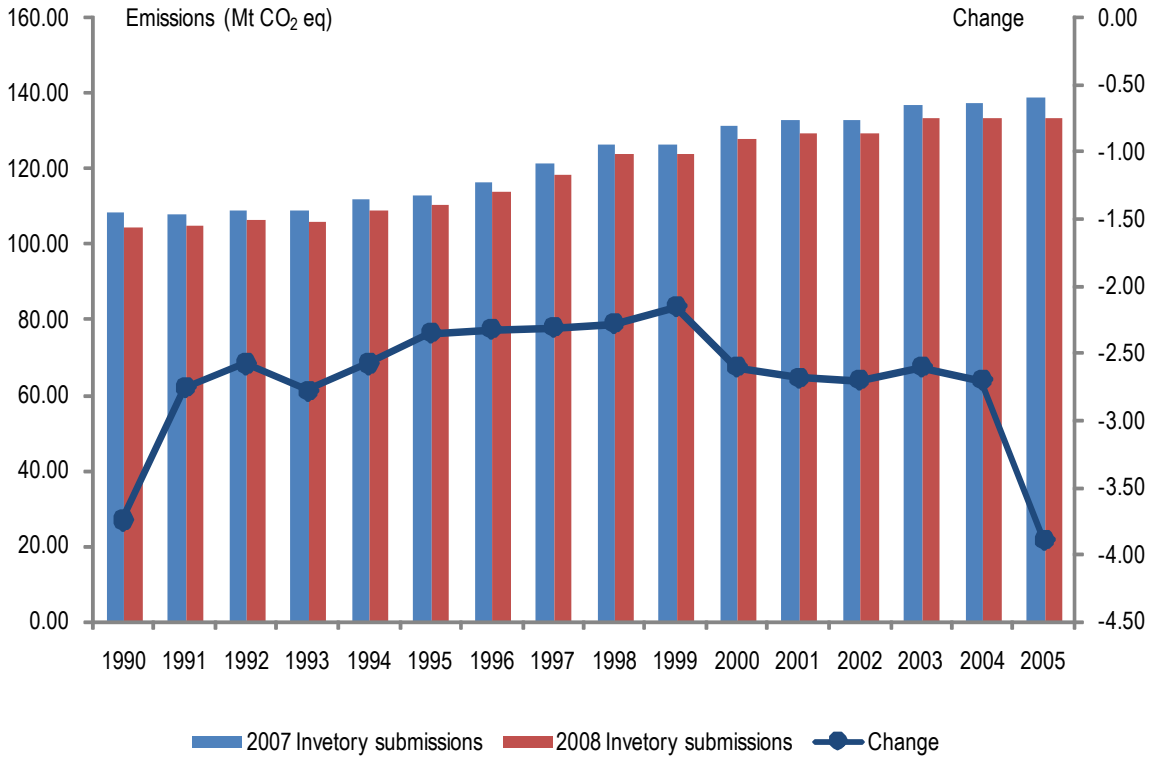


Figure 9.1 ***GHG emissions trends in Greece for the period 1990 – 2005 (without LULUCF) according to the inventory submitted in 2008***

9.4 Planned improvements

Table 9.7 summarises the actions that either have been implemented recently or are in process for implementation concerning the improvement of the National Inventory System.

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 (e.g. enteric fermentation for cattle).

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.

Table 9.7 Improvements of National GHG Inventory System

Action	Expecting Gain
New organizational structure of the inventory system. Decentralization of inventory system structure. Active participation of Ministry for the Environment.	➢ Establishment of institutional, legal and procedural arrangements necessary for the functions of national system. ➢ Ensuring of the continuity of the inventory preparation process and knowledge transfer.
Establishment of Climate Team within Ministry for the Environment.	➢ Ensuring of technical competence of the staff involved and capacity of the system for timely performance. ➢ Ensuring capacity of the system for timely performance.
Redefinition of official consideration and approval of the inventory.	➢ Establishment of institutional, legal and procedural arrangements necessary for the functions of national system.
Establishment of a formal co-operation with data providing agencies. Specific contact person appointment.	➢ Establishment of institutional, legal and procedural arrangements necessary for the functions of national system. ➢ Ensuring effective co-operation between involved entities in the inventory. ➢ Ensuring capacity of the system for timely performance.
Use activity data from verified emission reports of the installations covered by the emissions trading Directive.	➢ Improvement of consistency, comparability and accuracy of inventory.
Training of data providing agencies' representatives	➢ Effective co-operation between involved entities in the inventory.
Review of the system by independent experts.	➢ Improvement of transparency, consistency, comparability and accuracy of 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.

11. The use of source category-specific good practice methods is preferable, unless resources are unavailable.
12. 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*** and ***I.2***), 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.

The methodology for the determination of key categories with *LULUCF* is in fact the same as for the one for key sources (***Tables I.1 and I.3***). The key categories for the Greek inventory are presented in ***Table I.4***.

Table I.1 Key categories analysis without LULUCF (column G) and with LULUCF (column I) – Level assessment

A	B	C	D	E	F	G	H	I
IPCC key categories	Direct Greenhouse Gas	Emissions 2004 without LULUCF (Gg CO_2 eq)	LULUCF 2004 (Gg CO_2 eq)	Emissions 2004 (Gg CO_2 eq) Absolute values	Level assessment without LULUCF	Cumulative total of column F	Level assessment with LULUCF	Cumulative total of column H
Stationary combustion - Solid fuels	CO2	41889.43		41889.43	0.311	0.311	0.299	0.299
Stationary combustion - Liquid fuels	CO2	30306.60		30306.60	0.225	0.536	0.217	0.516
Mobile combustion - Road vehicles	CO2	19824.78		19824.78	0.147	0.683	0.142	0.658
Cement production	CO2	6460.86		6460.86	0.048	0.731	0.046	0.704
Stationary combustion - Gas	CO2	6117.21		6117.21	0.045	0.777	0.044	0.748
Forest Land remaining Forest Land	CO2		-3939.69	3939.69	0.000	0.777	0.028	0.776
Substitutes for ODS	F-gases	3893.80		3893.80	0.029	0.831	0.028	0.804
Animal Production	N2O	3386.98		3386.98	0.025	0.802	0.024	0.828
Enteric fermentation	CH4	2831.87		2831.87	0.021	0.852	0.020	0.848
Indirect N2O from nitrogen used in agr.	N2O	2816.32		2816.32	0.021	0.873	0.020	0.868
Solid waste disposal on land	CH4	2647.34		2647.34	0.020	0.909	0.019	0.887
Mobile combustion - Navigation	CO2	2302.36		2302.36	0.017	0.926	0.016	0.904
HCFC-22 manufacture	HFC-23	2290.39		2290.39	0.017	0.890	0.016	0.920
Agricultural soils - Direct	N2O	1699.03		1699.03	0.013	0.940	0.012	0.932
Coal mining and handling	CH4	1361.69		1361.69	0.010	0.950	0.010	0.942
Mobile combustion - Aircraft	CO2	1112.21		1112.21	0.008	0.961	0.008	0.950
Cropland remaining Cropland	CO2		-785.10	785.10		0.961	0.006	0.955
Nitric acid production	N2O	633.68		633.68	0.005	0.985	0.005	0.960
Mobile combustion - Road vehicles	N2O	541.60		541.60	0.004	0.977	0.004	0.964
Wastewater handling	CH4	519.12		519.12	0.004	0.965	0.004	0.968
Conversion to Forest Land	CO2		-492.33	492.33		0.977	0.004	0.971
Manure management	CH4	488.45		488.45	0.004	0.972	0.003	0.975
Lime production	CO2	409.00		409.00	0.003	0.968	0.003	0.977
Wastewater handling	N2O	371.68		371.68	0.003	0.980	0.003	0.980
Stationary combustion - Liquid fuels	N2O	319.29		319.29	0.002	0.953	0.002	0.982
Limestone and Dolomite use	CO2	315.19		315.19	0.002	0.987	0.002	0.985
Manure management	N2O	290.45		290.45	0.002	0.989	0.002	0.987
Aluminium production	CO2	254.06		254.06	0.002	0.991	0.002	0.989
Iron and Steel Production	CO2	222.02		222.02	0.002	0.973	0.002	0.990

A	B	C	D	E	F	G	H	I
IPCC key categories	Direct Greenhouse Gas	Emissions 2004 without LULUCF (Gg CO_2 eq)	LULUCF 2004 (Gg CO_2 eq)	Emissions 2004 (Gg CO_2 eq) Absolute values	Level assessment without LULUCF	Cumulative total of column F	Level assessment with LULUCF	Cumulative total of column H
Mobile combustion - Road vehicles	CH4	181.66		181.66	0.001	0.994	0.001	0.991
Stationary combustion - Solid fuels	N2O	163.04		163.04	0.001	0.928	0.001	0.993
Solvents	CO2	159.64		159.64	0.001	0.993	0.001	0.994
Oil and gas operations	CH4	142.06		142.06	0.001	0.995	0.001	0.995
Mobile combustion - Railways	CO2	128.78		128.78	0.001	0.996	0.001	0.996
Solid fuels - Other	CO2	101.13		101.13	0.001	0.997	0.001	0.996
Rice cultivation	CH4	93.66		93.66	0.001	0.998	0.001	0.997
Aluminium production	PFCs	70.53		70.53	0.001	0.999	0.001	0.998
Stationary combustion - Biomass	CH4	65.72		65.72	0.000	0.992	0.000	0.998
Ferroalloys	CO2	54.46		54.46	0.000	0.998	0.000	0.998
Stationary combustion - Biomass	N2O	36.26		36.26	0.000	0.995	0.000	0.999
Agricultural residues burning	CH4	27.63		27.63	0.000	0.999	0.000	0.999
Stationary combustion - Liquid fuels	CH4	26.69		26.69	0.000	0.999	0.000	0.999
Mobile combustion - Navigation	N2O	17.78		17.78	0.000	0.999	0.000	0.999
Forest Land remaining Forest Land	CH4		16.56	16.56		1.000	0.000	0.999
Mobile combustion - Railways	N2O	15.40		15.40	0.000	1.000	0.000	0.999
Other Mineral (Glass)	CO2	14.50		14.50	0.000	0.999	0.000	1.000
Mobile combustion - Aircraft	N2O	11.44		11.44	0.000	1.000	0.000	1.000
Agricultural residues burning	N2O	10.52		10.52	0.000	1.000	0.000	1.000
Oil, Natural Gas and Other sources	CO2	9.27		9.27	0.000	1.000	0.000	1.000
Stationary combustion - Solid fuels	CH4	7.56		7.56	0.000	1.000	0.000	1.000
Stationary combustion - Gas	N2O	6.47		6.47	0.000	0.999	0.000	1.000
Mobile combustion - Other transportation	CO2	4.91		4.91	0.000	1.000	0.000	1.000
Mobile combustion - Navigation	CH4	4.52		4.52	0.000	1.000	0.000	1.000
SF6 from electrical equipment	SF6	4.47		4.47		1.000	0.000	1.000
Stationary combustion - Gas	CH4	2.32		2.32	0.000	1.000	0.000	1.000
Forest Land remaining Forest Land	N2O		1.68	1.68		1.000	0.000	1.000
Mobile combustion - Railways	CH4	1.51		1.51	0.000	1.000	0.000	1.000
Waste incineration	CO2	1.00		1.00	0.000	1.000	0.000	1.000
Other Chemicals	CH4	0.74		0.74	0.000	1.000	0.000	1.000
Mobile combustion - Aircraft	CH4	0.67		0.67	0.000	1.000	0.000	1.000

A	B	C	D	E	F	G	H	I
IPCC key categories	Direct Greenhouse Gas	Emissions 2004 without LULUCF (Gg CO_2 eq)	LULUCF 2004 (Gg CO_2 eq)	Emissions 2004 (Gg CO_2 eq) Absolute values	Level assessment without LULUCF	Cumulative total of column F	Level assessment with LULUCF	Cumulative total of column H
Grassland remaining Grassland	CH4		0.18	0.18		1.000	0.000	1.000
Mobile combustion - Other transportation	N2O	0.04		0.04	0.000	1.000	0.000	1.000
Oil, Natural Gas and Other sources	N2O	0.03		0.03	0.000	1.000	0.000	1.000
Grassland remaining Grassland	N2O		0.02	0.02		1.000	0.000	1.000
Mobile combustion - Other transportation	CH4	0.00		0.00	0.000	1.000	0.000	1.000
		134669.8	-5198.7	139905.4	1.0		1.0	

Table I.2 Key categories analysis without LULUCF – Trend assessment

IPCC source categories	GHG	Base year (Gg CO_2 eq)	Current year (Gg CO_2eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
Stationary combustion - Gas	CO_2	295.94	6117.21	0.034	15.1	0.151
Mobile combustion - Road vehicles	CO_2	11759.50	19824.78	0.030	13.1	0.282
Substitutes for ODS	F-gases	164.74	3893.80	0.022	9.7	0.379
Stationary combustion - Solid fuels	CO_2	39161.10	41889.43	0.044	19.5	0.574
Wastewater handling	CH_4	2318.94	519.12	0.014	6.3	0.637
Stationary combustion - Liquid fuels	CO_2	21484.24	30306.60	0.019	8.5	0.722
Agricultural soils - Direct	N_2O	2759.79	1699.03	0.010	4.7	0.769
Indirect N2O from nitrogen used in agr.	N_2O	3605.75	2816.32	0.010	4.5	0.814
HCFC-22 manufacture	HFC-23	3253.07	2290.39	0.011	4.7	0.862
Cement production	CO_2	5778.28	6460.86	0.005	2.1	0.883
Enteric fermentation	CH_4	2865.83	2831.87	0.005	2.0	0.904
Animal Production	N_2O	3383.45	3386.98	0.005	2.3	0.927
Mobile combustion - Aircraft	CO_2	587.81	1112.21	0.002	1.0	0.936
Nitric acid production	N_2O	712.96	633.68	0.002	0.7	0.943
Mobile combustion - Road vehicles	N_2O	122.76	541.60	0.002	1.0	0.953
Iron and Steel Production	CO_2	202.83	222.02	0.000	0.1	0.954
Solid waste disposal on land	CH_4	1800.96	2647.34	0.002	1.0	0.964
Manure management	CH_4	496.76	488.45	0.001	0.4	0.968
Mobile combustion - Railways	CO_2	202.69	128.78	0.001	0.3	0.971
Coal mining and handling	CH_4	1095.27	1361.69	0.000	0.0	0.972
Mobile combustion - Navigation	CO_2	1824.81	2302.36	0.000	0.0	0.972
Solid fuels - Other	CO_2	0.00	101.13	0.001	0.3	0.974
Manure management	N_2O	301.45	290.45	0.001	0.2	0.977
Stationary combustion - Solid fuels	N_2O	110.43	163.04	0.000	0.1	0.977
Oil, Natural Gas and Other sources	CO_2	0.02	9.27	0.000	0.0	0.978
Stationary combustion - Gas	N_2O	1.26	6.47	0.000	0.0	0.978
Solvents	CO_2	154.65	159.64	0.000	0.1	0.979
Limestone and Dolomite use	CO_2	285.60	315.19	0.000	0.1	0.980
Stationary combustion - Biomass	CH_4	65.32	65.72	0.000	0.0	0.980
Wastewater handling	N_2O	325.05	371.68	0.000	0.1	0.981
Lime production	CO_2	367.25	409.00	0.000	0.1	0.983
Oil and gas operations	CH_4	88.71	142.06	0.000	0.1	0.983
Aluminium production	PFC	82.97	70.53	0.000	0.1	0.984
Aluminium production	CO_2	231.96	254.06	0.000	0.1	0.985
Stationary combustion - Biomass	N_2O	58.62	36.26	0.000	0.1	0.986
Stationary combustion - Liquid fuels	N_2O	567.19	319.29	0.002	1.0	0.997
Mobile combustion - Road vehicles	CH_4	108.19	181.66	0.000	0.1	0.998
Mobile combustion - Railways	N_2O	24.22	15.40	0.000	0.0	0.998
Stationary combustion - Solid fuels	CH_4	21.04	7.56	0.000	0.0	0.999
Ferroalloys	CO_2	47.36	54.46	0.000	0.0	0.999

IPCC source categories	GHG	Base year (Gg CO_2 eq)	Current year (Gg CO_2eq)	Trend Assessment	Contribution to trend (%)	Cumulative total
Rice cultivation	CH_4	69.10	93.66	0.000	0.0	0.999
Mobile combustion - Aircraft	N_2O	5.78	11.44	0.000	0.0	0.999
Other Mineral (Glass)	CO_2	23.07	14.50	0.000	0.0	1.000
Agricultural residues burning	CH_4	27.06	27.63	0.000	0.0	1.000
Mobile combustion - other transportation	CO_2	0.00	4.91	0.000	0.0	1.000
Stationary combustion - Liquid fuels	CH_4	17.82	26.69	0.000	0.0	1.000
Mobile combustion - Railways	CH_4	2.38	1.51	0.000	0.0	1.000
Agricultural residues burning	N_2O	10.05	10.52	0.000	0.0	1.000
Stationary combustion - Gas	CH_4	0.15	2.32	0.000	0.0	1.000
Waste incineration	CO_2	0.00	1.00	0.000	0.0	1.000
Mobile combustion - Navigation	N_2O	14.21	17.78	0.000	0.0	1.000
Mobile combustion - Navigation	CH_4	3.61	4.52	0.000	0.0	1.000
Mobile combustion - Aircraft	CH_4	0.10	0.67	0.000	0.0	1.000
Other Chemicals	CH_4	0.52	0.74	0.000	0.0	1.000
SF6 from electrical equipment	SF_6	3.59	4.47	0.000	0.0	1.000
Mobile combustion - other transportation	N_2O	0.00	0.04	0.000	0.0	1.000
Oil, Natural Gas and Other sources	N_2O	0.03	0.03	0.000	0.0	1.000
Mobile combustion - other transportation	CH_4	0.00	0.00	0.000	0.0	1.000
		106896.20	134669.8	0.2	100.0	

Table I.3 Key categories analysis with LULUCF – Trend assessment

IPCC source / sink categories	GHG	Base year (Gg CO_2 eq)	Current year (Gg CO_2eq)	Trend Assessment (Absolute)	Contribution to trend (%)	Cumulative total
Stationary combustion - Gas	CO_2	295.94	6117.21	0.036	14.2	0.142
Mobile combustion - Road vehicles	CO_2	11759.50	19824.78	0.032	12.7	0.269
Substitutes for ODS	F-gases	164.74	3893.80	0.023	9.1	0.360
Wastewater handling	CH_4	2318.94	519.12	0.015	5.9	0.419
Stationary combustion - Solid fuels	CO_2	39161.10	41889.43	0.043	17.3	0.592
Stationary combustion - Liquid fuels	CO_2	21484.24	30306.60	0.022	8.6	0.678
Agricultural soils - Direct	N_2O	2759.79	1699.03	0.011	4.3	0.721
Indirect N2O from nitrogen used in agr.	N_2O	3605.75	2816.32	0.010	4.2	0.763
HCFC-22 manufacture	HFC-23	3253.07	2290.39	0.011	4.4	0.807
Forest Land remaining Forest Land	CO_2	-2042.79	-3939.69	0.009	3.4	0.841
Cement production	CO_2	5778.28	6460.86	0.005	1.9	0.860
Enteric fermentation	CH_4	2865.83	2831.87	0.005	1.8	0.878
Animal Production	N_2O	3383.45	3386.98	0.005	2.1	0.899
Mobile combustion - Aircraft	CO_2	587.81	1112.21	0.002	0.9	0.908
Nitric acid production	N_2O	712.96	633.68	0.002	0.6	0.915
Conversion to Forest Land	CO_2	0.00	-492.33	0.003	1.2	0.927
Cropland remaining Cropland	CO_2	-1226.07	-785.10	0.005	1.8	0.945
Mobile combustion - Road vehicles	N_2O	122.76	541.60	0.002	1.0	0.955
Iron and Steel Production	CO_2	202.83	222.02	0.000	0.1	0.956
Solid waste disposal on land	CH_4	1800.96	2647.34	0.002	1.0	0.966
Coal mining and handling	CH_4	1095.27	1361.69	0.000	0.0	0.966
Manure management	CH_4	496.76	488.45	0.001	0.3	0.969
Mobile combustion - Railways	CO_2	202.69	128.78	0.001	0.3	0.972
Solid fuels - Other	CO_2	0.00	101.13	0.001	0.2	0.975
Manure management	N_2O	301.45	290.45	0.001	0.2	0.977
Mobile combustion - Navigation	CO_2	1824.81	2302.36	0.000	0.1	0.977
Oil, Natural Gas and Other sources	CO_2	0.02	9.27	0.000	0.0	0.978
Stationary combustion - Gas	N_2O	1.26	6.47	0.000	0.0	0.978
Stationary combustion - Solid fuels	N_2O	110.43	163.04	0.000	0.1	0.978
Solvents	CO_2	154.65	159.64	0.000	0.1	0.979
Forest Land remaining Forest Land	CH_4	48.08	16.56	0.000	0.1	0.980
Limestone and Dolomite use	CO_2	285.60	315.19	0.000	0.1	0.981
Stationary combustion - Biomass	CH_4	65.32	65.72	0.000	0.0	0.982
Lime production	CO_2	367.25	409.00	0.000	0.1	0.983
Stationary combustion - Liquid fuels	N_2O	567.19	319.29	0.002	1.0	0.992
Oil and gas operations	CH_4	88.71	142.06	0.000	0.1	0.993
Wastewater handling	N_2O	325.05	371.68	0.000	0.1	0.994
Aluminium production	PFC	82.97	70.53	0.000	0.1	0.995
Aluminium production	CO_2	231.96	254.06	0.000	0.1	0.996
Stationary combustion - Biomass	N_2O	58.62	36.26	0.000	0.1	0.997
Mobile combustion - Road vehicles	CH_4	108.19	181.66	0.000	0.1	0.998
Ferroalloys	CO_2	47.36	54.46	0.000	0.0	0.998
Mobile combustion - Railways	N_2O	24.22	15.40	0.000	0.0	0.998
Stationary combustion - Solid fuels	CH_4	21.04	7.56	0.000	0.0	0.999
Rice cultivation	CH_4	69.10	93.66	0.000	0.0	0.999
Mobile combustion - Aircraft	N_2O	5.78	11.44	0.000	0.0	0.999
Forest Land remaining Forest Land	N_2O	4.88	1.68	0.000	0.0	0.999
Other Mineral (Glass)	CO_2	23.07	14.50	0.000	0.0	1.000
Agricultural residues burning	CH_4	27.06	27.63	0.000	0.0	1.000
Mobile combustion - other transportation	CO_2	0.00	4.91	0.000	0.0	1.000
Stationary combustion - Liquid fuels	CH_4	17.82	26.69	0.000	0.0	1.000
Grassland remaining Grassland	CH_4	1.80	0.18	0.000	0.0	1.000

IPCC source / sink categories	GHG	Base year (Gg CO_2 eq)	Current year (Gg CO_2eq)	Trend Assessment (Absolute)	Contribution to trend (%)	Cumulative total
Mobile combustion - Railways	CH_4	2.38	1.51	0.000	0.0	1.000
Agricultural residues burning	N_2O	10.05	10.52	0.000	0.0	1.000
Stationary combustion - Gas	CH_4	0.15	2.32	0.000	0.0	1.000
Waste incineration	CO_2	0.00	1.00	0.000	0.0	1.000
Mobile combustion - Navigation	N_2O	14.21	17.78	0.000	0.0	1.000
Grassland remaining Grassland	N_2O	0.18	0.02	0.000	0.0	1.000
Mobile combustion - Aircraft	CH_4	0.10	0.67	0.000	0.0	1.000
Mobile combustion - Navigation	CH_4	3.61	4.52	0.000	0.0	1.000
Other Chemicals	CH_4	0.52	0.74	0.000	0.0	1.000
SF6 from electrical equipment	SF_6	3.59	4.47	0.000	0.0	1.000
Mobile combustion - other transportation	N_2O	0.00	0.04	0.000	0.0	1.000
Oil, Natural Gas and Other sources	N_2O	0.03	0.03	0.000	0.0	1.000
Mobile combustion - other transportation	CH_4	0.00	0.00	0.000	0.0	1.000
		103682.27	129471.1	0.3	100.0	

Table I.4 Key categories for the Greek inventory system

IPCC source / sink categories	GHG	Key category flag	Criteria	Comments
Energy				
Stationary combustion - Solid fuels	CO_2	YES	Level, Trend	
Stationary combustion - Solid fuels	N_2O	YES	Level	
Stationary combustion - Solid fuels	CH_4			
Stationary combustion - Liquid fuels	CO_2	YES	Level, Trend	
Stationary combustion - Liquid fuels	N_2O	YES	Level	
Stationary combustion - Liquid fuels	CH_4			
Stationary combustion - Gas	CO_2	YES	Level, Trend	
Stationary combustion - Gas	N_2O			
Stationary combustion - Gas	CH_4			
Stationary combustion - Biomass	CH_4			
Stationary combustion - Biomass	N_2O			
Mobile combustion - Road vehicles	CO_2	YES	Level, Trend	
Mobile combustion - Road vehicles	N_2O	YES	Trend	
Mobile combustion - Road vehicles	CH_4			
Mobile combustion - Navigation	CO_2	YES	Level	
Mobile combustion - Navigation	N_2O			
Mobile combustion - Navigation	CH_4			
Mobile combustion - Aircraft	CO_2	YES	Level, Trend	
Mobile combustion - Aircraft	N_2O			
Mobile combustion - Aircraft	CH_4			
Mobile combustion - Railways	CO_2			
Mobile combustion - Railways	N_2O			
Mobile combustion - Railways	CH_4			
Coal mining and handling	CH_4	YES	Level	
Oil and gas operations	CH_4			
Industrial processes				
Cement production	CO_2	YES	Level, Trend	
Lime production	CO_2			
Limestone use	CO_2			
Aluminium production	CO_2			
Iron and Steel Production	CO_2	YES	Trend	
Other Mineral (Glass)	CO_2			
Ammonia Production	CO_2			
Other chemicals production	CH_4			
Nitric acid production	N_2O	YES	Trend	
Aluminium production	PFC			
HCFC-22 manufacture	HFC-23	YES	Level, Trend	
Substitutes for ODS	F-gases	YES	Level, Trend	

IPCC source / sink categories	GHG	Key category flag	Criteria	Comments
Solvents				
Agriculture				
Enteric fermentation	CH_4	YES	Level, Trend	
Manure management	CH_4			
Manure management	N_2O			
Agricultural soils - Direct	N_2O	YES	Level, Trend	
Indirect N2O from nitrogen used in agriculture	N_2O	YES	Level, Trend	
Animal production	N_2O	YES	Level, Trend	
Rice cultivation	CH_4			
Agricultural residues burning	CH_4			
Agricultural residues burning	N_2O			
LULUCF				
Forest Land remaining Forest Land	CO_2	YES	Level, Trend	
Conversion to Forest Land	CH_4			
Cropland remaining Cropland	N_2O			
Forest Land remaining Forest Land	CO_2	YES	Trend	
Forest Land remaining Forest Land	CO_2	YES	Trend	
Grassland remaining Grassland	CH_4			
Grassland remaining Grassland	N_2O			
Waste				
Solid waste disposal on land	CO_2			
Solid waste disposal on land	CH_4	YES	Level, Trend	
Wastewater handling	CH_4	YES	Trend	

Annex II: CO2 emissions from Energy – Sectoral approach

The calculation of GHG emissions from the energy sector is based on the application of the CORINAIR methodology and 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 the CO_2 emission factors per sector (IPCC source category) and fuel. We also capitalize on them to estimate CH_4 and N_2O 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.8*** information from the national energy balance on lignite, natural gas, heavy fuel oil, diesel, gasoline, the other liquid fuels and other solid fuels is presented, while ***Table II.9*** presents the non energy consumption of fuels per sector.

Finally, in ***Tables II.10 – II.12*** information regarding the input data and the results of COPERT III model, which is used for the estimation of GHG emissions from road transportation

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	0301 – Industry / Combustion in boilers, gas turbines and stationary engines
Machinery	1.A.2f	
Mining	1.A.2f	
Food and tobacco	1.A.2e	
Paper, pulp	1.A.2d	
Wood and wood products	1.A.2f	
Construction	1.A.2f	
Textile and leather	1.A.2f	
Non-specified	1.A.2f	
TRANSPORT		
International civil aviation	Reference approach/Bunkers	080502 and 080504 – International airport/cruise traffic
Domestic air	1.A.3a	080501 and 080503 – Domestic airport/cruise traffic
Road	1.A.3b	07 (except 0707 and 0708) – Road transport per type of vehicle
Rail	1.A.3c	0802 – Diesel and gasoline machinery in railways

Energy balance sectors	IPCC source categories	CORINAIR activities
Internal navigation	1.A.3d	080402 – National sea traffic within EMEP area
OTHER SECTORS		
Agriculture	1.A.4c	0203 – Combustion plants in agriculture 0806 – Diesel and gasoline machinery in agriculture
Comm. and public. services	1.A.4a	0201 – Commercial and institutional plants
Residential	1.A.4b	0202 – Residential plants
Non-specified	1.A.4c	0203 – Plants in agriculture 0806 – Diesel and gasoline machinery in agriculture
NON-ENERGY USE	**Non-energy use**	

Table II.2 Energy balance of lignite (in kt) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Primary production	51896	52695	55051	54817	56672	57662	59781	58844	60884	62051	63887	66344	70468	68299	70041	69398	64521
Imports	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
Stock changes	157	-1144	-544	366	1301	-700	-1629	-197	-254	-1083	698	911	-1746	1770	827	698	-189
DOMESTIC SUPPLY	**52053**	**51551**	**54493**	**55183**	**57973**	**56962**	**58152**	**58625**	**60624**	**60947**	**64564**	**67255**	**68722**	**70069**	**70868**	**70096**	**64332**
Transfers	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
TRANSFORMATION	**50881**	**50616**	**53993**	**54501**	**57463**	**56431**	**57511**	**58098**	**60160**	**60637**	**64100**	**67005**	**68566**	**69874**	**70655**	**69840**	**63956**
Electricity plants	50531	50265	53790	54323	57249	56240	57354	57929	60027	60513	63864	66740	68221	69455	70233	55953	63690
CHP plants[9]	0	0	0	0	0	0	0	0	0	0	0	0	0	6670	9631	13476	0
BKB plants	350	351	203	178	214	191	157	169	133	124	236	265	345	419	422	411	266
FINAL CONSUMPTION	**1172**	**935**	**500**	**682**	**510**	**531**	**641**	**527**	**464**	**310**	**464**	**250**	**156**	**195**	**199**	**256**	**376**
INDUSTRY	*515*	*432*	*379*	*552*	*406*	*408*	*503*	*418*	*362*	*235*	*381*	*172*	*156*	*195*	*195*	*224*	*345*
Iron and steel	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
Non-ferrous metals	299	318	359	445	333	342	439	359	355	233	379	170	156	195	195	224	345
Non-metallic minerals	17	20	13	22	15	4	4	2	2	2	2	2	0	0	0	0	0
TRANSPORT	*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*
Agriculture	19	25	33	40	30	40	45	30	30	48	53	50	0	0	0	20	30
Commercial and public	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
Non-specified	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*

[9] Fuel consumption in CHP plants is included in electricity plants
[10] Fuel consumption in CHP plants is included in electricity plants
[13] Fuel consumption in CHP plants is added to the respective industrial sectors

Table II.3 Energy balance of natural gas in TJ (GCV) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Primary production	5783	5713	5279	3893	1992	1837	1939	1879	1687	105	1771	1683	1776	1298	1203	851	1209
Imports	0	0	0	0	0	0	321	5415	28900	50918	70696	69912	73460	83824	91013	108495	126604
Stock changes	0	0	0	0	0	0	-196	-135	-214	-29	-1102	-1130	173	-287	1098	141	-11
DOMESTIC SUPPLY	**5783**	**5713**	**5279**	**3893**	**1992**	**1837**	**2064**	**7160**	**30372**	**50994**	**71366**	**70466**	**75408**	**84835**	**93314**	**109487**	**127802**
Transfers	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
TRANSFORMATION	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1913**	**14267**	**35735**	**52324**	**51865**	**55058**	**61214**	**66404**	**74529**	**87877**
Electricity plants	0	0	0	0	0	0	0	1913	14267	35735	52324	51865	55058	61214	66404	73621	87060
CHP plants[13]	756	743	653	636	622	584	689	1027	491	545	1274	1098	1372	902	564	908	817
ENERGY SECTOR	**1737**	**1847**	**1603**	**1524**	**1756**	**1679**	**1769**	**1964**	**1460**	**138**	**2282**	**2102**	**1800**	**1595**	**1881**	**1768**	**1894**
Oil and gas extraction	1737	1847	1603	1524	1756	1679	1769	1879	1424	105	1771	1683	1776	1537	1670	1437	1501
Distribution losses	0	0	0	0	0	0	0	85	36	32	511	419	24	58	212	331	393
FINAL CONSUMPTION	**4046**	**3866**	**3677**	**2370**	**236**	**158**	**295**	**3283**	**14646**	**15180**	**16742**	**16498**	**18551**	**22010**	**25227**	**33190**	**38031**
INDUSTRY SECTOR	*4046*	*3866*	*3677*	*2370*	*236*	*158*	*295*	*3283*	*14090*	*14707*	*16178*	*15476*	*16931*	*19559*	*21471*	*19801*	*20690*
Iron and steel	0	0	0	0	0	0	0	104	1193	2072	2315	2697	2879	2476	2751	3252	3166
Chemical industry	4046	3866	3677	2370	236	158	150	1681	8563	6591	5385	2843	3732	6076	6694	8421	8036
Of which: Feedstocks	4046	3866	3677	2370	236	158	150	1681	8430	6256	5072	2479	3032	5175	5495	5959	6030
Non-ferrous metals	0	0	0	0	0	0	0	0	234	1094	1647	1495	1785	2280	2316	2946	2372
Non-metallic minerals	0	0	0	0	0	0	0	89	1095	1187	1638	2697	2927	2535	2793	3198	4316
Transport equipment	0	0	0	0	0	0	0	8	67	56	41	73	50	59	61	75	87
Food and tobacco	0	0	0	0	0	0	145	1269	1893	2721	3517	2807	2903	3350	3731	5074	5840
Paper, pulp	0	0	0	0	0	0	0	60	381	267	505	802	1036	1160	1301	1245	1557
Wood and wood products	0	0	0	0	0	0	0	0	0	0	0	0	0	1	23	35	28
Construction	0	0	0	0	0	0	0	0	0	0	0	0	82	363	0	0	0
Textile and leather	0	0	0	0	0	0	0	72	660	720	914	1276	1128	1259	1244	896	817
Non-specified	0	0	0	0	0	0	0	0	5	0	217	713	410	0	534	618	501
TRANSPORT	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*293*	*501*	*510*	*483*	*552*	*670*
Road transport	0	0	0	0	0	0	0	0	0	0	0	256	404	446	444	475	582
Pipeline transport	0	0	0	0	0	0	0	0	0	0	0	37	97	65	40	77	88
OTHER SECTOR	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*556*	*473*	*563*	*729*	*1119*	*1941*	*3272*	*6840*	*10648*
Commercial and public	0	0	0	0	0	0	0	0	365	311	360	510	761	1158	1822	3434	4168
Residential	0	0	0	0	0	0	0	0	191	163	203	219	358	783	1451	3406	6480
NON-ENERGY USE	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Table II.4 Energy balance of heavy fuel oil (in kt) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Production	5596	5374	5284	4419	5308	6061	7424	7149	6959	6326	7510	7361	7328	7543	7095	6956	6953
Imports	2233	1806	2040	1955	1342	733	151	435	411	298	174	169	36	184	171	264	389
Exports	2026	1217	1710	654	832	616	1032	696	196	280	220	255	564	649	748	604	835
International marine bunkers	2063	1846	2052	2444	2557	2641	2399	2413	2798	2452	2898	2933	2624	2757	2809	2542	2761
Stock changes	-80	-223	121	196	204	81	-72	7	-41	45	-32	25	-66	-36	159	-47	16
DOMESTIC SUPPLY	**3660**	**3894**	**3683**	**3472**	**3465**	**3618**	**4072**	**4482**	**4335**	**3937**	**4534**	**4367**	**4110**	**4285**	**3868**	**4027**	**3762**
Transfers	-733	-404	-287	-445	-453	-579	-653	-1135	-1125	-716	-1392	-1324	-1050	-1360	-955	-1006	-465
Statistical differences	-245	186	143	-14	-17	-178	139	60	-117	-89	-37	-72	-38	-68	-128	-62	-26
TRANSFORMATION	**1421**	**1559**	**1506**	**1598**	**1561**	**1697**	**1590**	**1541**	**1483**	**1585**	**1634**	**1539**	**1516**	**1513**	**1398**	**1601**	**1631**
Electricity plants	1421	1559	1506	1598	1561	1697	1590	1541	1483	1585	1634	1539	1516	1513	1398	1595	1624
CHP plants[15]	34	49	58	67	58	58	55	39	32	24	27	19	0	0	7	6	7
ENERGY SECTOR	**266**	**279**	**260**	**210**	**273**	**274**	**295**	**294**	**318**	**313**	**372**	**358**	**397**	**351**	**416**	**442**	**482**
Petroleum refineries	266	279	260	210	273	274	295	294	318	313	372	358	397	351	416	442	482
FINAL CONSUMPTION	**1485**	**1466**	**1487**	**1233**	**1195**	**1246**	**1395**	**1452**	**1526**	**1412**	**1173**	**1218**	**1185**	**1129**	**1227**	**1040**	**1184**
INDUSTRY	*1186*	*1156*	*1154*	*977*	*899*	*957*	*1122*	*1084*	*960*	*793*	*909*	*849*	*867*	*787*	*808*	*667*	*791*
Iron and steel	101	96	97	86	78	47	21	16	18	8	18	19	20	17	13	4	5
Chemical industry	92	45	43	26	24	29	106	124	159	81	87	82	82	74	110	106	123
Of which: Feedstock	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
Non-metallic minerals	159	174	188	177	165	179	178	182	94	67	89	86	86	78	132	138	157
Transport equipment	0	0	0	0	0	0	2	2	2	2	3	3	3	3	3	3	4
Machinery	0	0	0	0	0	0	13	13	13	12	15	15	15	10	7	6	7
Mining	22	21	23	21	20	50	67	52	42	42	43	43	45	3	3	3	4
Food and tobacco	241	250	255	257	240	235	249	224	236	181	208	187	203	208	166	104	125
Paper, pulp	84	81	80	71	65	59	77	85	66	66	81	66	67	64	47	42	47
Wood and wood products	0	3	2	2	2	4	3	1	2	2	2	2	2	2	2	2	3
Construction	0	27	26	22	21	50	20	17	21	18	30	36	35	30	25	28	32
Textile and leather	111	93	108	91	82	88	140	137	101	79	92	75	77	68	60	54	46
Non-specified	191	209	171	67	58	74	84	46	55	24	27	19	0	0	0	0	40
TRANSPORT	*237*	*231*	*255*	*201*	*256*	*268*	*245*	*340*	*538*	*591*	*236*	*335*	*283*	*306*	*375*	*326*	*359*
Internal navigation	237	231	255	201	256	268	245	340	538	591	236	335	283	306	375	326	359
OTHER SECTORS	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*
Commercial and public	13	24	21	15	15	10	15	15	15	15	15	18	18	19	21	47	29
Residential	13	20	19	15	10	11	13	13	13	13	13	16	17	17	23	0	0
Non-specified	36	35	38	25	15	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

[15] 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 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Production	3663	3289	3786	3259	3723	3987	4760	5144	5544	4866	5647	5452	5624	6053	5369	5653	6452
Imports	2303	2474	2042	2370	2198	2293	2788	2292	2539	2738	2013	2435	2993	3003	3672	3757	3591
Exports	556	496	509	201	267	342	493	185	284	586	576	794	891	1102	1164	1480	2311
International marine bunkers	510	514	657	718	801	966	776	771	758	706	750	612	549	497	472	384	398
Stock changes	-169	162	99	-51	-32	67	-166	-133	-468	419	108	35	-251	129	-327	-271	-204
DOMESTIC SUPPLY	**4731**	**4915**	**4761**	**4659**	**4821**	**5039**	**6113**	**6347**	**6573**	**6731**	**6442**	**6516**	**6926**	**7586**	**7078**	**7275**	**7130**
Transfers	0	0	0	-25	0	-171	-554	-667	-592	-646	-208	89	36	1	141	140	-20
Statistical differences	7	-23	-47	-150	-2	-176	-177	-158	-244	-83	-98	-61	-16	-214	133	-37	-503
TRANSFORMATION	**314**	**312**	**338**	**287**	**272**	**305**	**381**	**367**	**371**	**336**	**382**	**376**	**465**	**499**	**452**	**429**	**438**
Electricity plants	314	312	338	287	272	305	381	367	371	336	382	376	465	499	452	424	438
CHP plants	1	7	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0
ENERGY SECTOR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**33**
FINAL CONSUMPTION	**4410**	**4626**	**4470**	**4497**	**4551**	**4739**	**5355**	**5471**	**5854**	**5832**	**5950**	**6290**	**6513**	**7302**	**6634**	**7023**	**7142**
INDUSTRY SECTOR	*355*	*326*	*291*	*296*	*320*	*457*	*490*	*500*	*525*	*560*	*504*	*500*	*500*	*550*	*227*	*439*	*486*
Iron and steel	41	20	20	26	28	18	5	11	12	20	13	13	15	17	1	1	1
Chemical industry	15	12	11	11	12	8	5	3	9	10	9	9	9	9	9	10	10
Of which: Feedstock	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
Non-metallic minerals	49	30	31	31	34	48	36	40	49	53	49	48	42	48	3	4	4
Transport equipment	0	2	2	2	2	12	12	7	15	17	16	15	15	16	15	17	18
Mining	43	32	31	32	35	49	43	45	41	42	41	40	40	45	38	40	41
Food and tobacco	33	35	33	39	42	59	45	37	49	53	51	51	50	52	22	23	23
Paper, pulp	12	11	10	14	15	8	5	10	9	10	10	10	10	14	2	3	3
Wood and wood products	0	0	0	0	0	0	2	2	2	3	2	1	1	1	0	0	0
Construction	0	1	1	1	1	1	75	94	118	126	130	130	135	140	131	140	142
Textile and leather	17	16	15	20	22	18	10	3	5	8	10	10	7	8	5	5	4
Non-specified	145	142	113	95	102	198	224	235	195	195	150	150	156	177	0	194	238
TRANSPORT	*1761*	*1955*	*1952*	*1986*	*1978*	*1988*	*1985*	*2010*	*2245*	*2217*	*2193*	*2280*	*2295*	*2441*	*2406*	*2423*	*2598*
Road	1362	1549	1557	1588	1601	1660	1711	1732	1851	1888	1890	1895	1925	2100	2058	2055	2199
Rail	63	49	47	48	52	43	45	42	42	40	40	40	40	40	40	40	41
Internal navigation	336	357	348	350	325	285	229	236	352	289	263	345	330	301	308	328	358
OTHER SECTORS	*2294*	*2345*	*2227*	*2215*	*2253*	*2294*	*2880*	*2961*	*3084*	*3055*	*3253*	*3510*	*3718*	*4311*	*4001*	*4161*	*4058*
Agriculture	857	888	822	802	808	750	761	760	760	760	760	770	850	929	786	806	845
Commercial and public	145	167	155	150	160	165	200	192	195	195	203	270	278	300	285	365	371
Residential	1292	1290	1250	1263	1285	1379	1919	2009	2129	2100	2290	2470	2590	3082	2930	2990	2842
Non-specified	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*

Table II.6 Energy balance of gasoline (in kt) for the period 1990 – 2006

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Production	3379	3128	3581	3445	3543	3545	3383	3607	3671	3205	3758	3770	3802	3653	3629	4058	4327
Imports	213	162	345	242	98	217	180	45	152	477	415	116	514	749	1059	1023	1002
Exports	1097	884	1238	1077	1094	881	780	556	645	653	1011	678	809	942	1216	1261	1351
Stock changes	-45	59	-171	11	141	34	-4	-115	-69	169	-27	3	-122	53	11	2	-259
DOMESTIC SUPPLY	**2450**	**2465**	**2517**	**2621**	**2688**	**2915**	**2779**	**2981**	**3109**	**3198**	**3135**	**3211**	**3385**	**3513**	**3483**	**3822**	**3719**
Transfers	0	0	0	0	0	0	42	4	28	17	22	167	153	166	121	99	140
Statistical differences	27	-34	-65	-23	-7	141	-119	-50	-19	0	-123	-7	-5	-6	-159	3	-100
TRANSFORMATION	**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**
FINAL CONSUMPTION	**2423**	**2499**	**2582**	**2644**	**2695**	**2774**	**2940**	**3035**	**3156**	**3215**	**3280**	**3385**	**3543**	**3685**	**3763**	**3918**	**3959**
INDUSTRY	*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*
Road transport	2373	2447	2532	2594	2645	2724	2890	2985	3106	3165	3230	3336	3493	3650	3730	3888	3931
OTHER SECTORS	*50*	*52*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*49*	*50*	*35*	*33*	*30*	*28*
Agriculture	50	52	50	50	50	50	50	50	50	50	50	49	50	35	33	30	28
Non specified	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*

Table II.7 Energy balance of other liquid fuels (in PJ) for the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Production	168.29	146.23	146.88	131.06	164.28	180.46	209.15	209.78	215.34	194.73	235.84	217.17	208.18	218.83	216.21
Imports	48.60	50.88	40.04	49.45	27.18	20.06	17.71	21.37	10.18	29.60	21.97	25.09	21.99	29.46	32.56
Exports	110.28	76.46	60.31	43.51	73.01	68.82	88.24	92.45	88.63	88.22	95.58	91.73	65.44	90.79	73.34
International marine bunkers	1.57	1.45	1.65	1.77	1.49	1.53	1.41	1.37	1.04	1.57	1.53	1.57	1.97	1.73	2.05
Stock changes	9.36	-9.49	-0.40	-4.33	21.48	-1.17	-2.45	-1.83	5.04	0.50	-11.00	8.20	-3.15	0.07	-1.93
DOMESTIC SUPPLY	**114.40**	**109.71**	**124.55**	**130.90**	**138.45**	**129.00**	**134.76**	**135.50**	**140.88**	**135.04**	**149.70**	**157.16**	**159.61**	**155.84**	**171.44**
Transfers	0.00	0.08	-5.81	-4.54	-1.71	-0.94	-5.20	-2.08	-8.14	-5.13	-6.72	-17.14	-17.70	-13.76	-20.96
Statistical differences	-1.00	-0.44	3.27	4.39	9.60	-2.55	-2.23	-0.32	0.08	0.66	0.28	-1.77	0.13	-1.40	-0.13
TRANSFORMATION	**0.72**	**0.63**	**0.86**	**0.90**	**1.13**	**1.13**	**0.86**	**0.90**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP plants	4.86	4.91	5.20	4.57	3.42	2.99	2.60	3.37	3.32	3.23	3.08	3.47	3.76	7.56	6.89
Gas works	0.72	0.63	0.86	0.90	1.13	1.13	0.86	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENERGY SECTOR	**22.83**	**23.00**	**22.49**	**24.74**	**24.45**	**24.98**	**27.63**	**28.49**	**28.38**	**24.79**	**29.82**	**31.39**	**31.23**	**31.29**	**30.62**
Petroleum refineries	22.83	23.00	22.49	24.74	24.45	24.98	27.63	28.49	28.38	24.79	29.82	31.39	31.23	31.29	30.62
FINAL CONSUMPTION	**91.85**	**86.59**	**92.13**	**96.33**	**101.57**	**104.50**	**103.31**	**104.35**	**104.27**	**104.45**	**112.88**	**110.40**	**110.54**	**112.20**	**119.99**
INDUSTRY	*11.94*	*13.10*	*14.17*	*16.27*	*17.72*	*21.42*	*24.41*	*27.01*	*26.26*	*24.88*	*26.79*	*27.73*	*28.42*	*30.55*	*34.60*
Iron and steel	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.57	0.76	0.99	0.95	0.95	0.85	0.95	0.52
Chemical industry	4.48	5.25	4.82	4.92	4.39	5.91	6.54	5.50	4.16	3.79	4.92	4.32	3.17	5.02	6.91
Of which: Feedstock	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
Non-ferrous metals	0.00	0.00	0.00	0.00	0.00	0.00	0.80	1.04	1.32	1.61	1.66	1.56	1.42	1.51	1.56
Non-metallic minerals	3.16	2.98	3.63	5.30	6.14	6.67	7.51	9.93	9.05	9.31	10.38	11.78	13.90	13.95	17.67
Transport equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.09	0.09	0.05	0.05	0.05	0.05	0.05
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.71	0.90	1.04	1.09	1.04	1.18	1.28	1.09
Food and tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.95	1.18	1.42	1.47	1.61	1.51	1.61	1.42
Paper, pulp	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.66	0.85	1.04	1.04	1.04	0.95	0.95	0.47
Wood and wood products	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.09	0.09	0.09	0.09	0.05	0.05	0.00
Textile and leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00
Non-specified	4.31	4.87	5.72	6.06	7.19	8.85	7.05	7.43	7.80	5.44	5.11	5.25	5.29	5.15	4.91
TRANSPORT	*56.31*	*51.96*	*54.61*	*57.87*	*61.07*	*55.98*	*55.13*	*52.88*	*53.41*	*56.69*	*58.23*	*52.49*	*50.83*	*51.00*	*52.96*
International civil aviation	34.29	29.88	31.17	33.17	39.37	36.92	35.36	34.20	35.89	40.31	35.36	32.86	32.86	33.93	34.96
Domestic air	20.60	20.34	21.45	22.57	19.80	17.17	18.06	17.35	16.23	15.43	22.16	18.87	17.26	16.50	17.48
Road	1.42	1.75	1.99	2.13	1.89	1.89	1.70	1.32	1.28	0.95	0.71	0.76	0.71	0.57	0.52
OTHER SECTORS	*5.84*	*6.45*	*6.91*	*6.41*	*6.25*	*6.41*	*6.46*	*6.46*	*5.89*	*5.13*	*4.56*	*4.74*	*3.52*	*3.85*	*5.22*
Commercial and public.	0.00	0.85	0.90	0.90	0.95	1.42	1.70	1.66	1.66	1.28	1.14	1.18	0.80	0.95	2.27
Residential	5.84	5.60	6.01	5.51	5.31	4.99	4.76	4.80	4.23	3.85	3.42	3.56	2.72	2.90	2.95
NON-ENERGY USE	*17.76*	*15.08*	*16.44*	*15.78*	*16.52*	*20.69*	*17.31*	*18.00*	*18.72*	*17.76*	*23.30*	*25.44*	*27.77*	*26.80*	*27.20*

Table II.8 Energy balance of other solid fuels (in PJ) for the period 1990 – 2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Production	1.94	1.86	0.95	0.61	1.63	1.42	1.34	1.51	1.18	1.12	2.15	2.11	2.75	3.19	2.89
Imports	38.49	39.05	58.66	37.00	41.08	38.66	45.42	33.62	37.45	32.76	33.91	37.20	27.05	20.41	22.27
Exports	0.00	0.00	0.00	0.00	0.00	0.00	1.22	1.66	1.90	2.04	1.61	1.33	0.84	2.79	1.68
Stock changes	0.29	3.45	-6.23	3.00	-1.45	1.96	-4.19	4.24	-0.74	-2.61	-1.77	-2.34	-0.61	3.97	-0.40
DOMESTIC SUPPLY	**40.72**	**44.36**	**53.38**	**40.60**	**41.26**	**42.04**	**41.35**	**37.71**	**35.98**	**29.23**	**32.69**	**35.64**	**28.35**	**24.79**	**23.07**
Transfers	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
Statistical differences	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	0.08	0.00
TRANSFORMATION	**0.00**	**1.55**	**14.39**	**2.64**	**2.80**	**3.96**	**5.40**	**3.53**	**1.04**	**0.73**	**0.53**	**0.39**	**0.49**	**1.31**	**0.23**
Electricity plants	0.00	1.55	14.39	2.64	2.80	3.96	5.40	3.53	1.04	0.73	0.53	0.39	0.49	1.31	0.23
CHP plants	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	0.02
ENERGY SECTOR	**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**
FINAL CONSUMPTION	**40.72**	**42.81**	**38.98**	**37.96**	**38.47**	**38.09**	**35.94**	**34.18**	**34.93**	**28.49**	**32.16**	**35.25**	**27.86**	**23.40**	**22.84**
INDUSTRY SECTOR	*40.07*	*42.04*	*38.23*	*37.28*	*37.67*	*37.47*	*35.24*	*33.35*	*34.26*	*27.97*	*31.58*	*34.70*	*27.61*	*23.25*	*22.61*
Non ferrous metals	4.27	3.75	2.30	1.80	2.97	2.80	3.16	2.37	2.10	1.74	3.08	5.06	5.97	5.99	5.48
Non metallic minerals	35.18	37.77	35.37	35.02	34.20	34.31	31.65	30.39	32.08	26.20	28.46	29.52	21.55	17.17	17.01
Machinery	0.18	0.18	0.15	0.12	0.12	0.18	0.12	0.18	0.09	0.03	0.03	0.12	0.09	0.09	0.12
Food and tobacco	0.44	0.35	0.41	0.35	0.38	0.18	0.32	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TRANSPORT	*0.03*	*0.03*	*0.05*	*0.03*	*0.03*	*0.03*	*0.03*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Rail	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTHER SECTORS	*0.62*	*0.75*	*0.70*	*0.65*	*0.77*	*0.59*	*0.67*	*0.84*	*0.67*	*0.52*	*0.58*	*0.55*	*0.25*	*0.15*	*0.23*
Commercial and public	0.11	0.09	0.03	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residential	0.51	0.65	0.67	0.64	0.76	0.59	0.67	0.84	0.67	0.52	0.58	0.55	0.25	0.15	0.23
NON-ENERGY SECTOR	*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*

Table II.9 Non-energy fuel use per sector (in PJ) for the period 1990 – 2005

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INDUSTRY	**17875**	**16783**	**17109**	**15722**	**13537**	**16818**	**17691**	**17712**	**24534**	**22362**	**26841**	**25007**	**26117**	**30297**	**32668**	**35417**
Iron and steel	0	0	0	0	0	0	40	40	40	40	40	40	40	40	40	40
Chemical industries	9073	7419	7183	5233	2887	4319	4950	4811	10306	7693	10122	7927	8715	15386	15909	16522
Mining	0	0	0	0	0	0	40	40	40	40	40	40	0	40	40	5790
Wood	0	0	0	0	0	0	40	40	40	40	40	40	40	40	40	40
Constructions	8199	8962	9445	10007	10168	12017	12178	12338	13866	14227	16317	16639	17322	14790	16639	11092
Other	603	402	482	482	482	482	442	442	241	322	281	322	0	0	0	1931
TRANSPORT	**4702**	**3054**	**3095**	**3014**	**3054**	**2572**	**1969**	**2411**	**1527**	**1929**	**1728**	**2612**	**1929**	**2291**	**2492**	**2894**
Road	3939	2894	2853	2813	2773	2210	1648	1969	1005	1286	1246	2090	1407	1567	1889	2163
Rail	0	0	0	0	0	0	0	0	0	40	40	40	40	40	40	40
Navigation	764	161	241	201	281	362	322	442	522	603	442	482	482	683	563	691
OTHER SECTORS	**121**	**121**	**80**	**80**	**40**	**0**	**161**	**201**	**161**	**161**	**80**	**80**	**80**	**80**	**121**	**121**
Agriculture	0	0	0	0	0	0	40	40	40	40	40	40	40	40	80	80
Commercial and public	121	121	80	80	40	0	121	161	121	121	40	40	40	40	40	40
TOTAL	**22698**	**19958**	**20284**	**18817**	**16632**	**19390**	**19821**	**20324**	**26222**	**24452**	**28649**	**27700**	**28127**	**32668**	**35281**	**38431**

Table II.10 Number of vehicles circulating (in 1000s), per engine size or weight and technology for the period 1990 – 2006

Category	Fuel	Technology	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Passenger cars	Gasoline <1.4 l	PRE ECE	215.4	158.7	93.5	82.4	81.8	72.8	63.2	52.5	40.1	26.4	3.2	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	398.1	364.1	325.0	318.3	316.8	315.3	287.7	262.5	240.8	213.8	169.3	113.0	47.4	0.0	0.0	0.0	0.0
		ECE 15/02	114.5	103.2	90.2	88.0	87.7	87.0	74.9	70.0	61.5	52.7	41.5	27.4	10.9	0.0	0.0	0.0	0.0
		ECE 15/03	342.5	331.1	318.1	315.9	315.4	286.6	280.7	275.0	267.6	263.6	255.6	239.7	218.8	192.0	166.3	138.2	138.2
		ECE 15/04	385.7	492.8	627.6	734.8	817.6	831.2	865.6	900.0	936.5	995.8	1054.4	1027.1	1020.9	998.3	997.7	982.1	982.1
		Euro I_ 91/441/EEC	0.0	0.0	0.0	0.0	0.0	110.2	217.6	262.5	294.3	351.5	415.4	445.1	474.0	499.1	498.8	495.7	495.7
		Euro II_ 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	155.2	266.5	396.2	479.3	546.9	575.9	582.0	580.1	580.1
		Euro III_ 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	126.7	255.2	349.4	498.8	662.6	662.6
	Gasoline 1.4 - 2.0 l	PRE ECE	28.1	18.0	6.3	4.4	4.3	4.0	3.0	2.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	53.9	47.9	41.0	40.7	41.5	34.2	31.0	27.5	24.1	20.5	16.0	10.3	3.6	0.0	0.0	0.0	0.0
		ECE 15/02	14.9	12.9	10.6	10.2	10.2	10.0	9.5	7.5	7.5	5.9	5.1	3.8	2.0	0.0	0.0	0.0	0.0
		ECE 15/03	46.1	44.0	41.7	41.3	41.2	41.9	42.1	42.5	42.8	43.9	44.7	44.5	43.8	42.2	41.6	37.2	37.2
		ECE 15/04	67.5	135.2	205.5	251.7	277.4	304.3	322.8	337.5	347.8	351.5	351.5	342.4	328.1	307.2	291.0	287.9	287.9
		Euro I_ 91/441/EEC	0.0	0.0	0.0	0.0	0.0	22.0	51.5	87.5	93.6	102.5	111.8	119.8	127.6	134.4	124.7	122.8	122.8
		Euro II_ 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	53.5	114.2	198.1	222.5	255.2	268.8	291.0	289.1	289.1
		Euro III_ 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.5	145.8	288.0	469.7	562.0	562.0
	Gasoline >2.0 l	PRE ECE	5.5	4.8	4.0	3.9	3.9	2.8	2.0	1.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	10.1	9.7	9.2	9.2	9.1	7.0	5.0	3.5	2.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	2.9	2.8	2.6	2.6	2.6	2.3	2.0	1.7	1.4	1.1	0.8	0.5	0.2	0.0	0.0	0.0	0.0
		ECE 15/03	8.9	8.7	8.6	8.6	8.6	7.7	7.0	7.0	7.0	7.0	7.0	6.8	5.1	3.8	0.0	0.0	0.0
		ECE 15/04	9.9	12.1	13.7	15.4	24.8	22.0	21.1	20.0	18.7	17.6	16.0	13.7	10.9	7.7	4.2	2.3	2.3
		Euro I_ 91/441/EEC	0.0	0.0	0.0	0.0	0.0	11.0	18.7	20.0	21.4	23.4	25.6	27.4	29.2	30.7	33.3	32.7	32.7
		Euro II_ 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	16.1	23.4	32.0	41.1	43.8	46.1	45.7	45.7	45.7

		Euro III_ 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	14.6	30.7	45.7	49.6	49.6
	Diesel >2.0 l	Conventional	17.1	17.1	17.1	17.1	17.1	13.7	14.0	14.5	13.9	14.4	14.7	14.7	14.9	14.2	12.9	12.9	12.9
		Euro I_ 91/441/EEC	0.0	0.0	0.0	0.0	0.0	4.4	4.7	5.0	5.4	5.9	6.4	6.8	7.3	7.7	7.5	7.5	7.5
		Euro II_ 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.6	2.0	2.0	2.2	2.3	2.1	2.1	2.1
		Euro III_ 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	1.2	1.7	1.7	1.7
	Diesel >2.0 l	Conventional	11.4	11.4	11.4	11.4	11.4	11.0	10.5	10.0	9.4	8.8	8.0	6.8	5.5	3.8	2.1	1.5	1.5
		Euro I_ 91/441/EEC	0.0	0.0	0.0	0.0	0.0	1.1	2.3	5.0	5.4	7.3	9.6	12.0	12.8	13.4	14.5	14.3	14.3
		Euro II_ 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	5.9	8.3	11.0	13.1	15.4	17.5	17.5	17.5
		Euro III_ 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.0	5.4	6.2	7.0	7.0
	LPG	Conventional	3.0	3.0	2.9	2.8	2.7	2.2	2.4	2.2	2.1	1.9	1.9	2.0	1.9	1.9	1.9	1.9	1.9
		Euro I - 91/542/EEC	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
		Euro II - 91/542/EEC	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	0.2	0.2	0.2
		Euro III - 2000	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
Light duty trucks	Gasoline	Conventional	615.4	627.1	613.5	625.1	627.9	613.4	603.5	588.8	564.2	544.8	524.9	503.8	481.1	457.5	446.7	440.8	440.8
		Euro I-93/59EEC	0.0	0.0	0.0	0.0	6.3	32.0	52.5	80.3	87.3	94.2	100.9	107.5	106.9	106.1	108.3	105.4	105.4
		Euro II-96/69EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	33.6	47.1	47.0	53.5	59.7	67.7	67.7	67.7
		Euro III-98/59EEC Stage 2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	26.7	39.8	54.1	71.6	71.6
	Diesel	Conventional	20.7	30.9	48.7	60.3	66.9	85.1	87.9	96.7	103.2	116.6	124.9	127.8	127.1	124.9	125.6	121.2	121.2
		Euro I-93/59EEC	0.0	0.0	0.0	0.0	3.5	9.5	15.5	24.2	27.5	35.0	40.3	44.7	48.5	52.4	58.6	54.2	54.2
		Euro II-96/69EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	15.0	26.9	29.8	32.4	35.0	39.1	39.1	39.1
		Euro III-98/59EEC Stage 2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7	23.1	37.5	55.8	73.3	73.3
Heavy duty trucks	Gasoline	Conventional	3.8	4.0	4.0	4.1	4.2	4.4	4.6	4.8	5.4	5.7	6.0	6.3	6.5	6.8	7.2	6.1	6.1
	Diesel <3.5 t	Conventional	42.2	43.6	43.9	45.4	46.2	47.2	47.8	48.7	52.4	53.2	54.9	58.1	61.5	64.6	66.5	65.2	65.2

		Euro I-91/542 EEC Stage I	0.0	0.0	0.0	0.0	0.5	1.5	2.5	2.6	2.9	3.0	3.2	3.4	3.7	4.0	4.2	4.0	4.0
		Euro II-91/542 EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.3	3.6	5.1	6.8	7.4	8.0	8.4	9.7	9.7
		Euro III-1999/96 EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.2	5.0	7.8	7.8
		Euro IV-COM (1998)776	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
	Diesel 7 - 16t	Conventional	34.5	35.7	35.9	37.2	37.8	38.6	39.1	39.8	44.0	44.7	45.1	45.2	45.1	44.9	45.9	45.0	45.0
		Euro I-91/542 EEC Stage I		0.0	0.0	0.0	0.4	1.2	2.1	2.1	2.4	2.5	2.6	2.7	2.7	2.8	2.9	2.8	2.8
		Euro II-91/542 EEC Stage II		0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.9	3.0	4.1	5.3	5.4	5.5	5.8	6.8	6.8
		Euro III-1999/96 EC		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.2	3.5	5.7	5.7
	Diesel 16 - 32t	Conventional	39.1	40.4	40.7	42.1	42.9	43.7	44.3	45.1	46.7	47.4	47.8	48.0	47.9	47.6	48.7	47.7	47.7
		Euro I-91/542 EEC Stage I	0.0	0.0	0.0	0.0	0.4	1.4	2.3	2.4	2.6	2.7	2.7	2.8	2.9	2.9	3.1	2.9	2.9
		Euro II-91/542 EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.1	3.2	4.4	5.6	5.8	5.9	6.2	7.2	7.2
		Euro III-1999/96 EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	2.4	3.7	5.3	5.3
	Diesel > 32t	Conventional	10.7	11.1	11.2	11.6	11.8	12.0	12.2	12.4	13.9	14.1	14.3	14.3	14.3	14.2	14.5	13.8	13.8
		Euro I-91/542 EEC Stage I	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9
		Euro II-91/542 EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	1.0	1.3	1.7	1.7	1.8	1.8	2.0	2.0
		Euro III-1999/96 EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.1	1.5	1.5
Busses	Urban	Conventional	4.3	4.3	4.2	4.3	4.5	5.0	5.1	5.0	5.2	5.3	5.3	5.3	5.1	5.1	5.1	4.8	4.8
		Euro III - 2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.5	0.5
	Coaches	Conventional	12.2	12.7	13.5	13.9	14.3	14.7	15.0	15.6	15.6	15.5	15.5	15.5	15.5	15.5	15.5	12.5	12.5
		Euro III - 2000	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	3.0	3.0
Mopeds		Conventional	986.0	1079.1	1208.5	1271.6	1335.8	1396.8	1452.0	1507.1	1568.4	1620.9	1561.2	1607.9	1540.9	1616.6	1558.1	1470.0	1470.0
Motorcycles	50 - 250	Conventional	136.0	156.7	179.9	205.6	235.9	275.9	315.9	365.4	376.4	387.3	391.5	395.0	395.9	396.1	396.1	388.0	388.0
		97/24EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2	67.6	108.6	151.1	186.8	224.7	275.6	300.0	300.0

	250 - 750	Conventional	74.4	85.7	98.4	112.5	115.8	118.9	119.1	119.9	123.5	127.1	128.5	129.6	129.9	130.0	130.0	120.0	120.0
		97/24EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	22.2	35.6	49.6	61.3	73.7	90.4	105.0	105.0
	> 750	Conventional	48.8	56.2	64.5	73.7	77.2	80.9	82.9	85.6	88.2	90.8	91.8	92.6	92.8	92.8	92.8	90.8	90.8
		97/24EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	15.8	25.4	35.4	43.8	52.7	64.6	73.0	73.0

Table II.11 Emission factors per category of vehicles

			Emission factors in urban roads. rural and highways														
		Technology	COu	COr	COh	NOxu	NOxr	NOxh	N2Ou	N2Or	N2Oh	CH4u	CH4r	CH4h	VOCu	VOCr	VOCh
Passenger vehicles	Gasoline <1,4 l	PRE ECE	43.96	21.30	16.50	1.55	2.02	2.06	0.005	0.005	0.005	0.171	0.043	0.020	3.943	1.777	1.342
		ECE 15/00-01	33.40	14.38	16.60	1.55	2.02	2.06	0.005	0.005	0.005	0.171	0.043	0.020	3.144	1.319	1.160
		ECE 15/02	28.70	9.22	7.72	1.47	1.90	2.60	0.005	0.005	0.005	0.171	0.043	0.020	3.146	1.134	0.969
		ECE 15/03	27.03	10.69	7.26	1.55	2.01	2.89	0.005	0.005	0.005	0.171	0.043	0.020	3.146	1.134	0.969
		ECE 15/04	17.89	6.28	4.28	1.52	1.94	2.45	0.005	0.005	0.005	0.171	0.043	0.020	2.480	1.118	0.728
		Euro I - 91/441/EEC	5.19	0.56	1.86	0.40	0.32	0.49	0.053	0.016	0.035	0.067	0.022	0.017	0.397	0.109	0.079
		Euro II - 94/12/EC	3.53	0.38	1.27	0.14	0.12	0.18	0.053	0.016	0.035	0.014	0.005	0.004	0.083	0.023	0.017
		Euro III - 98/69/EC Stage2000	2.91	0.32	1.04	0.10	0.08	0.12	0.053	0.016	0.035	0.010	0.003	0.003	0.060	0.016	0.012
	Gasoline 1,4 - 2 l	PRE ECE	43.96	21.30	16.50	1.76	2.52	2.99	0.005	0.005	0.005	0.171	0.043	0.020	3.943	1.777	1.342
		ECE 15/00-01	33.40	14.38	16.60	1.76	2.52	2.99	0.005	0.005	0.005	0.171	0.043	0.020	3.144	1.319	1.160
		ECE 15/02	28.70	9.22	7.72	1.66	2.15	2.94	0.005	0.005	0.005	0.171	0.043	0.020	3.146	1.134	0.969
		ECE 15/03	27.03	10.69	7.26	1.56	2.34	3.14	0.005	0.005	0.005	0.171	0.043	0.020	3.146	1.134	0.969
		ECE 15/04	17.89	6.28	4.28	1.76	2.53	3.25	0.005	0.005	0.005	0.171	0.043	0.020	2.480	1.118	0.728
		Euro I - 91/441/EEC	5.59	1.14	1.57	0.40	0.32	0.45	0.053	0.016	0.035	0.067	0.022	0.014	0.299	0.104	0.072
		Euro II - 94/12/EC	3.80	0.77	1.07	0.14	0.12	0.16	0.053	0.016	0.035	0.014	0.005	0.003	0.063	0.022	0.015
		Euro III - 98/69/EC Stage2000	3.13	0.64	0.88	0.09	0.08	0.11	0.053	0.016	0.035	0.009	0.003	0.002	0.042	0.015	0.010
	Gasoline > 2 l	PRE ECE	43.96	21.30	15.52	2.11	3.66	5.50	0.005	0.005	0.005	0.171	0.043	0.026	3.943	1.777	1.247
		ECE 15/00-01	33.40	14.38	18.62	2.11	3.66	5.50	0.005	0.005	0.005	0.171	0.043	0.026	3.144	1.319	1.121
		ECE 15/02	28.70	9.22	8.26	1.88	2.43	3.68	0.005	0.005	0.005	0.171	0.043	0.026	3.146	1.134	0.950
		ECE 15/03	27.03	10.69	7.62	2.68	3.17	4.60	0.005	0.005	0.005	0.171	0.043	0.026	3.146	1.134	0.950
		ECE 15/04	17.89	6.28	4.29	2.26	2.54	3.69	0.005	0.005	0.005	0.171	0.043	0.026	2.480	1.118	0.698
		Euro I - 91/441/EEC	7.85	1.47	0.98	0.52	0.40	0.52	0.053	0.016	0.035	0.066	0.023	0.010	0.383	0.194	0.116
		Euro II - 94/12/EC	5.34	1.00	0.66	0.19	0.14	0.19	0.053	0.016	0.035	0.016	0.005	0.002	0.092	0.046	0.028
		Euro III - 98/69/EC Stage2000	4.40	0.82	0.55	0.13	0.10	0.13	0.053	0.016	0.035	0.011	0.004	0.002	0.061	0.031	0.018
	Diesel <2,0 l	Conventional	1.00	0.52	0.41	0.69	0.44	0.48	0.027	0.027	0.027	0.005	0.004	0.007	0.292	0.099	0.068
		Euro I - 91/441/EEC	0.88	0.17	0.10	1.00	0.52	0.54	0.027	0.027	0.027	0.005	0.004	0.007	0.131	0.043	0.026

			Emission factors in urban roads. rural and highways														
		Technology	COu	COr	COh	NOxu	NOxr	NOxh	N2Ou	N2Or	N2Oh	CH4u	CH4r	CH4h	VOCu	VOCr	VOCh
		Euro II - 94/12/EC	0.88	0.17	0.10	1.00	0.52	0.54	0.027	0.027	0.027	0.005	0.004	0.007	0.131	0.043	0.026
		Euro III - 98/69/EC Stage2000	0.88	0.17	0.10	0.77	0.40	0.42	0.027	0.027	0.027	0.004	0.004	0.006	0.112	0.036	0.022
	Diesel >2,0 l	Conventional	1.00	0.52	0.38	1.04	0.73	0.86	0.027	0.027	0.027	0.005	0.004	0.009	0.292	0.099	0.062
		Euro I - 91/441/EEC	0.88	0.17	0.10	1.00	0.52	0.54	0.027	0.027	0.027	0.005	0.004	0.007	0.131	0.043	0.026
		Euro II - 94/12/EC	0.88	0.17	0.10	1.00	0.52	0.54	0.027	0.027	0.027	0.005	0.004	0.007	0.131	0.043	0.026
		Euro III - 98/69/EC Stage2000	0.88	0.17	0.10	0.77	0.40	0.42	0.027	0.027	0.027	0.004	0.004	0.006	0.112	0.036	0.022
	LPG	Conventional	5.99	1.48	6.49	1.78	2.47	2.78	0.015	0.015	0.015	0.080	0.035	0.025	2.060	0.762	0.536
Light duty trucks <3.5 t	Gasoline	Conventional	33.02	6.74	11.02	2.29	3.03	3.57	0.006	0.006	0.006	0.150	0.040	0.025	3.495	0.891	0.427
		Euro I - 93/59/EEC	10.55	1.16	2.16	0.52	0.40	0.47	0.053	0.016	0.035	0.067	0.022	0.017	0.368	0.126	0.071
		Euro II - 96/69/EC	6.44	0.71	1.32	0.18	0.14	0.16	0.053	0.016	0.035	0.016	0.005	0.004	0.088	0.030	0.017
		Euro III - 98/69/EC Stage2000	5.49	0.60	1.12	0.11	0.08	0.10	0.053	0.016	0.035	0.009	0.003	0.002	0.052	0.018	0.010
	Diesel	Conventional	1.41	1.01	1.14	3.16	0.93	1.03	0.017	0.017	0.017	0.005	0.005	0.005	0.169	0.109	0.102
		Euro I - 93/59/EEC	0.66	0.32	0.54	1.51	0.98	1.11	0.017	0.017	0.017	0.005	0.005	0.005	0.169	0.109	0.102
		Euro II - 96/69/EC	0.66	0.32	0.54	1.51	0.98	1.11	0.017	0.017	0.017	0.005	0.005	0.005	0.169	0.109	0.102
		Euro III - 98/69/EC Stage2000	0.54	0.26	0.44	1.27	0.83	0.94	0.017	0.017	0.017	0.003	0.003	0.003	0.105	0.067	0.063
Heavy duty trucks	Gasoline >3,5 t	Conventional	70.00	55.00	55.00	4.50	7.50	7.50	0.006	0.006	0.006	0.140	0.110	0.070	7.000	5.500	3.500
	Diesel 3,5 - 7,5 t	Conventional	4.82	2.17	1.64	5.20	2.17	3.26	0.030	0.030	0.030	0.085	0.023	0.020	3.030	1.105	0.774
		Euro I - 91/542/EEC Stage I	2.41	1.30	0.90	3.64	1.52	2.93	0.030	0.030	0.030	0.064	0.017	0.015	2.272	0.828	0.580
		Euro II - 91/542/EEC Stage II	1.93	1.19	0.82	2.60	1.19	2.12	0.030	0.030	0.030	0.060	0.016	0.014	2.121	0.773	0.542
		Euro III - 2000 Standards	1.35	0.84	0.57	1.82	0.83	1.48	0.030	0.030	0.030	0.042	0.011	0.010	1.484	0.541	0.379
	Diesel 7,5 - 16 t	Conventional	4.82	2.17	1.64	10.50	4.29	4.17	0.030	0.030	0.030	0.085	0.023	0.020	3.030	1.105	0.774
		Euro I - 91/542/EEC Stage I	2.41	1.30	0.90	7.35	3.00	3.75	0.030	0.030	0.030	0.064	0.017	0.015	2.272	0.828	0.580
		Euro II - 91/542/EEC Stage II	1.93	1.19	0.82	5.25	2.36	2.71	0.030	0.030	0.030	0.060	0.016	0.014	2.121	0.773	0.542
		Euro III - 2000 Standards	1.35	0.84	0.57	3.67	1.65	1.90	0.030	0.030	0.030	0.042	0.011	0.010	1.484	0.541	0.379
	Diesel 16 - 32 t	Conventional	4.82	2.17	1.64	18.19	9.06	7.09	0.030	0.030	0.030	0.175	0.080	0.070	3.030	1.105	0.774
		Euro I - 91/542/EEC Stage I	2.65	1.30	1.06	10.00	5.44	3.90	0.030	0.030	0.030	0.087	0.052	0.053	1.515	0.718	0.580
		Euro II - 91/542/EEC Stage II	2.17	1.09	1.06	7.28	4.08	3.19	0.030	0.030	0.030	0.079	0.048	0.045	1.363	0.663	0.503
		Euro III - 2000 Standards	1.52	0.76	0.75	5.09	2.85	2.23	0.030	0.030	0.030	0.055	0.034	0.032	0.954	0.464	0.352

			Emission factors in urban roads. rural and highways														
		Technology	COu	COr	COh	NOxu	NOxr	NOxh	N2Ou	N2Or	N2Oh	CH4u	CH4r	CH4h	VOCu	VOCr	VOCh
	>32t	Conventional	4.82	2.17	1.64	25.69	13.52	10.78	0.030	0,030	0.030	0.175	0.080	0.070	3.030	1.105	0.774
		Euro I - 91/542/EEC Stage I	2.65	1.30	1.06	14.13	8.11	5.93	0.030	0,030	0.030	0.087	0.052	0.053	1.515	0.718	0.580
		Euro II - 91/542/EEC Stage II	2.17	1.09	1.06	10.28	6.09	4.85	0.030	0,030	0.030	0.079	0.048	0.045	1.363	0.663	0.503
		Euro III - 2000 Standards	1.52	0.76	0.75	7.19	4.26	3.40	0.030	0,030	0.030	0.055	0.034	0.032	0.954	0.464	0.352
Busses	Urban	Conventional	6.59	2.80	2.07	19.37	10.67	8.65	0.030	0,030	0.030	0.175	0.080	0.070	2.102	0.643	0.424
	Coaches	Conventional	5.39	2.05	1.46	18.23	8.26	7.94	0.030	0,030	0.030	0.175	0.080	0.070	3.246	1.170	0.817
		Euro III - 2000 Standards	1.70	0.72	0.66	5.10	2.60	2.50	0.030	0,030	0.030	0.055	0.034	0.032	1.022	0.492	0.372
Mopeds	<50 cm³	Conventional	15.00	15.00	0.00	0.03	0.03	0.00	0.001	0,000	0.000	0.219	0.000	0.000	9.000	9.000	0.000
Motorcycles	<250 cm³	Conventional	28.07	22.88	34.16	0.11	0.21	0.32	0.002	0,002	0.002	0.200	0.200	0.200	2.330	1.200	1.020
	<250 cm³	97/24/EC	8.44	7.46	13.49	0.16	0.28	0.40	0.002	0,002	0.002	0.200	0.200	0.200	0.995	0.530	0.389
	250 - 750 cm³	Conventional	24.91	20.45	24.20	0.11	0.22	0.33	0.002	0,002	0.002	0.200	0.200	0.200	1.940	0.926	0.986
	250 - 750 cm³	97/24/EC	8.44	7.46	13.49	0.16	0.28	0.40	0.002	0,002	0.002	0.200	0.200	0.200	0.995	0.530	0.389
	>750 cm³	Conventional	18.17	16.14	22.11	0.12	0.23	0.35	0.002	0,002	0.002	0.200	0.200	0.200	3.550	1.790	1.310
	>750 cm³	97/24/EC	8.44	7.46	13.49	0.16	0.28	0.40	0.002	0,002	0.002	0.200	0.200	0.200	0.995	0.530	0.389

Table II.12 Specific consumption and CO_2 emission factor per category of vehicles

			Emission Factor CO_2 gr/km			Fuel Consumption gr/km		
			Rural	Highways	Rural	Highways	Rural	Highways
Passenger vehicles	Gasoline <1,4 l	PRE ECE	369	169	181	101.955	55.000	58.883
		ECE 15/00-01	337	143	140	93.090	46.520	45.500
		ECE 15/02	308	142	146	85.111	46.240	47.650
		ECE 15/03	308	142	146	85.111	46.240	47.650
		ECE 15/04	233	138	138	64.289	44.740	44.920
		Euro I - 91/441/EEC	259	124	122	71.687	40.256	39.836
		Euro II - 94/12/EC	259	124	122	71.687	40.256	39.836
		Euro III - 98/69/EC Stage2000	259	124	122	71.687	40.256	39.836
	Gasoline 1,4 - 2 l	PRE ECE	443	206	220	122.358	67.000	71.676
		ECE 15/00-01	410	153	173	113.285	49.700	56.390
		ECE 15/02	382	154	171	105.508	50.048	55.502
		ECE 15/03	382	154	171	105.508	50.048	55.502
		ECE 15/04	308	159	152	85.039	51.572	49.352
		Euro I - 91/441/EEC	350	149	135	96.672	48.440	43.820
		Euro II - 94/12/EC	350	149	135	96.672	48.440	43.820
		Euro III - 98/69/EC Stage2000	350	149	135	96.672	48.440	43.820
	Gasoline > 2 l	PRE ECE	558	246	259	154.073	80.000	88.267
		ECE 15/00-01	472	171	192	130.332	55.700	66.300
		ECE 15/02	478	198	204	132.143	64.500	70.700
		ECE 15/03	478	198	204	132.143	64.500	70.700
		ECE 15/04	421	168	202	116.398	54.780	69.900
		Euro I - 91/441/EEC	452	164	157	124.833	53.210	51.050
		Euro II - 94/12/EC	452	164	157	124.833	53.210	51.050
		Euro III - 98/69/EC Stage2000	452	164	157	124.833	53.210	51.050
	Diesel <2,0 l	Conventional	297	139	141	83.947	43.849	44.329
		Euro I - 91/441/EEC	246	140	140	69.398	43.982	43.937
		Euro II - 94/12/EC	246	140	140	69.398	43.982	43.937
		Euro III - 98/69/EC Stage2000	246	140	140	69.398	43.982	43.937
	Diesel >2,0 l	Conventional	297	139	141	83.947	43.849	50.089
		Euro I - 91/441/EEC	246	140	140	69.398	43.982	43.937
		Euro II - 94/12/EC	246	140	140	69.398	43.982	43.937
		Euro III - 98/69/EC Stage2000	246	140	140	69.398	43.982	43.937
	LPG	Conventional	255	165	198	59.000	45.000	54.000
Light duty trucks <3.5 t	Gasoline	Conventional	424	193	179	117.208	62.690	58.370
		Euro I - 93/59/EEC	496	226	211	137.180	73.650	68.700
		Euro II - 96/69/EC	496	226	211	137.180	73.650	68.700
		Euro III - 98/69/EC Stage2000	496	226	211	137.180	73.650	68.700
	Diesel	Conventional	376	210	259	106.188	65.978	81.563
		Euro I - 93/59/EEC	377	185	230	96.954	58.340	72.260
		Euro II - 96/69/EC	377	185	230	96.954	58.340	72.260
		Euro III - 98/69/EC Stage2000	377	185	230	96.954	58.340	72.260

			Emission Factor CO_2 gr/km			Fuel Consumption gr/km		
			Rural	Highways	Rural	Highways	Rural	Highways
Heavy duty trucks	Gasoline >3,5 t	Conventional	692	461	507	225.000	150.000	165.000
	Diesel 3,5 - 7,5 t	Conventional	484	277	390	152.377	87.060	122.670
		Euro I - 91/542/EEC Stage I	484	277	390	152.377	87.060	122.670
		Euro II - 91/542/EEC Stage II	484	277	390	152.377	87.060	122.670
		Euro III - 2000 Standards	484	277	390	152.377	87.060	122.670
	Diesel 7,5 - 16 t	Conventional	801	467	584	252.061	147.006	183.939
		Euro I - 91/542/EEC Stage I	801	467	584	252.061	147.006	183.939
		Euro II - 91/542/EEC Stage II	801	467	584	252.061	147.006	183.939
		Euro III - 2000 Standards	801	467	584	252.061	147.006	183.939
	Diesel 16 - 32 t	Conventional	1254	721	775	394.591	227.040	244.050
		Euro I - 91/542/EEC Stage I	1254	721	775	394.591	227.040	244.050
		Euro II - 91/542/EEC Stage II	1254	721	775	394.591	227.040	244.050
		Euro III - 2000 Standards	1254	721	775	394.591	227.040	244.050
	Diesel >32t	Conventional	1630	989	995	512.951	311.460	313.290
		Euro I - 91/542/EEC Stage I	1630	989	995	512.951	311.460	313.290
		Euro II - 91/542/EEC Stage II	1630	989	995	512.951	311.460	313.290
		Euro III - 2000 Standards	1630	989	995	512.951	311.460	313.290
Busses	Urban	Conventional	1222			384.646	234.111	196.510
	Coaches	Conventional	1245	682	647	391.796	214.600	203.590
		Euro III - 2000 Standards	1245	682	647	391.796	214.600	203.590
Mopeds	<50 cm³	Conventional	77	77		25.000	25.000	0.000
Motorcycles	<250 cm³	Conventional	88	74	100	28.690	24.064	32.506
	<250 cm³	97/24/EC	101	79	94	32.850	25.834	30.511
	250 - 750 cm³	Conventional	117	84	99	38.000	27.460	32.260
	250 - 750 cm³	97/24/EC	101	79	94	32.850	25.834	30.511
	>750 cm³	Conventional	149	103	113	48.490	33.652	36.838
	>750 cm³	97/24/EC	101	79	94	32.850	25.834	30.511

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 III.1***). 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.

Table III.1 CO_2 emission factors (in t CO_2 / TJ) and basic fuel characteristics

Fuel types	Net Calorific Value (TJ/kt)	Carbon Content (tC/TJ)	Carbon Stored (%)	Oxidation factor (%)
Liquid fuels				
Crude oil	42,75	20,0		99,0
NGL (Natural Gas Liquids)	45,22	17,2		99,0
Refinery feedstocks	42,50	20,0		99,0
Refinery gas	48,15	18,2		99,0
LPG	47,31	17,2		99,0
Gasoline	44,80	18,9		99,0
Jet fuels	44,60	19,5		99,0
Kerosene	44,75	19,6		99,0
Diesel oil	43,33	20,2		99,0
Heavy fuel oil	40,19	21,1		99,0
Naphtha	45,01	20,0	75	99,0
Petroleum coke	31,00	27,5	80	99,0
Lubricants	40,19	20,0	50	99,0
Bitumen	40,19	20,0	100	99,0
Other products	40,19	20,0	50	99,0
Solid fuels				
Steam coal	27,21	25,8		98,0
Lignite				
Electricity production		34,0		98,0
Other sectors		27,6		98,0
Oven and gas coke	29,31	29,5		98,0
BKB / Dry lignite	15,28	25,8		98,0
Gaseous fuels				
Natural gas (domestic)		16,1	33	99,5
Natural gas (imports)		15,3	33	99,5
Gas works gas		15,3		99,5

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.2***.

Table III.2 ***Net calorific value of lignite (in TJ / kt) for the period 1990 - 2006***

Year	Primary production	Electricity generation	Industry	Other sectors
1990	5.744	5.711	8.399	5.740
1991	5.485	5.447	8.323	5.481
1992	5.321	5.225	9.504	5.288
1993	5.472	5.355	11.074	5.443
1994	5.472	5.355	11.317	5.418
1995	5.451	5.179	11.300	5.451
1996	5.037	4.915	11.204	5.037
1997	5.485	5.384	11.300	5.485
1998	5.589	5.506	11.380	5.589
1999	5.421	5.366	11.110	5.421
2000	5.388	5.346	10.902	5.388
2001	5.296	5.296	10.006	5.296
2002	5.099	5.087	8.620	5.296
2003	5.002	5.043	10.886	5.002
2004	5.109	5.182	9.807	5.109
2005	5.167	5.257	9.485	9.485
2006	5.297	5.257	9.485	9.485

The application of the reference approach for each year is presented hereafter (Tables 1.A(b) of the Common Reporting Format).

Table III.3 Reference approach for 2006

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)
Liquid Fossil	Primary Fuels	Crude Oil	kt	94,00	19.836,00	1.054,00		-61,00	18.937,00	42,75	NCV	809.556,75	20,00
		Orimulsion		NA	NA	NA		NA	NA	NA	NCV	NA	NA
		Natural Gas Liquids		NO	NA	NA		NA	NA,NO	NO	NCV	NA,NO	
	Secondary Fuels	Gasoline	kt		1.002,00	1.351,00	NA	259,00	-608,00	44,80	NCV	-27.238,40	18,90
		Jet Kerosene	kt		447,00	708,00	NA	-45,00	-216,00	44,59	NCV	-9.631,44	19,50
		Other Kerosene			NA	NA	NA	NA	NA	NA	NCV	NA	NA
		Shale Oil			NA	NA		NA	NA	NA	NCV	NA	NA
		Gas / Diesel Oil	kt		3.591,00	2.311,00	398,00	204,00	678,00	43,33	NCV	29.377,74	20,20
		Residual Fuel Oil	kt		389,00	835,00	2.761,00	-16,00	-3.191,00	40,19	NCV	-128.246,29	21,10
		Liquefied Petroleum Gas (LPG)	kt		22,00	236,00		2,00	-216,00	47,31	NCV	-10.218,96	17,20
		Ethane			NA	NA		NA	NA	NA	NCV	NA	NA
		Naphtha	kt		6,00	256,00		-42,00	-208,00	45,01	NCV	-9.362,08	20,00
		Bitumen	kt		NA	88,00		11,00	-99,00	40,19	NCV	-3.978,81	20,00
		Lubricants	kt		12,00	107,00	25,00	77,28	-197,28	40,19	NCV	-7.928,49	20,00
		Petroleum Coke	kt		563,00	NA		22,00	541,00	31,00	NCV	16.771,00	27,50
		Refinery Feedstocks	kt		2.585,00	NA		89,00	2.496,00	42,50	NCV	106.080,00	20,00
		Other Oil			NA	NA		5,00	-5,00	40,19	NCV	-200,95	20,00
Other Liquid Fossil												NA	
Other non-specified				NA	NA	NA	NA	NA	NA	NA	NCV	NA	NA
Liquid Fossil Totals												764.980,07	
Solid Fossil	Primary Fuels	Anthracite [2]		NA	NA	NA		NA	NA	NA	NCV	NA	NA
		Coking Coal		NA	NA	NA		NA	NA	NA	NCV	NA	NA
		Other Bituminous Coal	kt	NA	383,00	10,00	NA	-90,00	463,00	27,21	NCV	12.598,23	25,80
		Sub-bituminous Coal		NA	NA	NA	NA	NA	NA	NA	NCV	NA	NA
		Lignite	kt	64.521,00	NA	NA		189,00	64.332,00	5,21	NCV	334.964,05	33,95
		Oil Shale		NA	NA	NA		NA	NA	NA	NCV	NA	NA
		Peat		NA	NA	NA		NA	NA	NA	NCV	NA	NA
	Secondary Fuels	BKB [3] and Patent Fuel			NA	24,00		-1,00	-23,00	15,28	NCV	-351,44	25,80
		Coke Oven/Gas Coke	kt		NO	NA		NA	NA,NO	NO	NCV	NA,NO	
Other Solid Fossil												NA	
Other non-specified				NA	NA	NA	NA	NA	NA	NA	NCV	NA	NA
Solid Fossil Totals												347.210,84	
Gaseous Fossil		Natural Gas (Dry)	TJ	1.072,76	112.337,18	NA		9,76	113.400,18	1,00	NCV	113.400,18	15,31
Other Gaseous Fossil												NA	
Other non-specified				NA	NA	NA	NA	NA	NA	NA	NCV	NA	NA
Gaseous Fossil Totals												113.400,18	
Total												1.225.591,09	
Biomass total												19.649,74	
		Solid Biomass		18.073,74	147,00	NA		NA	18.220,74	1,00	NCV	18.220,74	29,90
		Liquid Biomass		48,00	4,00	NA		NA	52,00	1,00	NCV	52,00	20,00
		Gas Biomass		1.377,00	NA	NA		NA	1.377,00	1,00	NCV	1.377,00	15,00

Annex IV: Uncertainty analysis

Uncertainty analysis constitutes a key activity in the annual inventory cycle. The realisation of such an analysis is foreseen in the reporting guidelines under the Convention and represents a specific function to be performed by a National System (Decision 20/CP.7).

Uncertainty information is not intended to dispute the validity of the inventory estimates, but to help prioritize efforts to improve the accuracy of inventories and guide decisions on methodological choice. This will be achieved with the correct application of the analytic calculating methods at least for the key categories.

There are two methods for the uncertainty estimation suggested by the IPCC Good Practice Guidance, a basic method (Tier 1) which is mandatory and an analytic one (Tier 2).

The Tier 2 methodology is based on Monte Carlo analysis. The principle of Monte Carlo analysis is to select random values of emission factor and activity data from within their individual probability density functions, and to calculate the corresponding emission values. This procedure is repeated many times, and the results of each calculation run build up the overall emission probability density function. Monte Carlo analysis can be performed at the source category level, for aggregations of source categories or for the inventory as a whole. This analysis is suitable for a composite system such as the calculation of GHG emissions in national level, but its application requires significant resources and time.

The application of the Tier 1 methodology for uncertainty analysis is based on the following equations.

A. Uncertainty of total emissions

$$u_{i,g} = \sqrt{u_{AD,i}^2 + u_{EF,i,g}^2}$$

$$U_{i,g} = \frac{u_{i,g} \cdot E_{i,g}}{\sum_{i,g} E_{i,g}}$$

$$U_{tot} = \sqrt{\sum_{i,g} U_{i,g}^2}$$

where, i is the index referring to emission sources, g is the index referring to GHG, $u_{i,g}$ is the combined uncertainty for emissions of g-gas and i-source, $u_{AD,i}$ is the uncertainty of activity data of the i-source, $u_{EF,i,g}$ is the uncertainty of the emission factor of g-gas and i-source, $U_{i,g}$ is the uncertainty of the calculated emissions of g-gas and i-source, $E_{i,g}$ are the emissions of g-gas and i-source and U_{tot} is the uncertainty of total emissions.

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 2006 (without *LULUCF*).
- The uncertainty analysis was carried out both without and with the *LULUCF* sector.

In the following tables, the analytical calculations of the emissions estimates uncertainty are presented, with and without the sector of *LULUCF*.

Table IV.1 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	39161.10	41889.43	5	5	7.1	2.2	-0.0709	0.3967	-0.35	2.81	2.83
1A 1,2,4	Stationary Combustion - liquid fuels	CO_2	21484.24	30306.60	5	5	7.1	1.6	0.0303	0.2870	0.15	2.03	2.04
1A 1,2,4	Stationary Combustion - gaseous fuels	CO_2	295.94	6117.21	5	5	7.1	0.3	0.0544	0.0579	0.27	0.41	0.49
1A3	Road transport	CO_2	11759.50	19824.78	4	3	5.0	0.7	0.0472	0.1877	0.14	1.06	1.07
1A3	Navigation	CO_2	1824.81	2302.36	5	5	7.1	0.1	0.0000	0.0218	0.00	0.15	0.15
1A3	Civil Aviation	CO_2	587.81	1112.21	5	5	7.1	0.1	0.0035	0.0105	0.02	0.07	0.08
1A3	Other transportation	CO_2	0.00	4.91	5	5	7.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	CO_2	0.02	9.27	5	300	300.0	0.0	0.0001	0.0001	0.03	0.00	0.03
2A1	Cement Production	CO_2	5778.28	6460.86	2	2	2.8	0.1	-0.0078	0.0612	-0.02	0.17	0.17
2A2	Lime Production	CO_2	367.25	409.00	25	15	29.2	0.1	-0.0005	0.0039	-0.01	0.14	0.14
2C1	Iron and Steel Production	CO_2	202.83	222.02	5	5	7.1	0.0	-0.0003	0.0021	0.00	0.01	0.01
6C	Waste incineration	CO_2	0.00	1.00	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CO_2	81461.78	108659.66									
1A 1,2,4	Stationary Combustion - all fuels	CH_4	104.33	102.29	5	100	100.1	0.1	-0.0003	0.0010	-0.03	0.01	0.03
1A3	Road transport	CH_4	108.19	181.66	4	40	40.2	0.1	0.0004	0.0017	0.02	0.01	0.02
1A3	Navigation	CH_4	3.61	4.52	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH_4	0.10	0.67	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	88.71	142.06	5	300	300.0	0.3	0.0003	0.0013	0.09	0.01	0.09
1B	Coal Mining	CH_4	1095.27	1361.69	2	200	200.0	2.0	-0.0002	0.0129	-0.04	0.04	0.05
4A	Enteric fermentation	CH_4	2865.83	2831.87	5	30	30.4	0.6	-0.0074	0.0268	-0.22	0.19	0.29
4B	Manure management	CH_4	496.76	488.45	5	50	50.2	0.2	-0.0013	0.0046	-0.07	0.03	0.07

	A	B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO_2 eq	Gg CO_2 eq	%	%	%	%	%	%	%	%	%
4C	Rice cultivation	CH_4	69.10	93.66	2	40	40.0	0.0	0.0001	0.0009	0.00	0.00	0.00
4F	Field burning of agr. residues	CH_4	27.06	27.63	20	20	28.3	0.0	-0.0001	0.0003	0.00	0.01	0.01
6A1	Managed solid waste disposal	CH_4	542.24	986.98	12	40	41.8	0.3	0.0029	0.0093	0.11	0.16	0.20
6A2	Unmanaged solid waste disposal	CH_4	1255.14	1614.16	12	72	73.0	0.9	0.0003	0.0153	0.02	0.26	0.26
6B	Wastewater handling	CH_4	2318.94	519.12	30	30	42.4	0.2	-0.0228	0.0049	-0.68	0.21	0.71
		Total CH_4	8975.26	8354.76									
1A 1,2,4	Stationary Combustion - all fuels	N_2O	737.50	525.05	5	300	300.0	1.2	-0.0038	0.0050	-1.15	0.04	1.15
1A3	Road transport	N_2O	122.76	541.60	4	50	50.2	0.2	0.0037	0.0051	0.18	0.03	0.19
1A3	Navigation	N_2O	14.21	17.78	5	300	300.0	0.0	0.0000	0.0002	0.00	0.00	0.00
1A3	Civil Aviation	N_2O	5.78	11.44	5	300	300.0	0.0	0.0000	0.0001	0.01	0.00	0.01
1A3	Other transportation		0.00	0.04	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N_2O	712.96	633.68	5	100	100.1	0.5	-0.0025	0.0060	-0.25	0.04	0.26
4B	Manure management	N_2O	301.45	290.45	50	100	111.8	0.2	-0.0009	0.0028	-0.09	0.19	0.21
4D	Agricultural soils - direct emissions	N_2O	2759.79	1699.03	20	400	400.5	5.1	-0.0169	0.0161	-6.75	0.46	6.77
4D	Agricultural soils - indirect emissions	N_2O	3605.75	2816.32	20	50	53.9	1.1	-0.0164	0.0267	-0.82	0.75	1.11
4D	Animal Production	N_2O	3383.45	3386.98	50	100	111.8	2.8	-0.0083	0.0321	-0.83	2.27	2.42
4F	Field burning of agr. residues	N_2O	10.05	10.52	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
		Total N_2O	11653.69	9932.90									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	3253.07	2290.39	50	50	70.7	1.2	-0.0172	0.0217	-0.86	1.53	1.76
2F	Substitutes for ODS	HFC	164.74	3893.80	5	200	200.1	5.8	0.0349	0.0369	6.98	0.26	6.99
		Total HFC	3417.81	6184.19									
2C	PFC from Aluminium	PFC	82.97	70.53	1	1	1.4	0.0	-0.0003	0.0007	0.00	0.00	0.00
	TOTAL		105591.51	133202.03				9.315					10.980

Table IV.2 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	40,002.09	46,796.30	5	5	7.1	2.5	-0.0272	0.4358	-0.14	3.08	3.08
1A 1,2,4	Stationary Combustion - liquid fuels	CO_2	21,484.24	28,462.25	5	5	7.1	1.5	0.0163	0.2651	0.08	1.87	1.88
1A 1,2,4	Stationary Combustion - gaseous fuels	CO_2	295.94	5,095.56	5	5	7.1	0.3	0.0440	0.0475	0.22	0.34	0.40
1A3	Road transport	CO_2	11,872.66	18,134.99	4	3	5.0	0.7	0.0314	0.1689	0.09	0.96	0.96
1A3	Navigation	CO_2	1,824.81	2,153.36	5	5	7.1	0.1	-0.0011	0.0201	-0.01	0.14	0.14
1A3	Civil Aviation	CO_2	1,454.69	1,226.97	5	5	7.1	0.1	-0.0054	0.0114	-0.03	0.08	0.09
1A3	Other transportation	CO_2	0.00	2.21	5	5	7.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1B	Oil and Natural gas	CO_2	70.23	11.47	5	300	300.0	0.0	-0.0007	0.0001	-0.21	0.00	0.21
2A1	Cement Production	CO_2	5,778.28	6,382.22	2	2	2.8	0.1	-0.0075	0.0594	-0.01	0.17	0.17
2A2	Lime Production	CO_2	367.25	489.52	25	15	29.2	0.1	0.0003	0.0046	0.00	0.16	0.16
2C1	Iron and Steel Production	CO_2	202.83	476.41	5	5	7.1	0.0	0.0021	0.0044	0.01	0.03	0.03
6C	Waste incineration	CO_2	0.15	0.98	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	-2,042.79	-3,820.49	10	79	79.4	-2.3	-0.0119	-0.0356	-0.94	-0.49	1.06
5.A.2	Conversion to Forest Land	CO_2	0.00	-449.84	5	113	112.8	-0.4	-0.0042	-0.0042	-0.47	-0.03	0.47
5.B.1	Cropland remaining Cropland	CO_2	-1,205.41	-1,144.19	21	64	67.3	-0.6	0.0033	-0.0107	0.21	-0.32	0.38
		Total CO_2	80,104.97	103,817.71									
1A 1,2,4	Stationary Combustion - all fuels	CH_4	239.05	235.72	5	100	100.1	0.2	-0.0006	0.0022	-0.06	0.02	0.06
1A3	Road transport	CH_4	108.19	154.56	4	40	40.2	0.0	0.0002	0.0014	0.01	0.01	0.01
1A3	Navigation	CH_4	3.61	4.30	5	100	100.1	0.0	0.0000	0.0000	0.00	0.00	0.00
1A3	Civil Aviation	CH_4	0.25	0.44	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	144.93	5	300	300.0	0.3	0.0003	0.0013	0.09	0.01	0.09

A		B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO_2 eq	Gg CO_2 eq	%	%	%	%	%	%	%	%	%
1B	Coal Mining	CH_4	1,095.27	1,478.22	2	200	200.0	2.2	0.0011	0.0138	0.22	0.04	0.22
4A	Enteric fermentation	CH_4	2,865.83	2,885.93	5	30	30.4	0.7	-0.0063	0.0269	-0.19	0.19	0.27
4B	Manure management	CH_4	496.76	486.94	5	50	50.2	0.2	-0.0012	0.0045	-0.06	0.03	0.07
4C	Rice cultivation	CH_4	69.10	95.50	2	40	40.0	0.0	0.0001	0.0009	0.00	0.00	0.00
4F	Field burning of agr. residues	CH_4	27.06	29.80	20	20	28.3	0.0	0.0000	0.0003	0.00	0.01	0.01
6A1	Managed solid waste disposal	CH_4	1,082.09	3,421.97	12	40	41.8	1.1	0.0193	0.0319	0.77	0.54	0.94
6A2	Unmanaged solid waste disposal	CH_4	1,555.76	1,654.00	12	72	73.0	0.9	-0.0026	0.0154	-0.19	0.26	0.32
6B	Wastewater handling	CH_4	2,318.94	517.87	30	30	42.4	0.2	-0.0220	0.0048	-0.66	0.20	0.69
5.A.1	Forest Land remaining Forest Land	CH_4	48.08	10.36	11.28	70	70.9	0.0	-0.0005	0.0001	-0.03	0.00	0.03
5.C.1	Grassland remaining Grassland	CH_4	1.80	0.72	10	100.02	100.5	0.0	0.0000	0.0000	0.00	0.00	0.00
		Total CH_4	10,003.37	11,121.26									
1A 1,2,4	Stationary Combustion - all fuels	N_2O	2,839.27	3,501.22	5	300	300.0	7.9	-0.0003	0.0326	-0.08	0.23	0.24
1A3	Road transport	N_2O	122.76	451.67	4	50	50.2	0.2	0.0028	0.0042	0.14	0.02	0.14
1A3	Navigation	N_2O	14.21	16.94	5	300	300.0	0.0	0.0000	0.0002	0.00	0.00	0.00
1A3	Civil Aviation	N_2O	14.30	12.03	5	300	300.0	0.0	-0.0001	0.0001	-0.02	0.00	0.02
1A3	Other transportation	N_2O	0.00	0.02	5	300	300.0	0.0	0.0000	0.0000	0.00	0.00	0.00
2B	Nitric Acid	N_2O	712.96	351.99	*5*	*100*	100.1	0.3	-0.0050	0.0033	-0.50	0.02	0.50
4B	Manure management	N_2O	301.45	281.46	50	100	111.8	0.2	-0.0009	0.0026	-0.09	0.19	0.20
4D	Agricultural soils - direct emissions	N_2O	2,759.79	1,703.60	20	400	400.5	5.1	-0.0161	0.0159	-6.43	0.45	6.45
4D	Agricultural soils - indirect emissions	N_2O	3,605.75	2,879.89	20	50	53.9	1.2	-0.0149	0.0268	-0.75	0.76	1.06
4D	Animal Production	N_2O	3,383.45	3,562.36	50	100	111.8	3.0	-0.0060	0.0332	-0.60	2.35	2.42
4F	Field burning of agr. residues	N_2O	10.05	11.23	20	20	28.3	0.0	0.0000	0.0001	0.00	0.00	0.00
5.A.1	Forest Land remaining Forest Land	N_2O	4.88	1.05	11.28	70	70.9	1.0	-0.0381	0.0127	-2.67	0.20	2.68

	A	B	C	D	E	F	G	H	I	J	K	L	M
			Gg CO_2 eq	Gg CO_2 eq	%	%	%	%	%	%	%	%	%
5.C.1	Grassland remaining Grassland	N_2O	0.18	0.07	10	100.02	100.5	0.1	-0.0010	0.0009	-0.10	0.01	0.10
		Total N_2O	**13,769.05**	**12,773.51**									
2E	HFC-23 Emissions from HCFC-22 Manufacture	HFC	3,253.07	2,550.60	50	50	70.7	1.4	-0.0139	0.0238	-0.70	1.68	1.82
2F	Substitutes for ODS	HFC	167.94	3,158.83	*5*	*200*	200.1	4.7	0.0275	0.0294	5.49	0.21	5.50
		Total HFC	**3,421.01**	**5,709.43**									
2C	PFC from Aluminium	PFC	82.97	71.71	1	1	1.4	0.0	-0.0003	0.0007	0.00	0.00	0.00
	TOTAL		**107,381.35**	**133,493.63**				**12.080**					**10.344**

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 SO_2

Nitrogen oxides

Emissions of nitrogen oxides in 2006 increased by 12.6% compared to 1990 levels, with an average annual rate of increase estimated at 0.79% for the period 1990 - 2006. Emissions of NOx derive by 99% from the energy sector and especially from transport, which is responsible for the 47% of total NOx emissions. In ***Table V.1*** NOx emissions by source category for the period 1990 – 2006 are presented.

- The calculation of NOx 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 NOx emission factor for paper and pulp production, 1500 gr/t, derive from IPCC Guidelines, while the emissions factors for steel production, (200 kg/kt) and aluminium production (2150 kg/kt) derive from CORINAIR. NOx emission factor for nitric acid production (2540 kg/kt) is calculated based on NOx 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 2006 decreased by 26% approximately compared to 1990 levels, with an average annual rate of decrease estimated at 1.6% for the period 1990 – 2006. CO emissions derive by 93% from the energy sector and especially from transport, which is responsible for the 64% of total CO emissions. In ***Table V.2*** CO emissions by source category for the period 1990 – 2006 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 5% in 2006 compared to 1990, with an average annual rate of decrease estimated at 0.33%. NMVOC emissions derive by 65% from the energy sector and especially from transport, which is responsible for the 43% of total NMVOC emissions. In ***Table V.3*** NMVOC emissions by source category for the period 1990 – 2006 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 2006 increased by 13.6% compared to 1990 levels, with an average annual rate of increase estimated at 0.85% for the period 1990 - 2006. SO_2 emissions in year 2006 decreased by 1.7% compared to 2005 emission level. SO_2 emissions derive by 98% from the energy sector and mainly from the energy industries, which are responsible for the 75% of total SO_2 emissions. In ***Table V.4*** SO_2 emissions by source category for the period 1990 – 2005 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 - 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TOTAL	**280.27**	**290.25**	**294.84**	**294.67**	**301.48**	**298.29**	**302.40**	**308.82**	**324.48**	**313.76**	**305.48**	**317.35**	**319.83**	**320.47**	**316.85**	**328.65**	**315.62**
Energy	**276.63**	**286.72**	**290.95**	**291.01**	**297.86**	**295.07**	**299.25**	**305.45**	**320.41**	**311.04**	**300.79**	**314.43**	**317.09**	**317.86**	**314.02**	**325.52**	**312.51**
Fuel combustion	276.27	286.31	290.49	290.48	297.44	294.56	298.82	305.02	319.96	310.53	300.29	314.00	316.59	317.33	313.61	325.11	312.09
Energy industries	57.73	57.27	61.16	61.37	66.06	65.66	67.99	70.04	66.56	64.38	73.69	81.33	86.58	84.51	90.21	90.95	89.22
Industry	22.17	21.52	21.15	21.34	20.98	23.59	25.49	25.56	24.24	21.93	24.49	24.64	24.64	22.26	22.65	20.11	23.49
Transport	148.87	158.28	162.29	163.02	165.39	163.06	161.32	165.27	184.82	179.99	157.50	162.38	155.64	155.97	153.29	166.13	149.54
Other sectors	47.49	49.24	45.91	44.76	45.01	42.26	44.02	44.15	44.34	44.23	44.62	45.65	49.72	54.60	47.45	47.92	49.84
Fugitive emissions	0.36	0.41	0.46	0.52	0.41	0.51	0.42	0.43	0.45	0.51	0.50	0.43	0.51	0.53	0.41	0.41	0.42
Industrial processes	**1.88**	**1.64**	**1.68**	**1.60**	**1.53**	**1.54**	**1.62**	**1.52**	**1.38**	**1.42**	**1.47**	**1.36**	**1.45**	**1.37**	**1.39**	**1.70**	**1.69**
Nitric acid production	1.30	1.07	1.12	1.06	1.03	1.03	1.17	1.03	0.85	0.88	0.90	0.76	0.73	0.67	0.64	1.15	1.15
Steel production	0.20	0.20	0.18	0.20	0.17	0.19	0.16	0.20	0.22	0.19	0.22	0.26	0.37	0.34	0.39	0.18	0.18
Aluminium production	0.32	0.33	0.33	0.32	0.30	0.28	0.28	0.29	0.31	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.35
Paper and pulp	0.06	0.05	0.05	0.03	0.03	0.04	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Agriculture	**1.17**	**1.58**	**1.32**	**1.27**	**1.36**	**1.27**	**1.28**	**1.30**	**1.20**	**1.19**	**1.25**	**1.29**	**1.25**	**1.19**	**1.31**	**1.33**	**1.23**
Field burning of agricultural residues	1.17	1.58	1.32	1.27	1.36	1.27	1.28	1.30	1.20	1.19	1.25	1.29	1.25	1.19	1.31	1.33	1.23
LULUCF	**0.59**	**0.30**	**0.89**	**0.79**	**0.74**	**0.41**	**0.26**	**0.55**	**1.48**	**0.11**	**1.97**	**0.27**	**0.04**	**0.05**	**0.13**	**0.10**	**0.20**
Forest and grassland conversion	0.59	0.30	0.89	0.79	0.74	0.41	0.26	0.55	1.48	0.11	1.97	0.27	0.04	0.05	0.13	0.10	0.20

Table V.2 CO emissions (in kt) by source category, for the period 1990 - 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TOTAL	**1295.20**	**1307.46**	**1337.67**	**1337.75**	**1334.11**	**1328.23**	**1354.35**	**1355.29**	**1384.42**	**1310.01**	**1356.38**	**1265.90**	**1230.21**	**1192.61**	**1154.91**	**1052.09**	**956.00**
Energy	**1224.45**	**1236.14**	**1253.20**	**1259.96**	**1256.77**	**1265.02**	**1297.09**	**1286.61**	**1282.70**	**1255.53**	**1234.84**	**1204.02**	**1177.07**	**1140.40**	**1096.72**	**994.44**	**897.35**
Fuel combustion	1224.26	1235.92	1252.95	1259.68	1256.55	1264.75	1296.86	1286.38	1282.46	1255.26	1234.57	1203.79	1176.80	1140.12	1096.50	994.22	897.13
Energy industries	36.39	34.81	36.85	36.97	38.78	37.16	36.21	39.74	42.30	42.51	45.98	46.81	46.22	47.03	48.70	48.93	47.51
Industry	9.47	9.55	9.42	9.36	9.11	9.70	10.14	10.23	10.00	9.69	10.85	11.38	11.33	9.40	9.36	8.75	9.69
Transport	913.16	921.61	941.31	948.35	943.36	953.89	984.81	970.14	964.53	938.63	912.22	881.54	854.76	838.34	797.51	712.42	616.57
Other sectors	265.23	269.95	265.39	265.01	265.29	263.99	265.70	266.27	265.64	264.43	265.52	264.05	264.48	245.35	240.92	224.12	223.35
Fugitive emissions	0.19	0.22	0.24	0.28	0.22	0.27	0.23	0.23	0.24	0.27	0.27	0.23	0.27	0.28	0.22	0.22	0.22
Industrial processes	**22.91**	**22.78**	**22.19**	**20.60**	**19.18**	**18.47**	**18.55**	**19.28**	**21.46**	**22.82**	**23.13**	**22.44**	**22.89**	**23.66**	**23.78**	**24.11**	**24.05**
Glass production	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Ammonia production	2.47	2.02	1.33	0.55	0.43	0.63	0.87	1.36	1.73	1.22	1.17	0.54	0.74	1.19	1.26	1.26	1.58
Steel production	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
Aluminium production	20.20	20.57	20.67	19.94	18.63	17.67	17.67	17.91	19.72	21.59	21.95	21.87	22.13	22.46	22.50	22.83	22.46
Paper and pulp	0.22	0.18	0.18	0.10	0.10	0.16	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Agriculture	**27.06**	**37.93**	**30.86**	**29.54**	**32.23**	**30.26**	**29.65**	**29.97**	**28.13**	**27.62**	**29.21**	**29.91**	**28.91**	**26.69**	**29.80**	**30.09**	**27.63**
Field burning of agricultural residues	27.06	37.93	30.86	29.54	32.23	30.26	29.65	29.97	28.13	27.62	29.21	29.91	28.91	26.69	29.80	30.09	27.63
LULUCF	**20.78**	**10.62**	**31.42**	**27.65**	**25.94**	**14.48**	**9.06**	**19.44**	**52.13**	**4.05**	**69.21**	**9.53**	**1.33**	**1.87**	**4.62**	**3.46**	**6.97**
Forest and grassland conversion	20.78	10.62	31.42	27.65	25.94	14.48	9.06	19.44	52.13	4.05	69.21	9.53	1.33	1.87	4.62	3.46	6.97

Table V.3 NMVOC emissions (in kt) by source category, for the period 1990 - 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TOTAL	**307.71**	**317.78**	**327.14**	**332.87**	**340.68**	**343.02**	**348.23**	**347.71**	**356.83**	**352.78**	**354.43**	**349.99**	**346.55**	**339.18**	**331.85**	**286.28**	**291.42**
Energy	**216.84**	**224.74**	**233.52**	**238.83**	**248.60**	**246.61**	**252.33**	**252.95**	**256.30**	**251.66**	**248.26**	**244.09**	**238.19**	**236.95**	**224.81**	**193.38**	**188.31**
Fuel combustion	194.62	203.14	210.71	216.81	225.22	221.30	226.46	226.48	228.94	225.16	219.68	215.81	208.98	206.94	195.85	164.50	159.00
Energy industries	5.11	5.25	5.16	5.06	5.41	5.26	5.25	5.70	5.61	5.79	6.11	6.28	5.90	6.22	6.37	6.43	6.33
Industry	4.89	4.94	4.90	4.80	4.65	4.87	5.20	5.17	5.08	4.92	5.61	5.44	5.53	4.68	4.57	4.43	4.70
Transport	160.30	168.13	176.47	182.90	191.14	187.54	192.23	191.85	194.53	190.80	184.25	180.40	173.47	172.36	162.32	132.33	126.56
Other sectors	24.31	24.82	24.18	24.04	24.02	23.63	23.77	23.76	23.72	23.64	23.71	23.68	24.08	23.68	22.59	21.31	21.41
Fugitive emissions	22.22	21.60	22.81	22.02	23.39	25.31	25.88	26.47	27.37	26.50	28.58	28.28	29.21	30.01	28.96	28.88	29.31
Industrial processes	**34.22**	**34.77**	**36.17**	**37.88**	**37.77**	**44.76**	**44.84**	**43.33**	**49.16**	**47.37**	**52.96**	**53.56**	**55.87**	**49.62**	**54.30**	**39.85**	**49.44**
Asphalt roofing	0.83	0.91	0.96	1.02	1.03	1.22	1.24	1.25	1.41	1.44	1.66	1.69	1.76	1.50	1.69	1.13	1.48
Road paving with asphalt	22.36	24.44	25.76	27.29	27.73	32.77	33.21	33.65	37.81	38.80	44.50	45.38	47.24	40.33	45.38	30.25	39.68
Glass production	0.61	0.56	0.44	0.45	0.46	0.47	0.48	0.50	0.51	0.52	0.53	0.76	0.77	0.66	0.62	0.48	0.38
Ammonia production	1.47	1.20	0.79	0.33	0.26	0.38	0.52	0.81	1.03	0.72	0.69	0.32	0.44	0.71	0.75	0.75	0.94
Organic chemicals production	0.94	0.92	0.94	0.73	0.99	0.96	1.08	1.12	1.15	1.21	1.27	1.27	1.27	1.27	1.28	1.28	1.28
Steel production	0.09	0.09	0.08	0.09	0.08	0.08	0.07	0.09	0.10	0.09	0.10	0.12	0.17	0.15	0.18	0.08	0.08
Paper and pulp	0.15	0.12	0.12	0.07	0.07	0.11	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Food - Drinks	7.78	6.53	7.08	7.91	7.15	8.78	8.24	5.92	7.15	4.59	4.21	4.02	4.22	4.98	4.41	5.88	5.60
Solvents and other products use	**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**
	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

Table V.4 SO_2 emissions (in kt) by source category, for the period 1990 - 2006

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TOTAL	**471.60**	**512.79**	**528.87**	**524.64**	**516.29**	**539.17**	**529.11**	**522.45**	**529.92**	**548.30**	**499.39**	**504.49**	**515.74**	**554.08**	**548.31**	**544.79**	**535.62**
Energy	**462.03**	**503.69**	**520.58**	**516.77**	**508.25**	**530.41**	**520.52**	**513.56**	**520.89**	**539.02**	**490.99**	**496.13**	**507.21**	**545.49**	**539.59**	**534.86**	**525.85**
Fuel combustion	455.54	496.32	512.33	507.36	501.47	523.55	514.70	507.14	512.55	530.58	481.98	488.38	498.06	536.00	532.18	527.47	518.35
Energy industries	299.27	340.94	361.57	373.18	381.90	407.26	386.66	379.45	378.49	405.34	370.65	372.18	383.49	421.73	414.25	420.04	402.10
Industry	94.49	91.23	89.66	78.46	65.71	70.71	79.60	79.54	70.69	58.99	68.58	67.45	69.30	64.20	63.40	55.03	61.91
Transport	33.21	33.43	34.85	31.09	36.21	30.47	29.06	30.64	45.28	48.68	23.93	28.32	24.66	26.30	31.17	27.94	30.58
Other sectors	28.57	30.73	26.26	24.63	17.65	15.11	19.38	17.51	18.09	17.57	18.83	20.44	20.60	23.78	23.36	24.46	23.76
Fugitive emissions	6.49	7.37	8.25	9.41	6.78	6.86	5.82	6.43	8.35	8.44	9.00	7.75	9.15	9.48	7.41	7.39	7.50
Industrial processes	**9.57**	**9.10**	**8.29**	**7.87**	**8.04**	**8.77**	**8.59**	**8.88**	**9.03**	**9.28**	**8.40**	**8.35**	**8.54**	**8.60**	**8.72**	**9.94**	**9.77**
Cement production	3.19	3.17	3.25	3.26	3.28	3.52	3.53	3.55	3.54	3.53	3.62	3.64	3.50	3.53	3.53	3.78	3.69
Glass production	0.23	0.21	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.29	0.29	0.25	0.23	0.18	0.14
Ammonia production	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulphuric acid production	3.61	3.19	2.35	2.09	2.39	2.88	2.91	3.13	3.07	3.16	2.12	1.96	2.18	2.23	2.33	3.45	3.45
Steel production	0.13	0.13	0.12	0.13	0.11	0.12	0.11	0.13	0.14	0.12	0.14	0.17	0.24	0.22	0.26	0.12	0.12
Aluminium production	2.13	2.16	2.17	2.10	1.96	1.86	1.86	1.88	2.07	2.27	2.31	2.30	2.33	2.36	2.37	2.40	2.36
Paper and pulp	0.27	0.22	0.23	0.13	0.13	0.20	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO